EVALUATION OF THE LAND RESOURCES FOR AGRICULTURAL DEVELOPMENT - CASE STUDY: EL-HAMMAM CANAL AND ITS EXTENSION, NW COAST OF EGYPT

Dissertation

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AEZ	Agro-Ecological Zones
ALES	Automated Land Evaluation System
APT	Agricultural planning toolkit
asl	Above sea level
CEC	Cation exchange capacity
CRIES	Comprehensive resource inventory and evaluation system
CS	Coarse sand
DEM	Digital Elevation Model
DRC	Desert Research center
ECe	Electric conductivity in saturated paste
EEAA	Egyptian Environmental Affairs Agency
ESP	Exchangeable sodium percentage
EX.	Extremely calcareous
FAO	Food Agricultural Organization
FS	Fine sand
Fuzzy AHP	Fuzzy Analytical Hierarchy Process
G	Gravely
GIS	Geographic Information System
HA	Hard
Hectare	2.471 acre
ILWIS	Integrated Land and Water Information System
ITC	Geo-Information Science and Earth Observation
LC	Land Capability
LCA	Land Capability for Agriculture
LCs	Land Characteristics
LECS	Land Evaluation Computer System
LO	Loose
LQ	land quality
LS	Loamy sand
LURs	Land Use Requirements
LUTs	Land Utilizations Types
M.Alk.	Moderately alkaline
MA	Massive
Micro LEIS	Microcomputer Land Evaluation Information System
MO	Moderately saline
MS	Medium sand
NPP	Non-plastic
NS	Non-saline

NST	Non-sticky
SOC	Soil Organic carbon
OM	Organic matter
PH	Soil reaction
SG	Single grains
SHA	Slightly hard
SiL	Silt loam
Sl	Sandy loam
SL	Slightly saline
Sl.Alk.	Slightly alkaline
SO	Soft
SOMALES	Somalia Automated Land Evaluation System
SPL	Slightly plastic
SST	Slightly sticky
ST	Sticky
ST	Strongly saline
St.Alk.	Strongly alkaline
TOPSIS	Technique for Ordered Performance by Similarity to Ideal Solution
US	Unsorted Sand
USDA	United States Department of Agriculture
VFS	Very fine sand
VHA	Very hard
VSL	Very slightly saline
VSt.Alka	Very strongly alkaline
WEBLSA	Week sub-angular blocky
NRCS	Natural Resources Conservation Service
NASIS	National Soil Information System
10^3 ha	1000 hectares

CHAPTER 1: INTRODUCTION

Egypt is an arid land with virtually 96.4 % of the uninhabited parts of its territory, has the Nile Valley, which represent less than 3.6 % of Egyptian land, has more than 80 million inhabitants. Those inhabitants are mainly concentrated in the Nile Valley as well as in the coastal zone along the Mediterranean Sea, and small oasis in the western desert which is appropriate for agricultural production. The Nile Valley is nearly 33,000 km^2, while the Egyptian desert area is more than 1,000, 000 km^2, with an annual population growth rate of 2.5 %. The purpose of land reclamation is to increase the scarce Egyptian farmland and help feed the Egypt’s expanding population (Pautsch and Abdelrahman, 1998) In fact, increasing population has resulted in a decrease in the agricultural area per capita from 0.13 ha in 1947 to 0.05 ha in 2004. As a result, the agricultural sector suffered lower profitability, and widening of the gap between food production and consumption which caused the country to become increasingly dependent on imported food. This unbalanced distribution as well as overpopulation has caused serious socio-economic problems such as the undermining rising living standardsas wellas high unemployment and crime rate (Abd El-Kawy, 2010) and (Shalaby and Tateishi, 2007). Formerly, Egypt was self-sufficient agriculturally and during the 1960s, production grew at a rate of 3% annually, but it slowed down in the seventies and eighties. The major challenge Egypt is facing today is the need for better development and management of natural resources, to meet the needs of a growing nation. The ratio between the land resources and human resources is the most critical problem in Egypt. Therefore, agriculture expansion in the Western Desert is one of the most vital objectives in Egyptian policy to satisfy the food security needs of the ever- increasing population (Ismail et al., 2010)

The coastal zone of Egypt has become the major site for extensive and diverse economic activities. In order to meet the demands of a **growing population** with limited recourses, land reclamation has been an important issue in Egyptian agenda since 1950s. After the revolution in1952, Egypt’s main objective was to provide land and increase the standard of living of the ever-growing part of the population. The desert reclamation, founded in 1976, has made substantial progress; the construction of the high dam has had a positive impact on the development and are now currently working on extending agricultural production (Purzner, 2008)**.** The Nile River is shared by ten countries (Egypt, Sudan, Ethiopia, Eritrea, Tanzania, Uganda, Burundi, Rwanda, D.R. Congo, and Kenya); as well, most of the countries in the Nile Basin are highly dependent on the Nile’s water, as they are situated in arid or semi-arid regions. More than 95% of Egypt's water comes from the Nile (Waleed Hamza, 2004)**.** Although, the agricultural land of Egypt is as old as history, but it is entirely dependent on the Nile water, underground water in some scattered oases in the desert and some of the rainfall that falls on the northern coast during winter. People say that Egypt is truly the gift of the Nile. Generally, water resources in Egypt, are dependent entirely on Nile water, which amounts to 84 billion m^3 annually. The average annual evaporation and other losses in the High Dam Lake have been estimated at 10 billion m^3, leaving a net usable annual flow of 74 billion m^3 of water. Under the agreement with the Sudan in 1959, only 55.5 billion m^3 of water have been allocated to Egypt. The total capacity of the **Aswan High Dam** is 120 billion cubic meters. As a result of struggling for development, several issues forced their way in search for underground water in the Delta and Valley as well as in the desert areas and Sinai Peninsula (Hamdi and Abdelhafez, 2001)

In order to meet the increased food needs, two basic strategies are possible: importing food or growing more food. Different agriculture projects have been established with the aim to enlarge the cultivated area and to guarantee sufficient production of the main crops. During the period of **1952 through the 1980s** great efforts have been directed by governmental authorities for the extension of the arable lands to meet food security for the gross population. To fulfill this aim, an assessment of relative potentialities of all the available natural resources is necessary. For using the reclamation of new arable land, one should evaluate the soil resources to a serious degree and the soil water resources, which are crucial for plant growing. Egypt total cultivated area is approximately 3.15 million hectare comprised of 2.35 million hectare of old fertile high production land and 0.8 million hectare of new reclaimed land.

The country has a rapid population growth rate, expected to reach about 85 million inhabitants by the year 2025. Over 85% of Egypt's water resources are needed for agricultural use , due to arid conditions, very low annual rainfall and high vapor transpiration, irrigation is the only way to ensure crop production (Hafez, 2005). Land reclamation reached the highest rate during the 1960s, Egyptian government and the General Authority for Project Reclamation reclaimed about 3.24 (10^3 ha) annually. The Egyptian government gave to the General Authority for Project Reclamation the full responsibility to design and implement land reclamation projects and tested all necessary infrastructures to fully convert the land from the period 1952s to 1980s.

Since 1980s, the Egyptian government started plans to adjust this situation by re-distributing the population through applying an effective horizontal urban expansion along the desert areas and near the fringes of the Nile delta. Horizontal expansion is considered the main focus for sustainable agricultural development in Egypt, through reclaiming large areas in the northern and southern part of the country. The national strategy of Egypt for the expansion of agricultural land until 2017 aims at adding about 4.4 million acres in different region, depending on land suitability and water resources (Ismail et al., 2010). The west delta region has received the highest share of the land reclamation program 170.0 (10^3 ha). By the year 1997 the total cultivated area in the west delta fringes amounts to 445.2 (10^3 ha), (Ali et al., 2007). Currently, the gross population has forced the Government to launch a program to increase the cultivated area annually by about 60.0 (10^3 ha). On the same time the water resources have decreased in the year 1970 (1713 m^3) and it is expected to decrease from the current amount, less than 800 m^3/y, to about 630 m^3/y by the year 2025 (Moghazy et al., 2010). Therefore, the main projects, namely El Salam Canal and Toshky projects, will add 251.0 and 202.5 (10^3ha) respectively, to the cultivated areas in the near future. The main pillar of the sustainable agricultural developmen's expansion plan is to reclaim huge areas in the southern and northern parts of Egypt. The Western southern has three major projects, Toshky, East Owaynat and Drab El-Arbiaeen which have a net result of cultivating approximately 1,3 million hectares approximately (Hamdi and Abdelhafez, 2001). Another current project in the North East of Egypt is the El Salam Canal; it is one of the most important and largest of five irrigation projects in Egypt. The Egyptian Governorate envisions the reclamation up to 168.0 (10^3 ha) of desert situated along the Mediterranean coast of Sinai Peninsula (Hafez, 2005).

For the North Western coast, rain fed agriculture is limited to the Mediterranean coastal plain from Alexandria to El Saluom, which represents most of the resorts along the Mediterranean Sea. The Egyptian government organized several development programs. One of these programs was directed to wards the coastal zone of the western desert.whose effort is to extend water pipe lines from the Nile to the coast and improve the native wells as water resources for domestic use and agriculture. They start with additional projects like El Noubariya Canal - El Nasr Canal - El Hammam Canal and Extension. For the example, El Noubariya Canal is a second order irrigation canal diverted from El-Beheiry Rayah. The canal length is approximately 100 km and serves a command area of 250.0 (10^3 ha) approximately (Donia and Farag, 2010). In 1996, the Egyptian Environmental Affairs Agency (EEAA) issued guidelines for coastal development. The main objective of these guidelines was to establish environmental regulations mainly for the construction facilities along the Egyptian coastal areas and to introduce the basic principles to investors in ecological sensitive areas (Mostafa, 2012). Policies at local and international levels were introduced and implemented to control population and their impacts and to generate renewable resources. The results of the 1996s Census show that Matrouh governorate had a population of 211,866 inhabitants. Marsa Matrouh city and its hinterland had the biggest concentration of population, 80,279 inhabitants, representing about 40% of the total governorate Matrouh population. El-Alamein region had only 5800 inhabitants, accounting for no more than 2.7% of the total governorate population(Modernizing and Egyptian, 2001) and (Shalabi, 1999).

The northwestern of coastal plain region could be made a **highly attractive for tourism** development and with its investment in agriculture and grazing the nearly coastal plain could produce fruits, vegetable and crops to supply the tourist market. The study area is a very promising area for tourism activity. There are many attractive features in the area such as El-Alamein area and the resort villages along the Mediterranean coast. The coastline of the area is a sandy area, with a projection of rocks, fine sandy beach, and shallow, clear blue water, the sand was perpetually washed by the Gibraltar current, directed from west to east. A remarkable feature of the shoreline is the succession of bays, the first of which begins east of

Matrouh city and extends to El-Alamain. The unique location of Sidi Abdel Rahman area, a tourist village is planned to be established on this site.

The general situation with road network is very good, since there is a coastal highway between Alexandria and Marsa Matrouh, which is continuing further on towards Saloum and Libya. This road extending for 470 km from Alexandria to Salloum, this road is becoming an axis for more intensive exchange with Libya and transit trips between North Africa and Egypt. In addition, there is a single railway line, which currently being developed to be a double line. There are airports in Matrouh, El-Alamain, Borg El Arab and Alexandria which are used during the summer (from June to October). The airports are considered an important link for rapid transportation to the rest of the country. The nature of the changes of different land cover from 1987 to 2007 indicate the increase of cultivated areas from 5,6 to 21,7 % and urban areas from 0,4 to 2,5% , while there is a decrease of Sabakhas areas and grasslands (Shalaby et al., 2006) and (El-Bayomi, 2009).

The North-Western coast of the Mediterranean Sea in Egypt is considered as one of the most important regions for land reclamation for agricultural expansion and tourism development projects (Awad et al., 1994). The study area occupies a portion of the North-Western coastal zone of Egypt, which is an accessible area attaining the most promising lands for agricultural expansion beyond the Nile Valley and Delta.

Research activity for the region of the study has become necessary to bridge the gap between researchers and decision maker, therefore, to identify the priorities for research development plans providing adequate information is considered the most important and crucial step for the next steps (Ritung S, 2007). The coastal plains along the Mediterranean are considered to be one of the most important areas in Egypt suitable for tourism and other recreational activities. Up to date the tourist villages stretch along the northern coast from Alexandria to Saloum. To meet the food demands of the tourist sector, the study area is included in a strategic development plan (Long-term comprehensive development plan 2002-2022). Therefore, one aim of the current study is to demonstrate the applicability and the particular advantages in utilizing soil information provided by a comprehensive pedological study of the area under consideration for assessing its land capability by the adapted qualitative and quantitative rating systems.

This thesis has two **general objectives**; the first is to evaluate the land resources of a NW Egyptian coastal area for future agricultural development. Based on this study the objective of the second part is to assess different methods to qualify soil properties for irrigated land use. Here the focus is on the type of soil information (e.g. remote sensing, mapping, laboratory analysis), their spatial distribution and the methodswhich allow holistic assessments for land suitability for different types of agriculture. Based on these objectives **five overarching research questions** are considered:

1. Which evaluation criteria well be taken into account for designing land suitability models for agricultural crops under irrigation conditions in the study area?
2. How can local experts and land evaluators improve land suitability models in the study area?
3. Which evaluation methods are suitable for generating spatial distributions of land use potentials sensitive to general Egyptian environmental conditions in general?
4. Do the results obtained with the land evaluation systems correspond to the model land evaluation in the study area? Which results are more realistic?
5. Is it possible to apply this system in the land of Egypt and what are the important characteristics of the ground (including methods to be applied), which should be considered when selecting new areas for development?

Expected **outcomes** of this study are

1. Provide in-depth information that may be beneficial to the planning of agricultural development in the north coastal zone, particularly in the extension area around El-Hammam canal.
2. Carry out the essential analysis to characterize and classify soils and to evaluate soil and landscape properties with respect to potential land use options.
3. Compare and assess the results derived from land evaluation systems and use the ideal method under Egyptian conditions.
4. Elaborate data requirements for the evaluation of dry lands for agricultural development.

Consequently, to these objectives, a review of the literature on the evaluation of land resources for irrigation agriculture followed by informations about location, climate, geology, topography and geomorphology settings, hydrology conditions and natural vegetation are presented in Chapter 3. Methodology analysis soil properties; soil classification systems and land evaluation programs represented in Chapter 4. In Chapter 5, the results of the field studies on soil properties are presented. The soils could be classified according to the World Reference Base for soil resources (2006) and the key to soil taxonomy (2010) and cluster analysis. Land capability and land suitability for crops, as well as tools for land evaluation systems will be shown in Chapter 6. Chapter 7 contains discussion of the main research and the conclusions. Recommendations and summary in German, English, and Arabic are given in Chapter 8. References and appendices are present in Chapters 9 and 10, respectively

CHAPTER II: STATE OF THE ART – LITERATURE REVIEW

Soil evaluation plays important role in the sustainable agriculture development. Based on the value of several soil and environment indicators, the agricultural land evaluation methodology is applied to land mapping units in order to compute the suitability index. This index characterizes these land-mapping units. However, there are different methodologies which have been reviewed for land capability and suitability evaluation.This chapter focus on reviewing the most widely applied land evaluation methodologies in Mediterranean region and for arid to semi-arid soils. Moreover, the following section gives an overview of the soil assessment in the newly reclaimed land in Egypt, which covered by agricultural development plans.

2.1. Land Evaluation (Definitions and Objectives)

Land evaluation is concerned with the assessment of land performance when used for specified purposes. Land evaluation is defined according to (Sys, 1979) as "*a concept that describes the interpretation processes of the principal inventories belonging to soil characteristics, vegetation cover, environmental conditions, climatic status and many other aspects related to the land to identify the best land use among its alternatives*" (Sayed, 2006). Similar definition was given by (FAO, 1985) **"***Land evaluation is a process for matching the characteristics of land resources for certain uses using a scientifically standardized technique. The results can be used as a guide by land users and planners to identify alternative land uses*". (Ritung S, 2007) and (Rossiter, 1994) defined the planning as the process of allocating resources, including time, capital, and labour, in the face of limited resources, in the short, medium or long term, in order to produce maximum benefits to a defined group. Although individuals plan for the future, by 'planning' in the context of land evaluation we understand some form of collective activity, where the overall good of a group or society is considered. Land evaluation is "*the process of predicting the use potential of land on the basis of its attributes. It doesn't include optimal land allocation. However, land evaluation supplies the technical coefficients necessary for optimal land allocation*"(Rossiter, 1996).

In general, land evaluation provides essential information on land resource, landform, land use, vegetation, and climate and soil properties for a defined area. Concepts, definitions and case studies of Land Evaluation can be found in numerous publications such as (Beek, 1930), (Storie, 1933), (Klingebiel and Montgomery, 1961), (Beek, 1971), (FAO, 1976; FAO, 1983; FAO, 1985), (Dent and Young, 1981), (Rossiter, 1990; Rossiter, 1994; Rossiter, 1996), (Sys and Verheye, 1978) , (Sys, 1979) , (Sys.C et al., 1991) and (Sys, 1993). .

Food and Agriculture Organization (FAO, 1976) stated that "*Evaluation takes into consideration the economics of the proposed enterprises, the social consequences for the* *people of the area and the country concerned, and the consequences, beneficial or adverse, for the environment.*

The evaluation process does not in itself determine the land use changes that are to be carried out, but provides data on the basis of which such decisions can be taken. To be effective in this role, the output from an evaluation normally gives information on two or more potential forms of use for each area of land, including the consequences, beneficial and adverse, of each" (FAO, 1976).

2.2. The methodology of land evaluation

For land evaluation is considered as a set of methodological guidelines rather than a land classification system, such as Land Capability and Land Suitability for Irrigation. The differences among land evaluation systems are given by the particular use to be considered, the factors regarded as relevant for that use, and the scale of analysis. Land Evaluation systems are traditional or modern system and focus on qualitative or quantitative aspects. Traditional systems are most often qualitative assessments; a qualitative classification is one in which relative suitability is expressed in qualitative terms only, without precise calculation of costs and returns. They are based mainly on the physical productive potential of the land, with the economics only present as a background. They are commonly employed in reconnaissance studies, aimed at the general appraisal of large areas. Qualitative assessments depend on experience and intuitive judgment and they are real empirical systems. This system, usually representing less detailed technical approaches requires fewer data and generally produces quick but broad answer. Most difference between quantitative and qualitative procedures is the quantitative classification is mainly depended the numerical value for every class to assist in identifying the differences between classes relating to different kinds of land use, and requires more input data than the qualitative system. However, qualitative classifications are based mainly on the physical productive potential of the land, with economics only present as a background (FAO, 1976) and (Van Lanen et al., 1992).

Land evaluation system should include two components: The general and the specific evaluation. The general evaluation based mainly on economic factors, depending on the given socio-economic circumstances. The specific evaluation expresses the suitability of a given land for a given ecosystem or crop and depends on landsite characteristics, rationalization of land use and cropping pattern and farming technologies (Várallyay, 2011). (Stomph et al., 1994) *Proposed format allows a more realistic quantitative assessment of the performance of the bio-physical sub-system and a quantitative integration of the bio-physical and socio-economic sub-systems for the overall land use system evaluation"* (Stomph et al., 1994. In general, the quality of land evaluation systems is depending on the factors input and economic output. Currently applied of land evaluation systems are belong to 4 main groups: categoric systems (or capability system), parametric systems, special purpose systems and crop-specific assessment (Rosa and van Lanen, 2002). In the next sections reviews of the most common land evaluation methodologies and an explanation of some of the systems applied in the study are given. Summary of the most widely applied land evaluation methodologies and most important characteristics of land evaluation systems such as, land purpose, required data and output data Table 1.

2.2.1. Categoric systems (USDA land capability system)

The most traditional land evaluation system and maximum-limitations system is the USDA land capability classification that provides conceptual definitions of capability classes according to the degree of limitation to land use imposed by land characteristics based on permanent properties. The main product of land capability classification is a map in which areas of land are put into capability classes ranging from I (best) to VIII (worst) (Rossiter, 1994a). It was first developed by (Klingebiel and Montgomery, 1961), in the USA and is mainly soil conservation oriented. Thus class I land can be put to arable use without soil conservation measures while classes II to IV require increasingly costly conservation practices; classes VI to VIII should not be used for arable use (Dent and Young, 1981) .

Table 1: Characteristics of the major land evaluation methods

Land Evaluation System		Purpose & Land uses	Data required	Model Outputs
Categoric Systems	USDA system	Land capability & General land use	Physical properties	8 classes
Parametric systems	Sys and Verhye, 1978	Suitability	Suitability for irrigation	Physical and chemical properties
	Sys 1993 -Part III	Suitability	Suitability for crops	Physical and chemical properties
	Storie index 1978-2008	Land use and productivity	Specific land uses	Physical and chemical properties
	General (1)	Suitability	Specific land uses	Physical
Tools for land evaluation systems	MicroLEIS	Capability	General land capability	General land characteristics
		Suitability	Agricultural soil suitability	Physical and chemical properties
	ALES	Land use	specific land utilization	Land characteristics
		Capability	General land capability	General land characteristics

(1) : (Elaalem, 2010b)

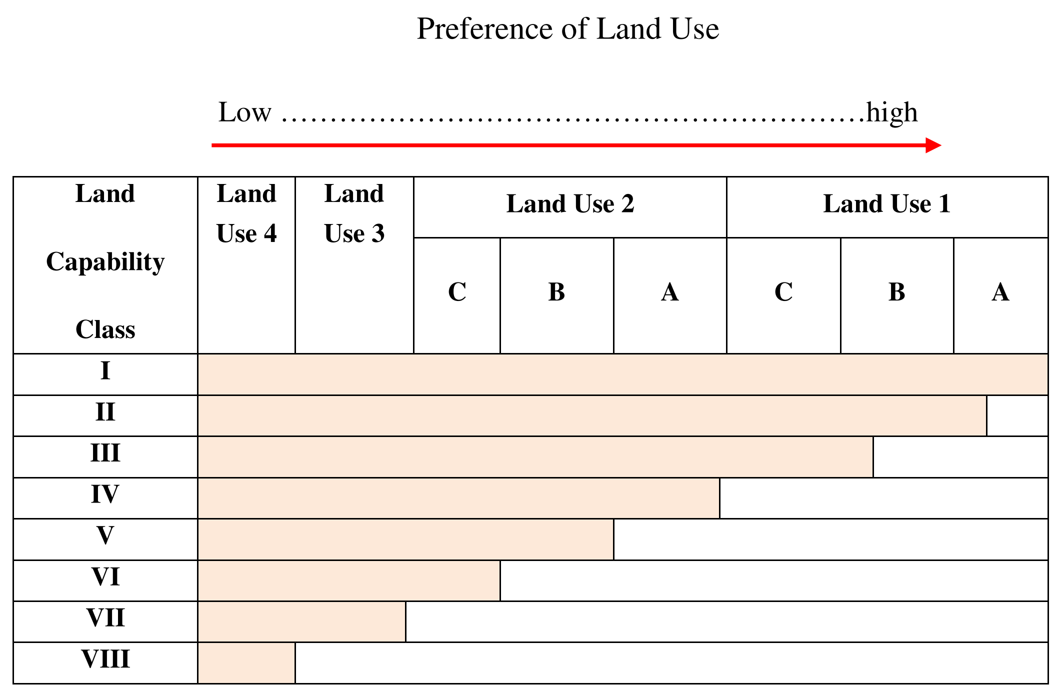
Land capability classes and description of the classes are presented in Table 2. Land capability is a qualitative methodology to classify land resources based on soil, topography and climate parameters without taking into account the yield and socio-economic conditions. The classification base on soil protection and it evaluates the most suitable kind of land use to achieve this target like rain-fed agriculture, extensive grazing, or forestry. Land is classified mainly on the basis of permanent limitations (FAO, 1976). The general rule is that if any one limitation is of sufficient severity to lower the land to given class it is allocated to that class, no matter how favorable all other characteristics might be. Thus it is useless to have level land, well drained and free from flooding, if it only has 10 cm of soil which is too shallow to practice any crop production (Dent and Young, 1981) study indicated that this type of classification emphasizes the negative features of land, which are taken into account in assigning different types of land to capability classes. Soil erosion hazard, and hence conservation requirements, normally gets more attention. (Klingebiel and Montgomery, 1961) noted that, land capability evaluation refers to a range of major land uses, such as agriculture, forestry, livestock production, and recreation. The most widely used categorical systems for evaluating agricultural land is termed land capability classification.

Table 2 : Land capability classes and their description (modified from Landon, 1984)

Class	Description
Class I	Soils that have slight limitations that restrict their use.
Class II	Soils that have moderate limitations that reduce the choice of plants or require moderate conservation practices.
Class III	Soils that have severe limitations that reduce the choice of plants or require special conservation practices, or both
Class IV	Soils that have very severe limitations that restrict the choice of plants or require very careful management, or both.
Class V	Soils those have little or no hazards of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
Class VI	Soils that have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
Class VII	Soils that have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.
Class VIII	Soils and miscellaneous areas that have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for aesthetic purposes.

(FAO, 1976) mentioned that capability is viewed as the inherent capacity of land to perform at a given level for a general use. Other peoples see capability as a classification of land primarily in relation to degradation hazards, whilst some regard the term "*suitability*" and "*capability*" as interchangeable.

General outline of a land capability classification system showed in Figure 1. Land capability defined as "*The potential of the land for use in specified ways, or with specified management practices"* (Dent and Young, 1981). According to (Land Capability Guidelines, 1999) land capability should not be mixed with land suitability. Land suitability is the assessment of how suitable a particular site is for a particular use, and depends on land capability and a range of other factors such as proximity to centres of population, land tenure, attractiveness of scenery and consumer demand. Land capability refers to the potential of land to sustain a number of predefined land uses in a built-in descending sequence of desirability: arable crops, pasture, woodland, recreation/wildlife (Mohamed A.G.M., 2002).



A: Intensive use possibilities C: Limited use possibilities

B: Moderate use possibilities : Suited for Specified Use

Figure 1: General outline of a land capability classification system, (Van Lanen, 1991)

2.2.2. Parametric system

Parametric systems find their origin in field trials and fertility tests especially where a good correlation could be found between crop yield and one or more key factors. Parametric systems like all numerical correlation are a simple quantified expression of soil productivity

(Sys and Verheye, 1972). Land evaluation parametric methods are semi-quantitative of land evaluation and positioned halfway between qualitative and quantitative methods. These arithmetical systems consider the most significant factors and account for interactions between such significant factors, either by simple multiplication or by addition of single-factor indexes (Rosa and van Lanen, 2002).

Land suitability*:* The land-evaluation analysis focuses on land suitability or productivity, and land vulnerability or degradation approaches .The land-evaluation process is developed on the basis of land characteristics, and uses land qualities as an intermediate between land characteristics and land suitability, (Rosa, 2005) *"the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined use"*(FAO, 1976).

Land Suitability concept is method to assess the degree of appropriateness of land for a certain use. Actual land suitability reflects the current condition of the soil based on current information; physical environment data generated from soil or land resources surveys. Potential Land Suitability is the suitability that could be reached after the land is improved. Land suitability is a land suitability that is based on current soil and land contestations, i.e. without applying any input (Ritung S, 2007). Land suitability evaluation can also be defined as the assessment or prediction of land quality for specific use. This process includes identification, selection and description of land use types relevant to the area under consideration; mapping and description of the different types of land that occur in the area and the assessment of the suitability of the different types of land for the selected land use types (FAO, 1976)**.** Land suitability evaluation requires specialists of different disciplines like soil scientists, agro-ecologists, socio-economists and planners. The evaluation relates to the environmental and socio-economic conditions of the area as it includes a consideration of inputs and projected outputs of production process (Baniya, 2008). The process of land suitability evaluation which depend on input and output it may be take more time to evaluate the production and surrounding environment. Suitability can be scored based on factor rating or degree of limitation of land use requirements when matched with the land qualities.

According to the Framework (FAO, 1976) there are four categories of decreasing generalization, namely: order, classes, subclasses, and land suitability units. Land suitability orders indicate whether land is considered as suitable or not suitable for use. Land suitability classes reflect the degree of suitability. These classes are numberd consecutively by Arabic numbers, in a sequence of decreasing degree of suitability within the order. The number of classes within the suitable order is not specific, and nevertheless it should be kept to the minimum necessary to meet interpretative aims. Within the order suitable, three classes are usually recognized, namely: highly suitable (S1), moderately suitable (S2) and marginally suitable (S3).

Within the order not suitable, there are normally two classes: the currently not suitable and permanently not suitable. Quantitative definition of these classes is normally unnecessary since both are uneconomic for a given use. Land suitability units are subdivision of subclasses. All the units within subclasses have the same degree of suitability on the class level and similar kinds of limitation at the subclass level. The units, however, differ from each other in their production characteristics, or in minor aspects of their management requirements. Briefly, the structures of suitability classification are summarized in Table 3. Land suitability subclasses reflect kinds of limitations, e. g, slope (s), soil depth (d), texture (t), gravel content (g), lime content (l), gypsum content (m), salinity (n) and exchangeable sodium percentage (e).

Table 3:Summary for the structure of land suitability classification (FAO, 1976)

Order	**Classes reflect the degree of suitability classification within the order**
(S) Suitable: Land on which sustained use of the kind under consideration is expected to yield benefits which justify the inputs, without unacceptable risk of damage to land resources	S (1) highly suitable Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
	S (2) Moderately suitable Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use although still attractive, will be appreciably inferior to that expected on Class S1 land
	S (3) Marginally suitable Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
(N) Not suitable: Land which has qualities that appear to preclude sustained use of the kind under consideration	N (1) Currently not suitable : Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
	N(2)Permanently not suitable: Land having limitations which appear so severe as to preclude successful sustained use of the land in the given manner

2.2.2.1. Storie Index (1978 and 2008)

The Storie index is a semi-quantitative method of rating soils used mainly for irrigated agriculture based on crop productivity data collected from major California soils in the 1920s and 1930s (Storie 1932, Reganold and Singer, 1979). The Storie Index assesses the productivity of a soil from the following four characteristics:

Factor A = the degree of soil profile development, factor B = surface texture, factor C = slope, and factor x = other soils and landscape conditions including the sub-factors drainage, fertility, acidity, erosion, and microelief. A score ranging 0 to 100 determined for each factor, and the score are then multiplied together to generate an index rating (Storie, 1978). The following simple description of these factors and for more information, refer to (Storie, 1933) to (O'GEEN, 2008)

Factor A: Soil profile group, is a rating of the character of the soil profile based on the degree of soil development.

Factor B: Surface texture is based on surface texture. Loamy soils receive the highest ratings, and clay-rich and sandy soils receive lower ratings. Rock fragment content is used to modify the scores, which range from 100 to 10%. The ratings for factor B can very as much as 30% for specific textural classes depending on the volume of coarse fragments present (Storie 1933, 1978).

Factor C: Slope, based on steepness of slope. Nearly level to gently sloping conditions (0 to 8% slope) receive high scores, which range from 100 to 85 %. Moderate to strongly sloping conditions (9 to 30%) have scores ranging from 95 to 70%,slops greater than 30% receive lower scores, ranging from 50 to 5 % (Storie, 1978).

Factor X: Drainage, alkalinity, fertility, acidity, erosion, and microrelief focuses on dynamic properties while soil inventory and landscape conditions require special management conditions. Characteristics considered are drainage class, alkalinity, nutrient status, degree of acidity, wind and water erosion, and microlief. Scoring for each characteristic in factor X (Drainage, alkalinity, fertility, acidity, erosion, and microrelief) is subjective. For example, drainage, erosion, and microlief scores range from 100 to 10 %, while fertility status and acidity from 100 to 60 and 95 to 80 %, respectively (Storie, 1978) and (O'GEEN, 2008).

Soil grading their description in Storie index 1978 (six soil grades have been set up in California by combining soils having ranges in index rating) can be distinguished as follows:

Grade 1 (excellent): Soils that rate between 80 and 100 per cent and which are suitable for a wide range of crops, including alfalfa, orchard, truck and field crops.
Grade 2 (good): Soils that rate between 60 and 79 percentage and which are suitable for most crops. Yields are generally good to excellent.

Grade 3 (fair): Soils that rate between 40 and 59 per cent and which are generally of fair quality, with less wide range of suitability than grade 1 and 2. Soils in this grade may give good results with certain specialized crops.

Grade 4 (poor): Soils that rate between 20 and 39 per cent and which have a narrow range in their agricultural possibilities. For example, a few soils in this grade may be good for rice, but not good for many other uses.

Grade 5 (very poor): Soils that rate between 10 and 19 per cent are of very limited use except for pasture, because of adverse conditions such as shallowness, roughness, and alkaline content.

Grade 6 (nonagricultural): soils that rate less than 10 per cent include, for example, tidelands, riverwash, soils of high alkali content and steep broken land.

2.2.2.2. Sys and Verheyes system (1978)

Land valuation and characteristics and for irrigation according to the FAO framework for land evaluation (FAO, 1976) was undertaken by Sys and Verheye (1978). The aim of this system was to provide a method that permits a suitable evaluation for irrigation purposes based on the standard granulometric and physico –chemical characteristics of the soil profiles. The factors influencing the soil suitability for irrigation can therefore be subdivided in the following four groups:

a. Physical properties, that determine the soil-water relationship in the soil such as permeability and available water content (both related to texture, structure, soil depth and calcium carbonates status);
b. Chemical properties, that interferes in the salinity/alkalinity status, such as soluble salts and exchangeable Na;
c. Drainage properties;
d. Environmental factors, such as slope.

Regrouping of their criteria is made in such a way that the classification can be done according to the FAO framework using specific guidelines for the definitions of the orders (S and N) and classes (S1, S2, S3, N1, N2). Following this system, the capability can be regrouped under the subclasses of the FAO framework as follows:

t = topographic limitations,
w = wetness limitations, mainly based on drained conditions,
S = Limitations concerning the soil physic-chemical conditions, these include,
S1 = texture including stoniness,
S2 = soil depth,
S3 = calcium carbonate status,
S4 = gypsum status,
n = salinity and alkalinity limitation.

The evaluation of these land characteristics can be achieved in a relative limitation scale where five levels are used Table 4. The limitation (severe) is used when the characteristics are very marginal. The relative limitation scale is transferred to a parametric approach using the ratings for the different limitation levels. Noteworthy to mention that evaluation of these characteristics is accomplished for gravity irrigation using good quality water. Further details about the rating of the concerned characteristics are shown numerically, and presented graphically elsewhere, Sys and Verheye (1978). Based on the number and intensity of limitations, Sys and Verheye (1978) suggested definitions of suitability orders and classes.

Table 4: Limitation levels and their rating

Symbol	Intensity of limitation	Rating %
0	No	95-100
1	Slight	85-95
2	Moderate	60-85
3	Severe	45-60
4	Very severe	<45

The suitability index for irrigation (Ci) is calculated, and this value is also integrated in the definition where:

Suitability index (Ci) =

$$\left[t \times (W / 100) \times (S1 / 100) \times (S2 / 100) \times (S3 / 100) \times (S4 / 100) \times (n / 100)\right]$$ **Equation 1**

In light of the calculated Ci values, the orders and classes of lands can be distinguished as follows:

Order S: Suitable land for irrigation: land units with only moderate, slight or no limitation and no more than one severe limitation that however does not exclude the use of the land. (Ci is more than 25).

Class S1: land units without or with only 3/4 slight limitations (Ci < 75).

Class S2: land units with more than 3/4 slight limitations and no more than 2/3 moderate limitations (Ci 50 to75)

Class S3: land units with more than 2/3 moderate limitations and /or one severe limitation that do not exclude the use of the land for irrigation (Ci 25 to 50).

Order N: Not suitable: land units with one or more severe limitation that excludes the use of the land, or with one or more severe limitation (Ci >25)

Class N1: land units with severe or very severe limitations that can be corrected.

Class N2: land units with severe or very severe limitations that cannot be corrected. (Sys and Verheye, 1978).

2.2.3. Tools for land evaluation systems

Computer systems have been used to develop land evaluation methods since FAO framework was published. Computerised models can integrate socioeconomic and biophysical factors and would help to store, manipulate and appraise large amounts of data; fulfil the appraisal within a specific timeframe; and distribute in sights for future land evaluation appraisals. However, the computerised models may also be expensive, time-consuming and draw needed resources away from other planning activities.Computer land Evaluation systems are different in each other on the basis of purpose, Land uses, data required and model outputs. There are many of these systems, such as Agricultural planning toolkit (APT), Comprehensive resource inventory and evaluation system (CRIES), Land Evaluation Computer System (LECS), the automated land evaluation system (ALES) and Microcomputer Land Evaluation Information System (MicroLEIS) (Kalogirou, 2002) and (Elaalem, 2010a)

2.2.3.1. The automated land evaluation system (ALES)

Automated Land Evaluation System is a microcomputer programme developed in 1989 by (Rossiter and Van Wambeke, 1989) and refined in 1990 by Rossiter and Van Wambeke to evaluate the land according to the FAO framework and taking local socio-economic evaluation into consideration. Automated Land Evaluation System (ALES) as "*a microcomputer program that allows land evaluators to build their own knowledge-based system which they can compute the physical and economic suitability of a land mapping units, in accordance with the FAO's Framework for Land Evaluation*" (Mahmoud et al., 2009a).

The ALES is a computer program that allows land evaluators to build expert systems that can evaluate land according to the method presented in the Food and Agriculture Organization's publication "Framework for Land Evaluation"(Rossiter and Wambeke, 1997). It is intended for use in projects, or regional-scale land evaluations. The ALES was developed at Cornell University from 1986-1996 and is still distributed by Cornell. It is supported by the program author, D.G Rossiter, who moved to International Institute for Geoinformation Sciences and Earth Observation (ITC), Enschede in the Netherlands in 1997. Although ALES is a DOS program which has not been updated since 1996, it is still a rich expert system environment and continues in use as part of the land evaluator's toolkit. Evaluators build their own expert systems with ALES, taking into account local conditions and objectives. The ALES is not by itself an expert system, and does not include by itself any knowledge about land and land use. The ALES is a framework that allows evaluators to encapsulate their own expertise and local knowledge. (Rossiter and Wambeke, 1997) define the Automated Land Evaluation System (ALES) as; a microcomputer program that allows land evaluators to build their own knowledge-based system which they can compute the physical and economic suitability of a land mapping units, in accordance with the FAO's Framework for Land Evaluation. The entities evaluated by ALES are map units, which may be defined either broadly (as in reconnaissance surveys and general feasibility studies) or narrowly (as in detailed resource surveys and farm-scale planning). Since each model is built by a different evaluator to satisfy local needs, there is no fixed list of land use requirements by which land uses are evaluated, and no fixed list of land characteristics from which land qualities are inferred. Instead, these lists are determined by the evaluator to suit local conditions and objectives (Wandahwa and van Ranst, 1996) conducted a study on qualitative land suitability for pyrethrum cultivation in west Kenya based upon computer-captured expert knowledge and GIS. They built a model PYCULT in the ALES program to select the best land for pyrethrum cultivation and determination of the limiting factors, where the land characteristics were matched with the crop requirements.“ (Rossiter, 1990) describes the ALES approach to land evaluation in two stages:

2.2.3.1.1. The ALES approach and model designed

Land evaluation models are designed in the following manner. First, the evaluator builds a preliminary version of the model, by: (1) Selecting a few representative LUTs. (2) Expressing these in terms of their most important LURs. (3) Determining which LCs is available to form the basis of evaluation. (4) Constructing decision trees to relate LCs to LURs. And (5) Collecting economic parameters, such as prices. (6) Selecting some representative or well understood map units. (7) Collecting and entering LC data for these map units. (8) Entering them into the database.Once the preliminary model has been completed, the evaluator may extend it to a wide set of LUTs.

2.2.3.1.2. Model Use

The model can at this point be turned over to clerical staff, which then enters definitions and data for the remaining land units in the evaluation area, using the data entry forms designed by the model builder. Then, they request the program a final comprehensive evaluation and printed reports showing the best land areas for each use and the use for each land area” (Mohamed A.G.M., 2002) .The land use requirements are expressed in terms of land qualities, each one was described by its related land characteristics. For each land characteristics there are four limitation levels with corresponding land classes and rating values as S1 = highly suitable.,S2 = moderately suitable ,S3 = marginally suitable and N= not suitable.

El Fayoum Governorate occupies a circular depression in the Eocene limestone plateau at the north part of western Desert. (Shendi et al., 1997) studied land capability and suitability depend on some soil properties such as: Soil depth texture, permeability, available water, slope, drainage, $CaCO_3$, gypsum, salinity and alkalinity. The main steps were done evaluate area under study; matching land use requirements with land qualities using the Automated

Land Evaluation Systems (ALES) and displaying the results as maps in ILWIS GIS. Results of the studied are were moderately suitable for agricultural in the southern part and marginally or not suitable in the middle. The main limitations found in the middle were salinity and cementation constrains. Land capability model was used built using ALES software and the resulting tables were imported into ILWIS GIS to produce the capability map, and the potential capability map was also generated in El Hammam area The assessment of physical land suitability for 10 different land use types (LUT) has been conducted for the capable soil units using Automated Land Evaluation System, ALES, by implementing the FAO framework. The main recorded soils in these units are; Typic Torripsamments, Typic Haplocalcids, Calcic Petrocalcids and Typic Aquisalids. The main physical and chemical characteristics of the studied soils it is observered that the majority of the upper areas have calcic horizons in their representative profiles. With getting closer to the sea in the lower area, Salic horizons appear and are intercalated with calcic horizons; he results showed that more than 23.000 hectares in the study area are marginally capable for agriculture. This area is studied for sustainability under different conditions of irrigation water availability. It is found that, the most sustainable land use recommended under the limited water resources (scenario I) are clover, barely, wheat and sorghum as field crops, and figs and guava are the most sustainable orchards cultivations. Whereas the most sustainable land use in case of irrigation water availability (scenario II) are wheat, maize against figs and guava. On the other hand, there are various limitations for agricultural use, some of which are correctable. Therefore, proper soil management is required in order to increase the soil suitability for different crops (Mahmoud et al., 2009).

2.2.3.2. Mediterranean land evaluation information system (Microleis)

Although increasing thought is given to agricultural diversification and lower inputs, it is still important to identify optimum land use systems for sustainability and environmental quality. In Mediterranean regions, the central question is 'Can the semi-arid ecosystems be managed for productive and sustainable agriculture given the cyclical nature of climate and the intensive use of land?' (Stewart, 1989) As pointed out by (Elliott and Cole, 1989) the aims of ecologists and agricultural scientists are now converging within agro- ecosystem science. This integration should solve many current environmental problems. Land evaluation offers the ideal framework for agro- ecological integration, within which observational and experimental information can be used to improve our understanding of sustainable agricultural systems. Land evaluation makes it possible to use land according to its biophysical potentialities and limitations.

Recently, increasing application of information technology to land evaluation procedures has led to the development of land evaluation information systems (LEIS). LEIS integrate observational and experimental information using simulation modelling and geographic information systems (GIS), such as discussed by (Lanen et al., 1992). Land evaluation procedures have recently been improved by the usc of expert systems The Automated Land Evaluation System (ALES) developed by (Rossiter, 1990) is a framework for evaluators to build their own expert system, and has many possible applications .For all these computerized applications, the microcomputer (PC) has become an essential tool. This paper explains the construction of a microcomputer based system called MicroLEIS, and reviews the integrated land evaluation methods developed by (De la Rosa et al., 1977, 1981, 1987). MicroLEIS aim to establish an interactive user-friendly procedure for the optimal allocation of land use systems and to define production levels for arable and forest crops under Mediterranean conditions.

Land evaluation is the appropriate way to interpret resource inventories for land user and planners. The term 'land' is used in a broad sense to include soil, climate and land use. MicroLEIS include several biophysical evaluation methods to decide appropriate agricultural and forestry land uses in Mediterranean regions. It uses scale-appropriate models varying from purely qualitative (reconnaissance scales) through semi-quantitative (semi-detailed scales) to quantitative (detailed scales). The FAO concepts of land characteristic (LC), land quality (LQ), land utilization type (LUT) and land use requirement (LUR) are widely used in the interpretative stage. General and relative land aptitudes, as referred to a range of uses and to one tightly defined use, respectively, are basic concepts used to differentiate capability and suitability evaluation methods. Social and economic attributes, such as capital intensity, labour cost, farm size or land tenure, were not considered. Also, the present version of MicroLEIS does not have a spatial reference, each land unit or soil unit being evaluated independently of geographical location (De la Rosa et al., 2004).

2.2.3.2.1. General land capability

As a first stage of MicroLEIS, the general land capability module includes the evaluation method designed by (De la Rosa and Magaldi, 1982), and then calibrated and validated by application in Andalucia (De la Rosa and Moreira, 1987) and Puglia in Italy (Ferrari and Magaldi, 1989). The land qualities or factors considered are (a) site, (b) soil limitation, (c) erosion risks and (d) bioclimatic deficiency, which are inferred from generalized values of land characteristics, namely (a) slope, (b) useful soil depth, soil texture, stoniness, drainage and salinity, (c) slope, soil erodibility, rainfall erosivity and vegetation density, and (d) rainfall and frost risk. These are used to define four capability classes by the maximum limitation method: Class S 1-Excellent, Class S2-Good, Class S3-Moderate, and Class N-Marginal and Not Suitable. Four subclasses are also defined according to the maximum limitations of site (t), soil (l), erosion risk (r) and bioclimatic deficiency (b). In MicroLEIS, the first stage is to screen land units according to whether they are suitable or not suitable for agricultural use. The component CERVATANA (land capability model) microcomputer program allows an automated application of this first land capability method. The program works through a sequence to match land characteristics with the conditions required for each capability class. The land unit is then assigned to a subclass determined by the most limiting land qualities (Aa et al., 2010).

2.2.3.2.2. Agricultural soil suitability

The soil suitability module (De la Rosa et al., 1977) was based on an analysis of edaphic factors which influence the production of twelve traditional crops: wheat, corn, melon, potato, soybeans, cotton, and sunflower, and sugar-beet, alfalfa, peach, citrus and olive. Effective depth (p), texture (t), drainage (d), carbonate content (c), salinity (s), sodium saturation(a) and degree of profile development (n). For each major soil quality, ease of root growth, water availability, oxygen availability and available nutrients, a matrix relating values to the corresponding crop requirements was established. Following the maximum limitation procedure, five suitability classes were determined: Class S1-Very High, Class S2-High, Class S3-Moderate, Class S4-Low and Class S5 %-Very Low. Subclasses are indicated by letters corresponding to the main limiting soil criteria (Aa et al., 2010). The ALMAGRA (land suitability model) microcomputer program within MicroLEIS is an automated application of this soil suitability method. The most important land characteristics of computerized land evaluation methods were used in case of the study of the soils adjacent El-Hammam canal area and its extension. The selection of the Mediterranean land evaluation information system (MicrolEIS) for land evaluation systems in El-Hammam canal , western coastal plain in Egypt will allow the matching of land characteristics against crop needs and the assessment of a suitability rating and capability for each selected land characteristic. The matching is very much a requirement in area under study, where the land suitability for certain crops is required to meet the national policy. These matching programs for the properties of the soil in the northwest coast of Egypt will be explained in Chapter VI.

2.3. Overview of the application evaluation systems

In the developed world, modern agriculture faces many problems, e.g., associated market regulations force farmers to change or adapt their production methods. The impact of alternatives on current agricultural practices, such as low-input in agricultural production systems and introduction of industrial crops needs investigation. Recently, land use can not be made without evaluating the potentials and constraints of land, such as climate, topography, hydrology and soil (Van Lanen et al., 1992) .

The Delta of Wadi Hodein in the southern desert of Egypt represents one of the promising areas for sustainable development. Therefore, a great attention has been paid towards the investigation and mapping of the natural resources of this region. Remote sensing technology used to asses and to evaluate an area covers about 550 km. The characteristics of soil were determined. Soils of wadi deposits, alluvial plain and beach classified as Typic Torrifluvents, Duric Torrifluvents Typic Torriorthents, Typic Torripsamments Typic Aquisalids and Sodic Haplogysids according the US Soil taxonomy (2010). Land capability was applied to determine the areas of high potentiality for agricultural development Wadi Hodein region classified as capability classes III, IV and V. The limiting factors in this region are: water resources, climate and texture (El-Taweel, 2006). Land capability classification (USDA, 1976) was used to asses soils at a site in Idoffa, Southwestern of Nigeria . The result showed that the most soils are ranged from class II to VI indicating good to fairly good value for arable land use (Suitable for cropland), with limitations such as ; shallow effective soil depth , highly gravel content and low fertility status. Land capability classification rated the land area as 50% arable, 25 % moderately arable, and 25 % non-arable in the soils studied (Oluwatosin, 2006).

Southern Somalia, land suitability assessment of the Juba and Shabelle Riverine areas which located lies between 41° 53' and 46° 09' east of the Prime Meridian; and between 0° 16' south of the Equator and 5° 04' north of the Equator. Land uses in this area are transhumance pastoralism, rained agriculture and irrigated agriculture. Pastoralism is often combined with wood collection, either as firewood or for charcoal production. In this study applied Somalia Automated Land Evaluation System (SOMALES). SOMALES is the application of the FAO Framework for Land Evaluation with the use of computer software called the Automated Land Evaluation System (ALES).

Somales Land suitability Classes:
S1 = highly suitable (no limitations, level 1)
S2 = moderately suitable (most severe limitation is at level 2)
S3 = marginally suitable (most severe limitation is at level 3)
N = not suitable (most severe limitation is at level 4)

Main limitations in soil characteristics are texture, gravel content, slope and rock outcrops. Land suitability for rainfed agriculture has no land very suitable (S1), roughly 10 to 25 per cent is moderately suitable (S2) and around 35 % of the study area are unsuitable (N), (Management and Road, 2007). The Republic of Namibia has a land surface of 824 km^2 situated along the south Atlantic coast of Africa between 17 and 19 degrees south of the equator. Land suitability using The Automated Land Evaluation System (ALES) in north of Tsumeb town situated in the Guinas constituency, Oshikoto region, Namibia. The soil classification and characteristics for study area in Oshikoto, were about 50 % Petric Cacisols , with sandy to loamy topsoil , are with high lime concentrations in indurated from in the subsoil. The other 20 % are Calcic Vertisols, 20 % are Gleyic Solnetz sodic soil and 10 % are Haplic Arenosols. Most of these soils were not suitable for cropping due to shallow soils on calcrete, but good grazing area for large livestock according to AEZ. Land suitability for crops; maize, pearl millet, cowpea and sorghum according to ALES. The result indicated all observed points are marginally and moderately suitable for all crops. The maximally limiting factors were moisture, rooting conditions and soil toxicity (Mwazi, 2006).

Land suitability for agricultural development and used MecrLEIS programs in Sirt and Benghazi, Libya, North Africa. Soil characteristics in Sirt were as non- saline , non-alkaline, low fertility , calcareous , low organic matter , light texture and subjected to wind erosion , While , soil characteristics foe soils in Benghazi were high salinity and sodicity , medium to fine texture with a high levels of calcium carbonate , low soil moisture retention and low permeability. Soils are classified, as Aridisols and Entisols in Sirt, while, soil classification great group in Benghazi are Aridisols, Entisols and Inciptisols according to US Soil Taxonomy, 2010. According to MecroLIES Model prediction, most of the studied area 62, 2 % in Sirt and 62, 6 % in Benghazi were classified S3r, which moderately capability with erosion risks as a limiting factor. Land suitability for agricultural crops are S2, S3 and S4 for most of crops e.g. olive, peaches, citrus, alfalfa, wheat, corn melon and potatoes (Abdulaziz, 2008). Land suitability classification for Barley using Fuzzy AHP and the TOPSIS methods in Jaffara Plain, North western of Libya studied by (Elaalem, 2010c). Comparison of the most locations of the studied area were mapped as class 2 from the use the Fuzzy AHP classification, while from the use the TOPSIS classification the most part of the study area was mapped as class 3. For all the two land evaluation models, few areas less suitable classes have been found. Using the KHAT accuracy and overall accuracy for assessing the results show that there is good agreement when the comparison between the Fuzzy AHP and TOPSIS classifications has been made. Land evaluation model based on using Fuzzy AHP and TOPSIS methods showed that the percentages of land units which ranked as highly suitable and less suitable classes for barley are very small. The results of the Fuzzy AHP method are not completely comparable with that created from TOPSIS method.

Land evaluation of the area between Mersin Province and Tarsus District, located in southern Turkey and planning to open irrigated agriculture. Land evaluation was performed according the (FAO, 1976 and 1993) using ILSEN (the Automated Land Evaluation System) after quantification of land characteristics. Land quality, capability and suitability for crops in ILSEN depend on soil characteristics surface and subsurface soil texture, subsurface soil structure, hydrologic conductivity, lime content, salinity, alkalinity, effective soil depth, surface stoniness and rockiness and topography data input slope, altitude and slope direction. Land suitability of the studied area showed that around 65, 8% has S1; S2 and S3 classes were suitable for all crops.

GIS and land evolution of the high land in east Mediterranean region,Turkey studied by (Özcan, 2006): Computer-based land evaluation information system (MicroLEIS, 1991) was development for optimal use of agricultural and forestry land systems under Mediterranean conditions. This system include land capability, suitability and yield prediction methods through semi-quantitative (semi-detailed) to quantitative (detailed). A MicroLEIS was developed from published land information of Cordoba Province, Andalucía. Basic information of topography, climate and soil characteristics were added, values for soil chemical characteristics were measured in control sections of soil profiles. The general land capability evaluation results of the CERATANA (land capability model) program were land for agricultural included classes (S1, S2, S3 and N). Soils units are represented N has severe limitations, mainly of useful depth. Land suitability for crops ELMAGARA (Land suitability model) program found the most of the crops are suitable except peach, citrus and olive, because they have a very heavy soil texture (Rosa et al., 1992).

In Mediterranean region is little experience in using GIS as an aid to land evaluation. (Davidson, 1992) used a GIS in association with a soil survey in Greece and land evaluation Boolean and fuzzy (land suitability assessment) methodologies.. Viotia area in Greece is typical of many basins in Greece, an extensive plain land mantled with Pleistocene and Holocene sediments and surrounded by uplands and mountains formed of Tertiary and Cretaceous flysch and limestone. Soil factors and properties used, drainage, elevation, slope, and land use, availability of irrigation water, erosion water, and erosion hazard and soil texture at different depths. Major difficulties are encountered in assessing the relevance of particular land properties to individual crops. The use of fuzzy set methodology means that much less information is rejected at all stages of analysis and is much better for classification of continuous variations Land evaluation analysis on the basis of fuzzy set methodology is to be preferred to one using Boolean logic. Instead of presenting land suitability classes a neat crisp sets, results when given as membership values and after field validation give a more realistic and graded pattern.

South soils of Damghan in Iran were classified based on semi detailed studies three physiography units, four map units and tow order Aridisoils and Entisoils. Climatic data are used from Damghan metrological synoptic stations for climate evaluation for barley. Determine land properties including soil depth, soil texture, gypsum and lime contents, soil salinity and alkalinity, drainage and percentage of aggregates. In addition, organic matter content and soil acidity were considered in term of soil fertility. Climatic characteristics of region are not suitable (N2) for barely plantation and land suitability methods results for barley plant showed all of evaluation methods were N2. The most important limiting factors in barely production in the Damghan plain included climate and physical properties of the soils such as gravelly content, Exchangeable Sodium percentage and salinity (Ashraf et al., 2011). The vast areas in the arid region with low rainfall in the world were affected by land degradation due to natural factors, anthropological activities (agricultural) and ultra-utilization of land, and they became vain and desert land. In another side in north Iran located and Northwestern region of the Semirom County. Based on the studies and operations that were carried out, almost 30 to 35% of the basin’s total lands are in the mountain area with high outcrops and slopes. In addition, there are series of limitations in the soil of the observed land that include: Topographical factors, water erosion, soil appropriate physical condition, soil type, lack of nutrient (micro and macro), flooding of the flat plain and calcification of the area by which each of these limitations were identified and measured. Land capability for each of the land unit components for various applications was determined by using studies conducted in each land component, and these capabilities include: irrigation forming, dry forming, range management, forest, urban and village improvement. These capabilities have declined all or parts of the major limitations by directly affecting land capability (Korosh et al., 2011).

The Canda land inventory designates soils with excessive carbonates as conferring moderately severe (Class 4) to sever (Class 5) limitations to the growth of commercial forests. Land capability for Forestry maps in southeastern British Columbia recognize limitations due to excessive levels of calcium and nutritional problems associated with high levels of carbonates at the subclass level (Kishchuk, 2000). In General, main limitations of soil properties are Useful depth, soil texture, calcium carbonate content, salinity and alkalinity and drainage. The Comparison between land evaluation methods are little variation depend on input values. Soil characteristics and soil properties rating were the most important input of each all methods. The comparison between the Fuzzy AHP and TOPSIS classifications methods had very little variation. This variation was found because the TOPSIS classification has some biasness towards negative and positive ideal values. Additionally, the results of the Fuzzy AHP method are not completely comparable with that created from TOPSIS method. This was resulted because some functions which employed to the TOPSIS model are not similar with that used to the Fuzzy AHP classification (Elaalem, 2010a). In case of the study in North Coastal plain of Egypt calcium carbonate content, useful depth and soil texture were the most limitations and the results of the different land evaluation methods depend on rating input of this factors.

2.4. Soil assessment in Egypt for reclamation

As for the desert reclamation soils in Egypt, most of the newly developed lands in Egypt, were distributed in the desert soil and fringes of Nile Delta. Most of cultivated land is located close to the banks of the Nile River. Nile delta and main branches are represented mostly cultivated area. The West Delta region received around 170 (10^3ha) from land reclamation program. In 1970s the total cultivated area in West Delta reaches to 445.2 (10^3ha). Main canals and drains in west delta are showing in Figure 2 (http://www.mwri.gov.eg). The soil capability mapping for the west Delta is an essential action in order to maintain the sustainable development of effort and investment as well as the sustainable usage of the soils (Ali et al., 2007).This study area includes old cultivation and newly reclaimed soils; different land forms i.e. river terraces, levees, flood plain and alluvial wind borne deposits. The obtained limitations were used; erodability, surface slope, $CaCO_3$ content, texture class, soil depth, salinity, alkalinity and drainage condition. The results indicated that the soils of very high, high, marginal, low and very low capability classes for agriculture represent 7.26, 22.45, 43.62, 21.11 and 5.56 % of the studied area respectively. The low capability classes in the area are mainly due to the shallow soil depth, coarse texture, poor drainage and the salts accumulation. Therefore, action measures of land management are essential for sustaining the agricultural land uses in this area. The spatial distribution of soil capability in the area indicates that soil of old deltaic plain have low capability classes compared with those of aeolian and flood plain. An area of 5.51 % of the total area is currently not suitable for agricultural use, while 64.06 % of the area needs to high grade of liability for sustaining the agricultural land uses. (Abd El-Kawy, 2010) found that the soils located in the western part of the Nile Delta between Wadi El-Natrun and Nubaria city.

Figure 2: Main canals and drains in west delta (Ministry of Water Resources and Irrigation, Egypt)

This area covers approximately 14,194 hectares and consists mostly of uncultivated land although some private agricultural activities have recently started using the groundwater for irrigation. Land capability indices and land suitability limitations for 27 crops indicates to most of this soils are poor (C4 - 68.46 %), very poor (C5 -27.58%) and Fair (C3 - 3.96%). The most suitable crops to grow in the study area are alfalfa, barley, wheat, sugar, beet, onion, and pear, in order indicated. The general dominant limiting parameters affecting land capability and suitability for suitable crops are sandy soil texture, available water, soil permeability, cation exchangeable capacity (CEC), exchangeable sodium percent (ESP), content of organic matter and available nitrogen and phosphorous. The national strategy of Egypt for horizontal expansion of agricultural lands until year 2017 aims at adding about 1.5 million hectares in different regions, depending on land suitability and water resources. Wadi El-Natrun area located in the North West desert of Egypt could be considered as one of the promising areas for agricultural development. Studied part of the area in Wadi El-Natrun, this area covers 50.0 hectares approximately. Thirty four soil profiles and seventy minipits were examined to represent the soils of the studied area. Land suitability techniques were done using the rating tables suggested by (Sys and Verhye, 1978), (FAO, 1976), (Sys, 1985) and (Sys C, Van Ranst, et al, 1991). The results indicate that about 3.8% of the studied area is permanently not suitable for agriculture, 48.9% are marginally suitable and 44.2% are moderately suitable. Texture, salinity and slope are the limiting factors. By applying improvements the potential capability of the soils are developed. The results also indicate that the grape is the best crop followed by alfalfa and fodder beet in the studied area. Land capability assessment was done to define maps of the suitable areas for agricultural production in El-Hammam area, North-Western Coast of Egypt, using a capability model built in ALES software and the results are exported to GIS by (Shendi et al., 2006).The aim of this study was use GIS, remote sensing and soil data, as a mean for decision making in natural resources management and planning the sustainable land use in El-Hammam area. The selected region represents one of the high priority regions for future development in the country with a total area of about 31,600 hectares. Results indicated that the area currently lacks high capability and moderate capability classes. The most sustainable land use recommended under the present limited water resources are clover, barely, wheat and sorghum as field crops, whereas, fig, olive and occasionally guava are the most sustainable orchards cultivations. Considerable decrease in the erosion soil loss can be achieved by applying the recommended sustainable land use with proper erosion control practices. The dominant limitations mentioned that these soils in north western Egypt were soil texture, soil depth, drainage, Calcium carbonate content, salinity, alkalinity and expandable sodium present. In fact soil depth and texture limitations cannot be corrected while another limitations as, salinity; alkalinity and expandable sodium present could be corrected.

On the eastern side of the northern coast of Egypt and in the most important area of political interest and tourism is the Sinai Peninsula, there are El-Salam Canal from the South El-kantara Sharak to El- Arish. The Total length of El- Salam Canal is 242 km Figure 3. The big part of El-Salam canal occupies about 155.km in the northern part of Sinai and small part 87 km in western of Suez Canal. The east bank command area is composed of the Tina Plain, south El Kantara Shark, El Rabaa, Biar El Abed and El-Arish Area. General land evaluation of soils in the northern part of the Sinai Peninsula along the El-Salam Canal soil project revealed that these soils classified in four grades (III, IV, V and VI soil grades). The soils of the El-Tina Plain belong to grade VI and V; the soils of the grade (VI) have severe limitations. Extreme salinity, texture and soil profile depth. The soils of grad V have severe limitation, as they are extremely saline. However, some soils profiles are extremely saline and they have sever limitations texture and drainage but through removal of the soluble salts in these soils could be belong to grade IV or III (Hassan, 2002).

Soils represented in the South El-Kantara Shark belong to grade III and IV, grade III have moderate limitations, and texture was the main limiting factor. The grade (IV) is affected by moderate to severe limitations of texture, soil profile depth and relatively higher salinity. The study soils of Bair El-Abd, Wadi El-Arish and Rabaa soils revealed that these soils classified in tow grades (III) and (IV). The main limitations were texture, soil depth and salinity and sometimes slope and wind erosion. The results of land evaluation for the observed soils in the northern part of the Sinai Peninsula lead to the classification in four classes (III, IV, V and VI) according to soil texture, profile depth, slope and risk of wind erosion. The soils in grade (IV) are restricted by texture, soil depth and relatively higher salinity, as well as their texture and high calcium carbonate contents. The soils in grade (V) and (VI) are affected by extreme salinity, texture soil profile depth, gypsum; high carbonate content and poor drainages (Hassan et al., 2001)

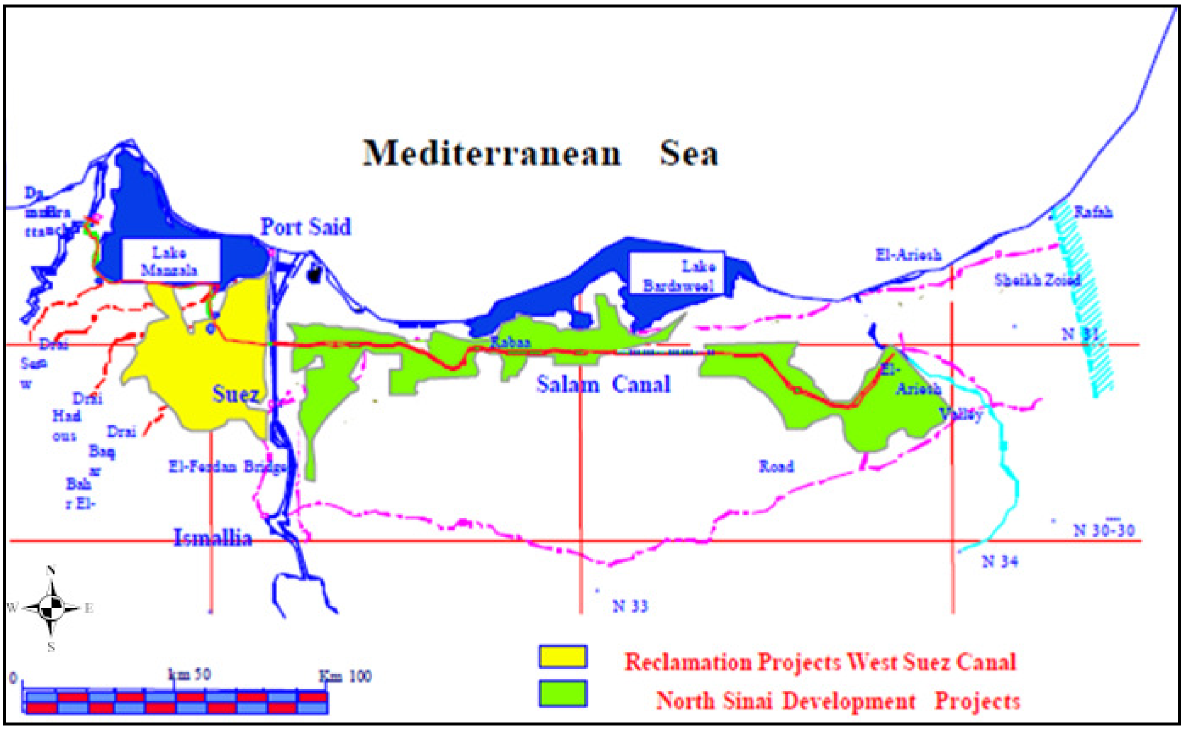


Figure 3: El Salam canal project area (Hafez, 2005)

Remote sensing and GIS were used to produce the soil map and assess the current and potential suitability for crops in El-Tina plain – South El-Kantara Shark area, north Sinai. The landscape of the studied area includes marine plain (311.69 km^2), fluvio-marine plain (288.13 km^2) and aeolian plain (730.00 km^2). Results indicated that the area currently ranges from moderately capable (II) to not capable (IV). The current suitability indicates that the area of El-Tina Plain has a marginal suitable for sugar beet and alfalfa and not suitable for the wheat, corn, melon, potato, sunflower, peach, citrus and olive trees. El-Tina Plain has limited by high soil salinity and shallow soil depth. The area of South El-Kantara Shark is not suitable for rice but have a moderate to marginal suitable for the rest of the selected crops. The main limiteds in South El-Kantara Shark area were soil texture and nutrient availability (Ali and Abdel Kawy 2007). El-Maghara area is one of the most important areas in north Sinai that received a special governmental attention. Geomorphic units were identified in El-Maghara area are mountain and escarpment, present wadis, sand dunes, gravel plain and flood. The capability soil map is classified as class C2, C3, C4, C5 and C6 and the land suitability are good, fair, poor, very poor and non-agriculture soils grades.This study indicated that this soil degradation of El-Maghara area includes mining, quarrying, salinity of water irrigation, land deterioration by intensive grazing and infringement of mobile sand bodies or sand dunes and water erosions. The main limitations in north east coastal area where extreme salinity, texture soil profile depth, gypsum, high carbonate content and poor drainages and sometimes slope, wind erosion and nutrient availability (Arnous and Hassan, 2006). After the events of the Egyptian Revolution January 25, 2011 increased attention to the central Sinai and placed under the plans for agricultural development. Focus on the large agricultural projects to provide employment opportunities and to reconsider the distribution of the population, these projects include the El-Hammam canal and extension in north-western coast, El-Salam canal in the north-eastern coast, Toshky, East Owaynat and Drab El-Arbiaeen which located in the south western desert of Egypt.

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CHAPTER III: DESCRIPTION OF THE STUDY AREA

The particulars relating to the general description of the area, geographical setting of the study area, location, climate, geology, topography and geomorphology sittings, hydrology conditions, natural vegetation and land use adopted in the investigation are briefly presented in this chapter.

3.1. Location

Egypt is located on the northeastern coast of Africa, and borders the Mediterranean Sea between Libya and the Gaza Strip. Egypt is a desert nation; only four percent of the country's total land area of 1 million km^2 is arable, while is the most populous nation in the mean region, with over 80 million inhabitants.

The study area occupies a portion of the northwestern side of the coastal zone in western Desert of Egypt Figure 4. It has extends from Burg El-Arab in the east and El-Dabaa in the west. The study area has a size of about 110 km in length and 5 km in width (approximately 65.0 (10^3 ha)and lies between latitudes 30° 45′ - 31° 00′ N and longitudes 28° 30′ 29° 00′ E.

3.2. Climate

The climatic conditions of the study area are typically arid to semi-arid, characterized by a long hot dry summer, mild winter with little rainfall, high evaporation with moderately to high relative humidity.

Table 5 and Table 6, postulates the average meteorological data (1971-2000) from Alexandria in the west and Matrouh in the East, (data from ministry of agriculture and land reclamation-2007). The maximum temperature (30.6 and 29.7 ℃) is recorded in (August) in Alexandria and Matrouh respectively, while the minimum (9.1 and 8.4 °C) is recorded in January, respectively. The annual rate maximum temperature is 25 °C. Rainfall variability within Egypt is almost inconsequential; given that the country receives very little rainfall, as well as the fact that its agriculture is irrigated and not rain-fed .The Mediterranean coastal zone of Egypt receives noticeable amounts of rainfall, especially in winter.`The annual rainfall is low as it does not exceed 16. 6 mm. The maximum monthly rainfall is 55.6 mm in December in Alexandria while the maximum monthly rainfall is 33.2 mm in January in Matrouh.

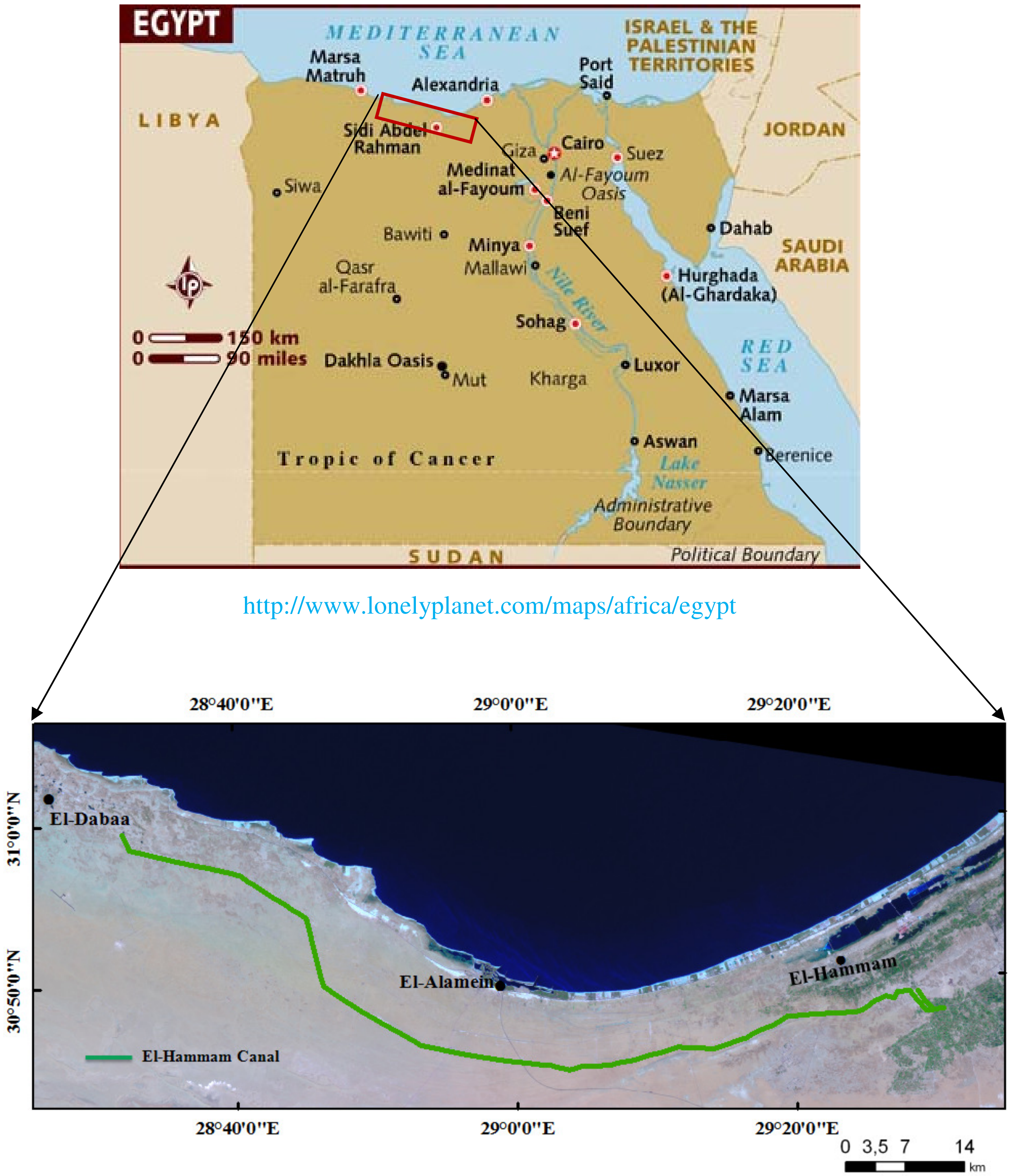


Figure 4: Location map of the study area

Precipitation is considered as the main source of recharge of groundwater aquifers in the northwestern Mediterranean coastal zone and affects greatly the amount of water stored in such aquifers. The relative humidity plays an important role in the amount of evaporation and evapotranspiration. The values of relative humidity in Alexandria are relatively high in summer months. The maximum and the minimum values of relative humidity are recorded in July and March, being 72.0% and 65.0%, respectively. While the maximum and the minimum values of relative humidity in Matrouh are recorded in July to August and April, being 73.0 % and 61.0%, respectively.

Table 5: Climatologically normal's at Alexandria station (1971-2000)

Month	Temperature (C°)			Rainfall	Relative Humidity	Wind Velocity	Avg. Et_0
	Max.	Min.	Mean.	mm	%	km/h	mm/d
Jan.	18,40	9,10	13,50	54,90	70,00	7,50	2,20
Feb.	19,30	9,30	14,10	26,60	68,00	7,50	2,60
Mar.	21,30	10,80	15,80	12,90	65,00	7,80	3,40
Apr.	23,50	13,10	18,30	4,20	65,00	7,30	4,10
May.	26,60	16,40	21,20	1,50	67,00	6,80	4,90
Jun.	28,60	20,20	24,30	0,00	69,00	6,80	5,70
Jul.	29,70	22,00	25,90	0,00	72,00	7,40	5,80
Aug.	30,60	22,70	26,50	0,30	71,00	6,80	5,50
Sep.	29,60	21,10	25,60	1,00	68,00	6,20	4,90
Oct.	27,60	17,60	22,50	9,30	68,00	5,30	3,70
Nov.	24,20	14,40	19,10	33,10	69,00	5,80	2,70
Dec.	20,30	10,80	15,20	55,60	70,00	7,00	2,30

Table 6: Climatological normals at Matrouh station (1971-2000)

Month	Temperature (°C)			Rainfall	Relative Humidity	Wind Velocity	Avg. Et_0
	Max.	Min.	Mean.	mm	%	km/h	mm/d
Jan.	18.00	8.40	12.80	33.2	66.0	11.5	2.70
Feb.	18.80	8.60	13.00	15.0	65.0	11.5	3.00
Mar.	20.40	10.20	15.10	12.0	63.0	11.9	3.80
Apr.	22.70	12.10	17.40	2.80	61.0	10.2	4.60
May.	25.40	14.70	20.10	2.60	64.0	9.3	5.20
Jun.	28.10	18.40	23.30	2.00	68.0	9.7	5.90
Jul.	29.10	20.40	24.90	0.00	73.0	9.8	5.80
Aug.	29.70	21.10	25.50	0.60	73.0	8.9	5.60
Sep.	28.60	19.70	24.30	1.10	68.0	8.3	5.10
Oct.	26.90	16.90	21.60	15.60	67.0	8.1	4.00
Nov.	23.20	13.40	18.10	22.5	68.0	9.1	3.10
Dec.	19.5	10.10	14.40	30.20	66.0	11.1	2.80

Prevailing winds at the study area are chiefly directed southwest in the winter months while being northwest in the summer months. Surface wind velocity varies from (5.3 to 7.8) and (8.1 to 11.9) km/h in Alexandria and Matrouh stations, respectively. The lowest and highest wind velocities are recorded in October and March, respectively.

Evaporation data indicate that the lowest values of evaporation (2.2 and 2.7 mm/day) are recorded in January while the highest values is are monitored in July and June (5.8 and 5.9 mm/day) in Alexandria and Matrouh respectively. With such high annual evaporation, both irrigation water and energy costs required for irrigation would be very high. For further evaluation of the meteorological data, climate diagram of the study area is presented in Figure 5 and Figure 6.

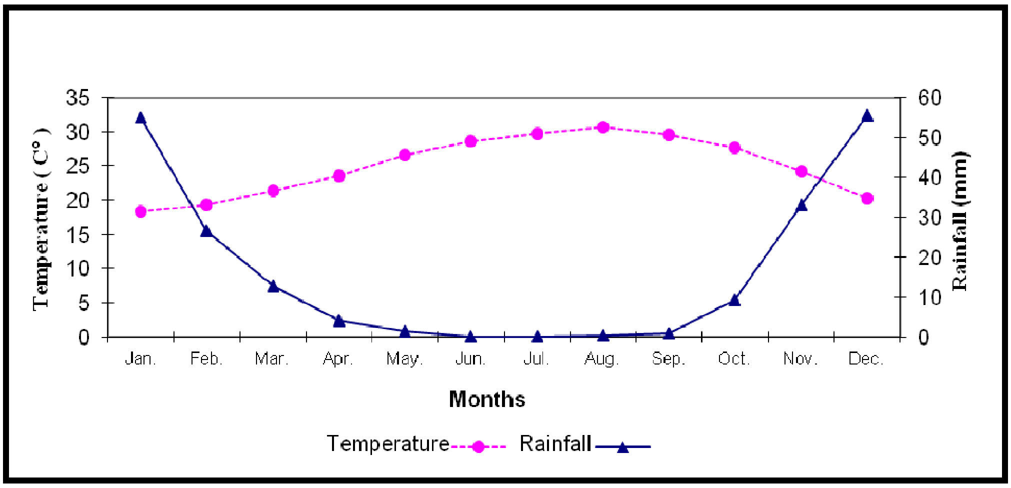


Figure 5: Climate diagram of Alexandria metrological station

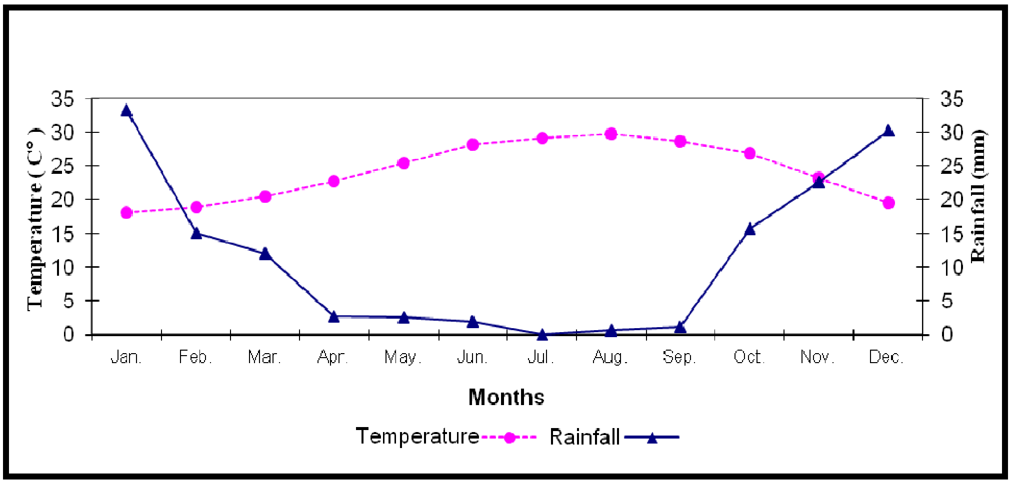


Figure 6: Climate diagram of Matrouh metrological station

3.3. Geology

The northern part of Egypt including, the north Western Desert, the Nile Delta and north Sinai lie in the unstable shelf area. The main part of Egypt west of the river Nile is covered by thick sequences of relatively undisturbed sedimentary strata of Paleozoic, Mesozoic and Cenozoic age (Said, 1990)**.** The north part of the Western Desert is covered mainly by thin blanket of Miocene rocks forming a vast persistent limestone plateau. It extends from the western side of the Nile valley and delta in the east to El-Salum in the west and the Mediterranean coastal plain in the north to the Qattara and Siwa depression in the south (El-Bastwasy, 2008). The geology surface of the study area is essentially dominated by sedimentary rocks of **Tertiary** and **Quaternary** ages, see Figure 7. The Quaternary is exposed in the coastal plain, wadis and raised beaches. The Pliocene and Miocene of the Tertiary is exposed major part of the tableland, the Miocene is forming the surface beds of the tableland. The geology is characterized by the presence of a plateau formed, essentially of Tertiary Miocene, mainly composed of limestone and sand stone reaching the shoreline at several areas. The coastal zone to the north of the Miocene plateau is covered by Quaternary deposits which rest with conformable and or unconformable relation of the Tertiary deposits. These deposits are mainly represented by the Holocen**e** deposits of coastal sand dunes, lagoonal and alluvial deposits and the Pleistocene oolitic limestone ridges and old lagoonal deposits. The Quaternary carbonate ridges in the present area are cemented into moderately hard limestone except the coastal ridge which is mostly less cemented (Zahran, 2008) .The different stratigraphic units in the surface and subsurface in the area under study and surroundings are described from younger to older as follows:

3.3.1. Quaternary

The Quaternary sediments of the deserts of Egypt are varied and complex. In the deserts, however, the Quaternary sediments are thin and incomplete (Said, 1990). Quaternary coastal plain of North West Egypt is bordered to the south and to the west by the outcropping Middle Miocene Marmarican Limestone which forms a tableland. The Quaternary oolitic limestone of the beach-dune ridges and lagoonal sabkha sediments, found to the west of the Nile, inter finger with and descend beneath the deltaic deposits of this river (Hassouba, 1995).The Quaternary deposits are represented by unconsolidated eolian sands, sabkhas and wadi filling uncomfortably overlying the Miocene rocks. Over large areas of Qattara Depression, the bedrock is covered by younger deposits including wind-blown sand, sabkhas and Quaternary evaporite sediments (Aref et al., 2002).

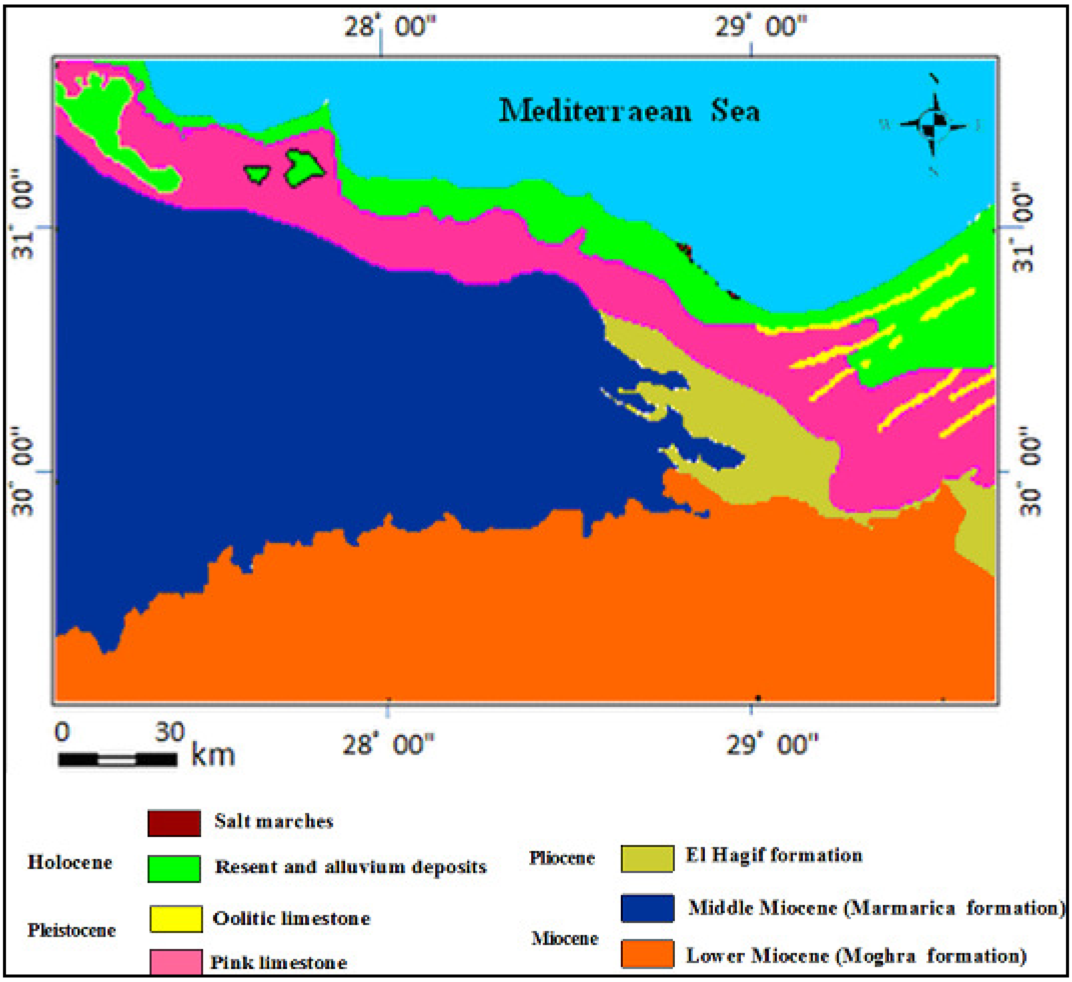


Figure 7: Geological map of the study area, (Rizk and Davis, 1991) and (El-Bayomi, 2009)

3.3.1.1. Pleistocene Sediments

The Pleistocene sediments are also widely distributed along the north-western Mediterranean coastal zone and are mainly represented by white oolitic limestone, cardium limestone and Pink limestone. Pleistocene formation is located mainly on the ridges, the piedmont and tableland (Ayyad, 1999). Pleistocene and Holocene alluvial deposits are composed of calcareous materials formed of oolitic sand and shell fragments together with organic matter, quartz and clays.

3.3.1.2. Holocene Deposits

The Holocene formation is formed of beach sediments, sand dunes accumulations, alluvial deposits and lagoonal deposits, see Figure 8. Sand dunes are developed in series either along the Mediterranean coast or the hinterland. They trend in an almost E–W direction, sub-parallel to the shore line, and are free or stationary, resting irregularly above the Pleistocene limestone (ridges) (Yousif and Bubenzer, 2012). Beach sediments are composed of loose calcareous oolitic sands with few quartz grains and shell fragments, sand dunes accumulations are composed of snow white, coarse calcareous oolitic sand and lagoon deposits are composed of gypsum intermixed with sand alluvium. Alluvial deposits are composed of fine sandy loam intermixed with gravel, and derived mainly from the older Pliocene rocks (Ayyad, 1999). These deposits are developed in the shallow and elongated depressions and along the channels of the drainage line in the some wadi terraces. These deposits are loamy and composed of quartz sand, silt and clay with abundant carbonate grains in the north while pebbles and gravels are abundant to the south (Draft et al., 2005). Lagoon and lagoon margin muds, sabkha silts and sands, and nearshore marine (closed basin) were located in Holocene deposits (Warne and Stanley, 1993) .

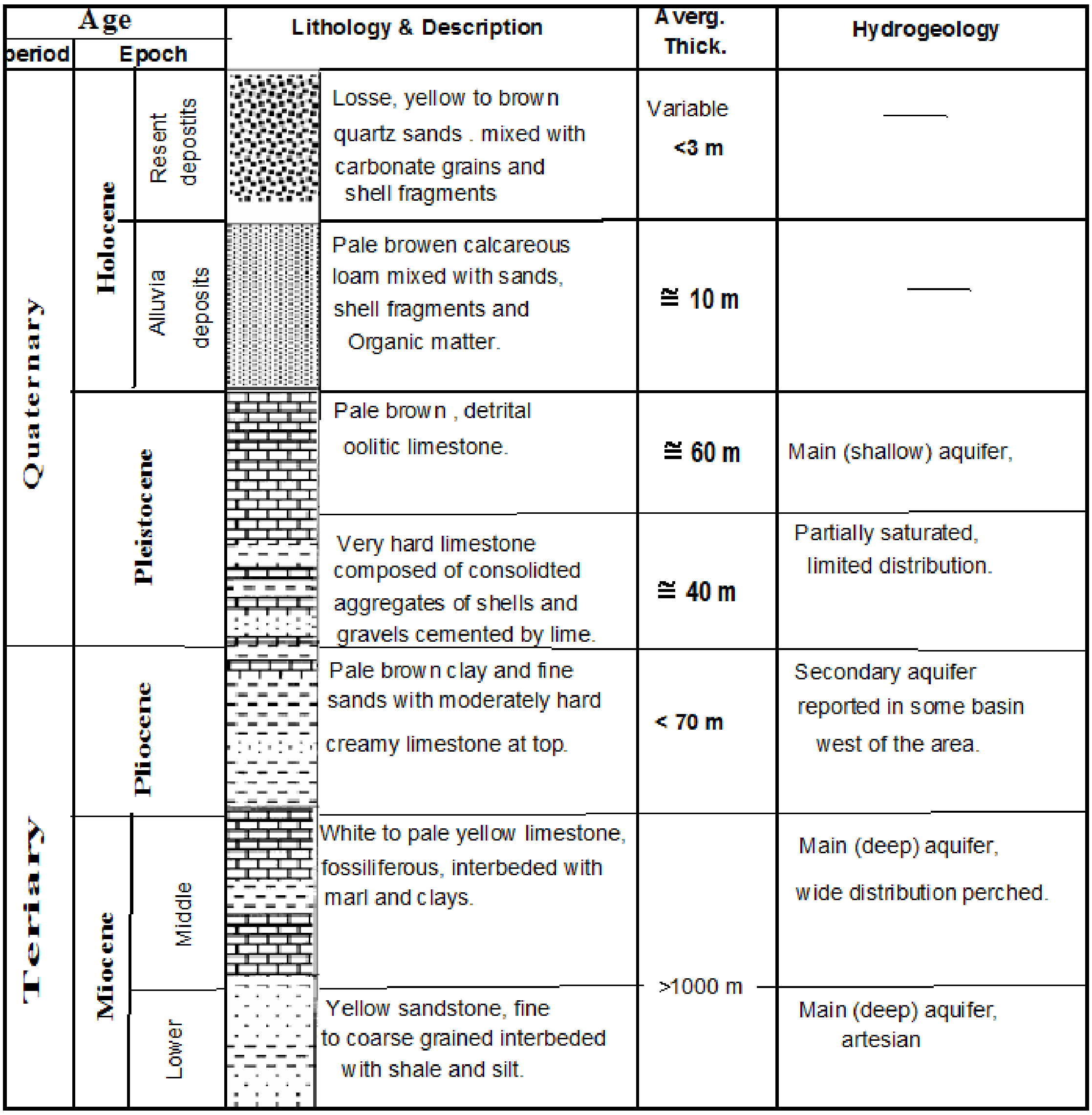


Figure 8: Generalized lithostratigraphic column for study area, (Shaaban, 2001)

3.3.2. Neogne

The Neogene deposits are exposed throughout the area under study and constitute the major part of the tableland.

3.3.2.1. Pliocene Sediments

Pliocene sediments have limited exposures along the north-western coastal zone and have been encountered in the subsurface where they are concealed beneath younger deposits. Local Pliocene deposits are known at some localities, e.g. to the south of El Dabaa and Mersa Matruh. In Burg El Arab on the east, the Pliocene is mostly developed in a shale or clay facies, about 50 m thick.

3.3.2.2. Miocene Sediments

The Miocene sediments in the Western desert are distinguished into two main rock units (Said, 1962); these units are as follows from younger to older:

a. **Marmarica limestone Formation;** covers the larger part of the northern plateau of the Western Desert, which is of Middle Miocene age. These formations are built up of cavernous limestone intercalated with clay and marl interbeds. The Marmarica is a limestone, dolomite and shale sequence of middle Miocene age (Said, 1990).

b. **Moghra Formation***:* It represents lower Miocene clastic sediments. Moghra Formation is made up of sands, sandstone and shale intercalated with occasional subordinate limestone beds. Moghra Formation is Early Miocene in age and composed mainly of about 180 m of fine- to medium-grained, reddish brown friable sandstone (Abdeldayem, 1996)

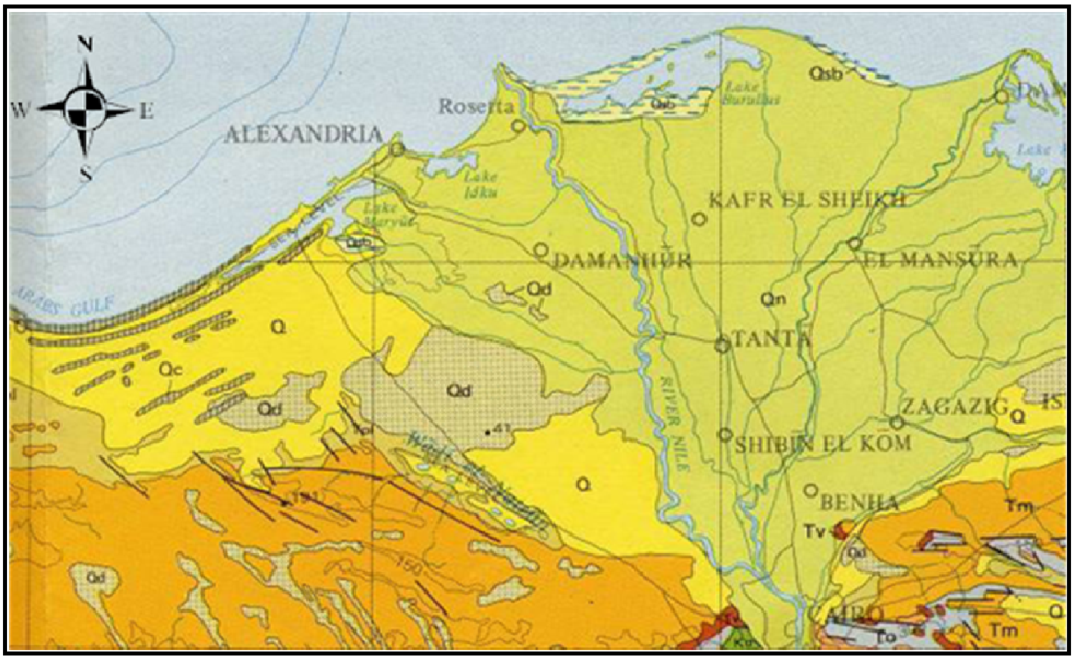
3.3.3. Pre-Neogene Rocks

The subsurface Pre-Miocene succession has been differentiated from top to bottom into:

3. **Upper Eocene – Oligocene (Dabaa Formation):** During the late Eocene –Oligocene, thick open marine calcareous shales (Dabaa Formation) were deposited in the northern reaches of the Western Desert. Dabaa Formation consists of shale with thin beds of limestone. The maximum thickness of Dabaa Formation in the coastal area is about 650 m.
4. **Paleocene –Eocene (Appollonia Formation):** The Appollonia Formation ranges in age from Paleocene to late Eocene. It consists of an open marine sequence of limestone and some shales.
5. **Cretaceous:** The Upper cretaceous is divided into three rock units, namely; Bahariya, Abu Roash and Khoman Formations. The base of Upper Cretaceous is mainly sandstones, shale and limestone while the top part (Khoman Formation) is mainly chalky limestone. The Lower Cretaceous is also subdivided into two main rock units, namely; Borg El-Arab and El-Alamin formations. Borg El-Arab Formation made up a dominantly thick

sequence of fine to coarse grained clastics, and divided into Alam El Buieb and Kharita units (Said, 1990)

6. **Jurassic:** The Lower Jurassic, present in the north-western corner of the western Desert (Wadi Natrun Formation) consists of lagoonal deposits that are alternating dense limestone, green shale, and dolomite with subordinate interbeds of sandstone and anhydrite. While the Middle to late Jurassic is represented by the Khataba Formation composed of thick carbonaceous shale sequence with interbedded sandstone, coal seams and limestone streaks.
7. **Paleozoic:** The Paleozoic sediments nonconformably overlie the basement rocks and is overlain unconformable by the Jurassic or younger sediments. It is dominated by sandstone and siltstones with an abundance of limestone and shales in the upper part the section. In general, the Palaeozoic sediments of the north western desert are of monotonous composition and are made up of interbedded sandstone and shale with a few carbonate beds.



Qd: Sand Dunes, **Qsb**: Sabkha Deposits, **Qn** :Nile Deposits, **Q** Undivided Quarternary and **Qc** : Calcarenite Bars - along the Mediterranean coast- 1:2.000.000

Figure 9: Geological Map of the Nile Delta and study area (Purzner, 2008)

Generally the area is underlain by sedimentary rocks belonging to both **Quaternary** and **Tertiary** periods. Quaternary sediments of the Nile delta and study area Figure 9, which coverd from the southwest Delta to the northern coastal plain.The Quaternary deposits are represented by oolitic limestone, alluvial and lagoonal deposits. The Tertiary rocks are represented by Middle Miocene limestone, sandstone and clay sediments (Awad et al., 1994) . Pleistocene and Holocene alluvial deposits are composed of calcareous materials formed of oolitic sand and shell fragments together with organic matter, quartz and clays, (Yousif and Bubenzer, 2012)

3.4. Topography and Geomorphologic Settings

The Northwest Coast of Egypt forms a belt about 20 Km deep, which extends for about 500 km between Amria (20 Km west of El-Alexandria) and El-Salloum near the borders with Libya. The North Western coastal zone of Egypt may be distinguished into two main physiographic provinces: An eastern province between El-Alexandria and Ras El-Hikma (about 230 km West of El-Alexandria) and a western province between Ras El-Hikma and Salloum. The landscape is distinguished into a northern coastal plain and a southern tableland.The study area is located in eastern province with a topographically low area with no distinct relief. The land surface of the frontal plain slopes in a northward direction showed Figure 10. However, the slope of the land surface is about 5 m/km which is considered as gentle slope. This gentle slope does not accelerate surface runoff where the area has an indistinct drainage pattern. The surface runoff is captured by low lying depression where most of this surface storage evaporates.The area under investigation is situated on one of Pleistocene beach dunes which are orientated more or less parallel to the present coastal. The hills and valleys of the so called (Inland Plain) beach dune system evolved by the varying of the sea level during the Pleistocene. Soils on the dunes are manly formed on airborne quartzitic sand, which is alternatively shifted in the valleys by water and wind erosion (Fehlberg and Stahr, 1985).

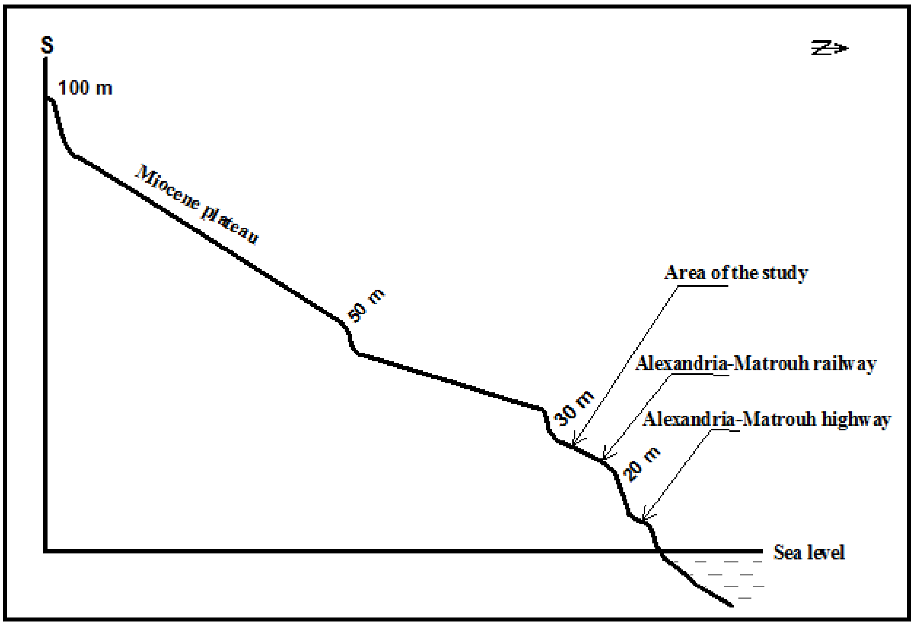


Figure 10: Geomorphology profile and infrastructure of the coastal zone (DRC, 2003)

The area includes a narrow coastal plain, followed at some areas to the south by sand dunes. Southwards of the dunes, the plain rises gradually until the altitude of the plateau reaches 50 to 250 meters above sea level Figure 11. The coastal plain stretches in general east-west direction, bounded by the sea to the north and a pediment plain to the south. Its width varies, controlled by the geologic formations, from some meters to about 10 km. This plain mainly consists of alluvial fans, descending from the plateau, wadis extensions, rocky plains, sabkhas, sand sheets and sand dunes. Most of the cultivable soils in the northwestern coast are located in the alluvium. The sediments have been transported by water to alluvial fans and flood plains. However, aeolian sediments in some locations are being cultivated. The subsoil layers are formed locally from marine limestone (El-Bastwasy, 2008).

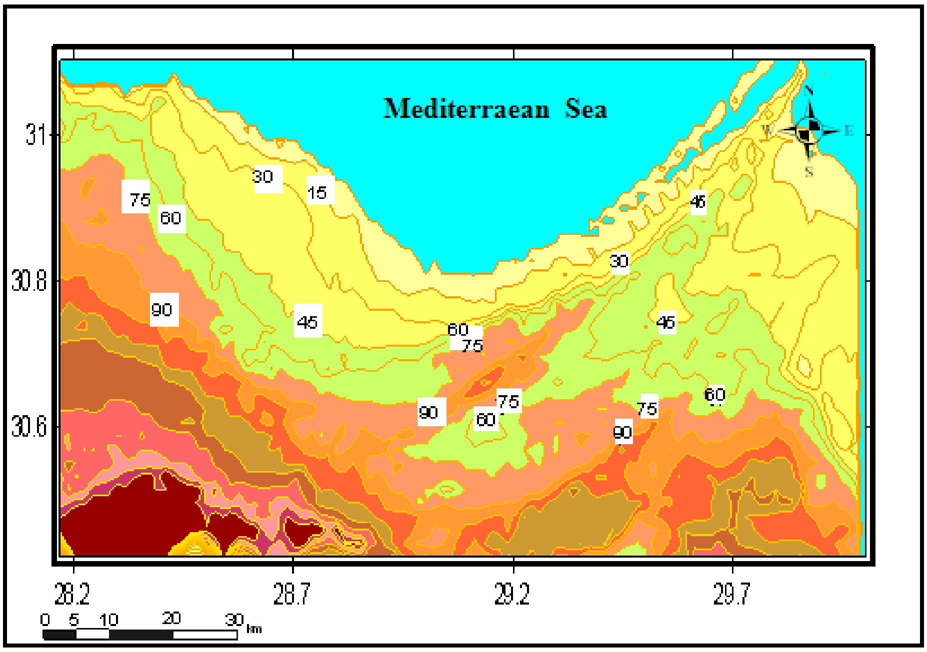


Figure 11: Digital elevation model of the study area, (http://srtm.csi.cgiar.org/)

The landform of the northwestern coastal zone can be summarized as shown in, Figure 12. The following geomorphologic units can be described as follows:

3.4.1. The Northern Coastal plain

The area includes a narrow coastal plain, followed at some areas to south by sand dunes. The northern coastal plain occupies a peripheral zone parallel to the present Mediterranean shoreline. It extends in an east-west direction for about 500 km. The average width of this plain varies at different localities by the situation of the southern tableland. This plain slopes generally towards north and exhibits elevations ranging from 60 m above sea level to about the mean sea level or slightly below. This plain mainly consists of alluvial fans, descending from the plateau, wadis extension, rocky plains, sabkhas, sand sheets and sand dunes. Most of the cultivable soils in the northwestern coast are alluvium. The sediments have been transported by water to alluvial fans and flood plains. However, Aeolian sediments in some locations are being cultivated. The subsoil layers are formed locally from marine limestone (El-Bastwasy, 2008). The coastal plain becomes wider eastwards (Eastwards from El Dabaa) and becomes narrow where the headline exist (West El Dabaa). Different phases of tectonics took place during Middle to late Tertiary. Endogenous processes besides the exogenous ones which were prevailing during Pleistocene time adding to the present dry climate in Holocene times are responsible for the present situation and form the coastal plain. The north western coastline is interrupted by a pronounced series of headlands separating embayment and bays. The coastal plain is locally backed by limestone ridges and calcareous sand dunes, and is therefore characterized by markedly different coastal morphologies and sediment sources than found on the Nile Delta. The rocks covered by a veneer of carbonate sand mostly composed of carbonate oolitic grains, the source of this carbonate from the cliffs and seabed are entirely composed of Pleistocene limestone ridges (Frihy et al., 2010).

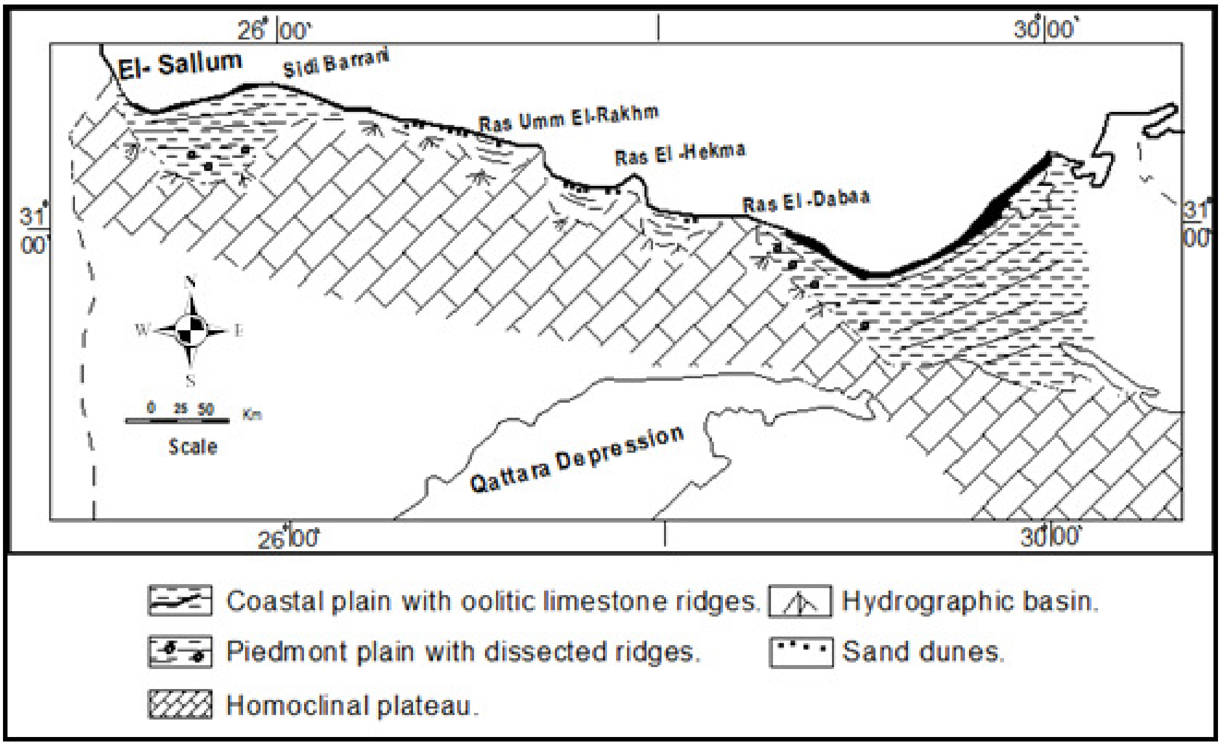


Figure 12: The main landforms along the Mediterranean Coastal Zone, (Raslan, 1995)

3.4.1.1. The Beaches

The famous beaches along the Mediterranean Sea are normally between headlands, facing the synclinal embayments. They are covered with loose carbonate sands which are concentrated eastward of respective headlands (Al-Alamien , Sidi Abdel Rahman , Fuka, East Ras El Hekma, Baqqush, Matruh, East Matruh) , (Draft et al., 2005) The beaches are 500 m to more than 1.5 km long Figure 13, the sandy beaches along shorelines are mainly made up of loose sands eroded in oolitic limestone ridges. The size of sand grains on the beach varies from medium to fine. The sand is mixed with little amount of shell fragments and heavy minerals (El-Bayomi, 2009).

Figure 13: Beach along El Alamein area (El-Bayomi, 2009)

3.4.1.2. Coastal Dunes

The coastal dunes are found close to the beaches at the synclinal areas. These dunes constitute an outstanding land feature at several locations of the coastal plain (Burg El Arab, El Dabaa, Fuka, bagusch, El qaser, etc). They cover portions of the near shore ridge that runs parallel to Mediterranean Sea. These Dunes are composed of loose oolitic carbonate sands derived from the lying beaches by on- shore wind Figure 14. These dunes are developed in series either along the Mediterranean coast or inland and trend in an almost E–W direction. They have special importance as water bearing aquifer as rain water accumulates in the coastal dunes in the form of the fresh lenses floating on the main saline water. Sand dunes along the Western Mediterranean coast of Egypt are formed of loose oval pseudo-oolitic grains consist of calcium carbonate. These dunes area close of the sea and exposed to northerly winds and affected by sea spray (Abbas et al., 2008).

Figure 14: Coastal dunes cover with Nebak along North Western Coast, (El-Bayomi, 2009)

3.4.1.3. Coastal Ridge

The North West coastal plain of Egypt comprises a sequence of carbonate ridges. The coastal plain is characterized by a series of at least nine elongated parallel carbonate beach-dune ridges. A coastal beach-dune ridge mainly composed of oolitic and biogenic calcareous sand with a coastal sabkha to land ward. These ridges are developed along the receding Quaternary shore-lines of an embayment of the Mediterranean Sea (Hassouba, 1995).

The coastal ridge is weathered completely where the headlands exist. It is well developed along the synclinal embayment. This ridge is composed of white, cross bedded, friable oolitic limestone. Locally this ridge is covered by snow white carbonate sand. Accordingly three formations are identified, these are from younger to older; the Alexandria ooliitic limestone Formation of late Pleistocene to Holocene age, the Burg El-Arab limestone Formation, and the El-Hammam bioclastic limestone Formation of middle to late Pleistocene age Figure 15. The Burg El-Arab fossiliferous limestone Formation represents the marine shelf platform and beach deposits exposed at the drainage ditch of Bahig .The El-Hammam bioclastic limestone Formation was proposed to comprise the aeolianites at the third ridge and the paleosols at the top of the fourth ridge with total average thickness of 50 m (El-Asmar, 1994) and (El-Asmar and Wood, 2000).

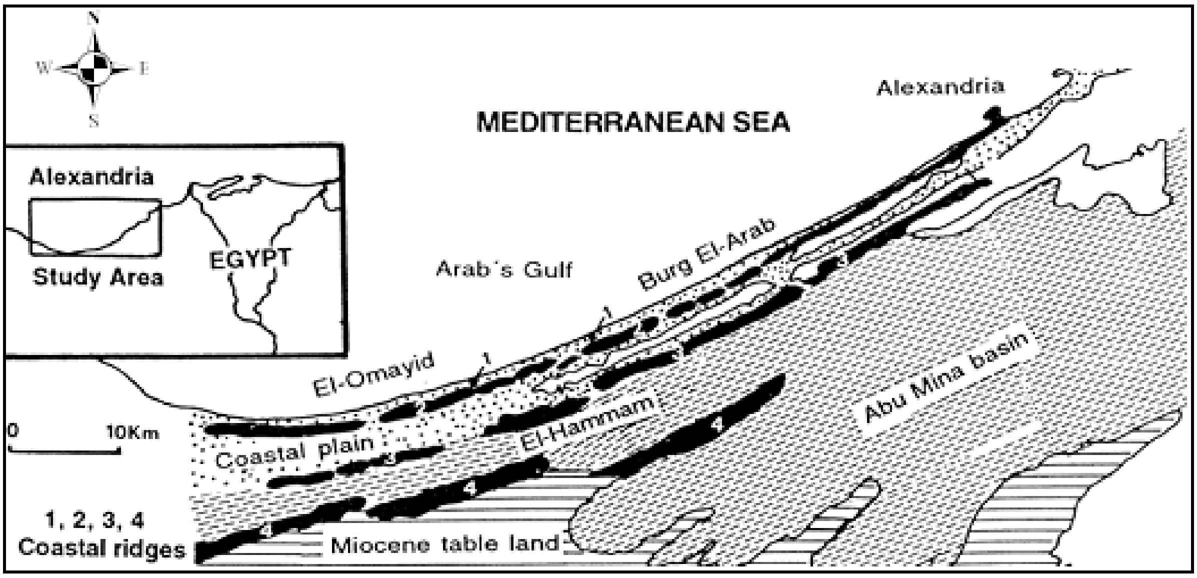


Figure 15: Coastal ridges of the studied area. (El-Asmar and Wood, 2000)

3.4.1.4. Coastal Depressions

The coastal ridges are separated by elongated shallow topographic depressions oriented in E-W directions. The magnitude of this depression is proportional to the width of the coastal plain. The elongated depression represent old lakes during Early and Middle Pleistocene glacial and interglacial periods as the surface of the depression approaches sea level, it is turned into salt marshes and lakes. The surface of these depressions is almost flat to gently undulating with a gentle slope to the north. The elevations are ranging between + 30 m above sea level to about the mean sea level. It is occupied by reddish brown soil deposits mostly composed of calcareous loam. In the inland depressions, a thick layer of brown alluvium exists favoring the growth of natural vegetation and which is also suitable for cultivation.

3.4.1.5. Lagoons

Lagoons deposits are widely distributed in the subsurface bellow alluvial deposits. The saline deposits are composed of calcareous loam mixed with oolitic sands and contain high amount of evaporates, (El-Bayomi, 2009)

3.4.1.6. Salt marshes and lakes

Salt marshes and lakes were found between dissected ridges with lower elevation below sea level as west Matruh where it is formed due to surface erosion by drainage lines. Many lakes, sabkhas are distributed along the northwestern coast at El Dabaa, **Figure 16**, Ras El Hekma, Ras Alam El Rum, Ras Um El Rakham, Mersa Matruh, Mersa El Negila and El Sallum, (Raslan, 1995)

Figure 16: Salt marshes in El-Dabaa area (El-Bayomi, 2009)

3.4.1.7. Off shore Islands

Offshore islands are separated in the Mediterranean Sea. They are the remnants of younger ridges submerged in recent times as new cycle of submergence. They are found in Ras El Hekma, opposite Baqqush and West Matruh.

3.4.1.8. Inland dunes

They are accumulated on the slope of the ridges. These dunes are composed of both carbonate and quartz sands. They are normally washed from the inland ridge, the pink limestone and the formations. They are found at North east El Garwala, East Ras El Hekma and Fuka.

3.4.1.9. Inland Depressions

These depressions are found between the inland ridges.The surface of the inland depression is covered by alluvial deposits.

3.4.1.10. Inland Ridges

The coastal ridge is followed to the south by a series of elongated oolitic limestone ridges with an elevation varying from 56 to 85 m which are composed of hard oolitic limestone (El-Bayomi, 2009), Figure 17

Figure 17: Inland ridges of the studied area

3.4.2. The piedmont plain

The piedmont plain represents an extended sloppy surface separating the tableland to the south from the frontal and coastal plains to the north. It is developed at the foot slope of the structural plateau and it is well developed where the tableland escarpments are well pronounced (Burg El Arab, El Alamein, .etc). The surface of the piedmont plain is either covered with thin layer of alluvial and sand deposits or degraded and appears as a rocky surface.The plain contents inland ridges, depressions , duns and salt marches are recorded in a few spotes inside the palin, (Yousif and Bubenzer, 2012).

3.4.3. The structural plateau

The structural plateau acts as major catchments area feeding the drainage lines during winter times. The plateau runs from the Qattara Depression southward to the piedmont plain northward with elevation varies from 100 m at Matruh escarpment. The tableland extends generally in an E-W direction with slopes regionally in the northward direction.

3.4.4. Hydrographic basins.

Drainage basins are stretching along the northwest coast and the most direction of these valleys from south to north. Basins in north coastal area (Mandour - Majid - Am Shtaan - Habis - Am El Rekam-hash elsharqay ..etc) have different size from less than 6 to 23.7 km^2 in Am Shatan.

3.5. Hydrological conditions

Groundwater (mostly recharged by the Nile water) is of relatively limited use in the Valley but is specially used in the desert fringes. Regional information on the hydrological conditions of the northwestern coastal zone of Egypt can be found in several publications such as (Guindy, 1989), (Awad et al., 1994) and (Shaaban, 2001).The study area is characterized by extremely low rainfall (average 160 mm/years) with high evaporation and evapotranspiration rates. The scanty rainfall is confined to the winter season and rain usually occurs as thunderstorms and showers. The fresh groundwater in the region is believed to originate mainly from the Nile delta to the east of the investigated area; seepage of the fresh water from the Nile delta may also reach to the west of the study area. Further to the west, fresh groundwater originates from the infiltration of the rainwater.

3.5.1. Groundwater:

The study area lies in the semi-arid zone, where the winter precipitation varies by time and space. The groundwater exists under free water table condition. The saturated thickness of the coastal aquifer is about 30 m in oolitic limestone. The groundwater flow is mostly towards the Mediterranean Sea coast (Atta et al., 2005) The coastal aquifer mostly contains brackish water that has been recharged annually by local rainfall and the Nile seepage water from El-Nasr, El-Hammam and Maryut canals. The main groundwater aquifers in the western Nile Delta of Egypt showed in Figure 18. (Guindy, 1989) classified the groundwater bearing formation in the area and surrounding into:

1- Post-Miocene aquifers, which include:
   a. An unconsolidated coastal dunes (Holocene) aquifer.
   b. A consolidated detrial oolitic limestone (Pleistocene) aquifers.
2- Miocene aquifers, which include:
   a. A consolidated cavernous sandy limestone (Middle-Miocene) aquifer.
   b. A consolidated sandstone and sandy shale (Lower Early-Miocene) aquifer.

These aquifers have direct contact with the Mediterranean Sea at different levels and over different thicknesses. The post- Miocene aquifers are connected hydraulically to each other and have large intake areas of well-defined character, with adequate gradient for the groundwater movements. The main hydrological factors that affect the groundwater regime in the study area are:

1- Saline water intrusion from the Mediterranean Sea. The denser seawater tends to penetrate inland below the fresh water body, which is derived from rainfall and/or newly excavated irrigation canals.
2- Man- made hydrological disturbances including the exploitation of groundwater, drainage and irrigation reclamation works and dewatering of gypsum quarries (Shaaban, 2001b).

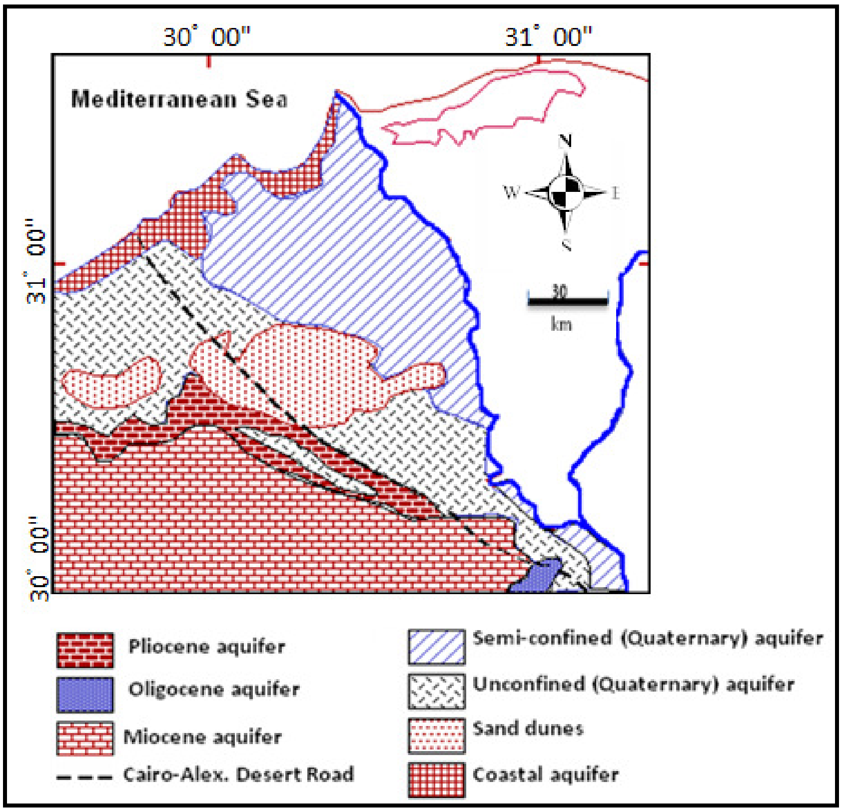


Figure 18: The groundwater aquifers in the western Nile Delta of Egypt (Sharaky et al., 2007)

3.5.1.1. Post-Miocene aquifers

3.5.1.1.1. Unconsolidated coastal dune aquifer (Holocene)

This hydrological unit consists of unconsolidated calcareous sand of high porosity. The groundwater in the aquifer is unconfined. The water table possesses a smooth curved surface above sea level and follows the surface dune topography, i.e. it follows the free surface of the aquifer. However, it is mainly recharged from the annual rainfall, and discharges naturally to the Mediterranean Sea in the north, and to salt marches, salt discharged artificially thought a number of dug wells and galleries. The seaward seepage of the fresh water from the aquifer maintains the hydraulic equilibrium between the upper fresh water and underlying intruded seawater.

3.5.1.1.2. The Oolitic limestone (Pleistocene)

The Oolitic limestone forms the most important aquifer throughout the region to the west of Alexandrian. It covers the whole coastal plain forming elongated ridges. The source of groundwater found in the oolitic limestone ridges comes either from direct infiltration and percolation of annual rainfall or from the rainwater falling on the tableland located to the south (El-Hammam landfill project, 2005). The saline water invades the shallow Pleistocene aquifers, as well as the deeper aquifers, which have direct contacts with it. Consequently, the denser (saline) water tends to penetrate inland below the relatively fresh water body, which is developed mainly in the Pleistocene aquifer from the infiltration of rainwater. This indicates that the saline/fresh water interface in the study area is located within the Pleistocene aquifer. The interface may deepen southward, raising the probability of fresh water accumulation.

3.5.1.2. Miocene aquifers

3.5.1.2.1. The Middle Miocene

The Miocene formation, which from the underlying rocks of the whole area, composed of limestone with few clay intercalations. Such as limestone may be dolomitic, marly, clayey or chalky limestone according to the local environment of sedimentation. Miocene formations have no importance as an aquifer eastward from El Alamein.

3.5.1.2.2. The Moghra Aquifer

The Moghra Formations also occupies most of the floor of the Qattara Depression. It is made up of sandy and clayey layers of the lower Miocene. The Moghra aquifer is recharged from five different sources: direct rainfall on the aquifers outcrops, groundwater seepage from the overlying Marmarica limestone aquifer, The Mediterranean Sea, the Nile delta aquifer and upward leakage from the Nubian artesian aquifer. In general, The Pleistocene aquifer is free in the south and both fringes (from Nile Delta), while become semi-confined and locally confined toward the north. The groundwater in the Quaternary aquifer is in hydraulic contact with the surface water system (irrigation canals and drainage canals). The aquifer is a large storage reservoir supplied by the Nile water itself through the irrigation systems (Elewa and El Nahry, 2009).

3.5.2. Precipitation

The annual average rainfall in the study area is 178.9 mm. The rain falling on any given area in the region (NWCE) is insufficient for agriculture. The water management problem to be solved is how to increase the amount of water penetrating into the ground and how to maintain it there long enough to enable the plant root to draw adequate supplies. A small portion of the rain either runs off into the sea or infiltrates downwards (deep percolation). Much larger quantities are lost by evaporation from the surface, or by capillary rise (Mohamed A.G.M., 2002)

3.5.2.1. Run-off water accumulates

Cisterns is usually defined as small hand-dug reservoirs with maximum depth 50 m., in which water is exploited by primitive way or by air fan (i.e. wind energy) to save drinking water for persons and animals. Cisterns are usually located in areas characterized by converging flow of runoff water. During field visits, about 8 cisterns were located and they were found to be fully or partially filled with transported sediments. Furthermore local inhabitants said that over thirty cisterns are found in the area, only two of them were restored (Draft et al., 2005)

3.5.3. Surface water of River Nile

River Nile water and Lake Nasser representing the largest man-made fresh water lake extending about 500 Km south of Aswan beyond the sudanese. The old Nile water conveyance system is still functioning with additional major canals conveying fresh Nile water to the newly reclaimed desert soils in the fringes of the Valley which are of relatively higher elevations. Sizable amounts of the agricultural drainage water of the old Valley are recycled in the conveyance system and mixed with the fresh Nile water to be used for horizontal expansion of cultivated areas (Hegazi and El-Bagouri, 2003) The Nile water reaches the study area via two irrigation canals; the first is Bahieg canal, and the second is El-Hammam canal, which has been constructed recently. These two canals receive their water from El-Nasser canal. The Egypt Ministry is keen on carrying out many national infrastructure works relating to horizontal expansion projects which can be summarized as follows:

3.5.3.1. El-Hammam Canal

The implementation of the main canal is completed along 50 km Figure 19, with a cost of (44 million L.E) allocated from the Ministry's investment budget. The project aims to reclaim and plant 18.3 (10^3 ha) in El-Hammam region and to provide drinking water to the governorate of Marsa Matrouh and the Northern Coast and pass the drainage needed for El-Hammam Canal Extension.

Figure 19: Surface water in El-Hammam canal (July 2011)

3.5.3.2. El-Hammam Canal Extension

The main canal and the related industrial works were finished for a length of 57 km, with a cost of (60 million L.E) a grant from Abou Dhabi Fund Figure 20. The project aims to resume the stages of agricultural development for the Northwestern Coast areas by providing supplementary annual irrigation for an area of 60.0 (10^3ha) in El-Dabaa and El-Alamein areas that depend basically on rainwater for growing winter crops (wheat and barley), in addition to providing 66.000 m^3/d to the North Coast areas and Marsa Matrouh governorate.

Figure 20: El-Hammam canal extension (Julie 2011)

3.5.4. Chemical composition of groundwater and surface water

The groundwater samples were analyzed for cations and anions Table 7. The major cations are (Na, K, Ca and Mg) and the anions (C1, SO_4, NO_3 and HCO_3) . The results indicated high salinity of the ground water could be due to long residence time in the marine Miocene sediments which offer the possibility for rock water interaction (dissolution of salts and rock weathering) in El-Dabaa and the Pleistocene aquifers in El-Alamein area (Awad et al., 1994) and (Shaaban, 2001).

Table 7: Chemical composition of groundwater, El -Dabaa and El-Alamein

Location	Well No.	pH	ECe	Cations (mg^{-1})				Anions (mg^{-1})				SAR
				Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	HCO_3^-	CO_3^{--}	
El –Dabaa Area.	1	7,0	5,30	768,0	45,60	88,0	144,0	763,0	744,0	769,0	n.d	11,60
	2	6,9	6,70	938,0	44,50	80,0	238,0	919,0	1382,0	622,0	n.d	11,80
	3	7,3	5,30	814,0	37,40	48,0	158,0	675,0	979,0	659,0	n.d	12,70
	4	7,2	4,80	702,0	42,90	38,0	138,0	525,0	1,9	311,0	n.d	11,80
El -Alamein Area.	1	7,9	5,58	726,0	19,00	219,0	175,0	897,0	1315,0	117,0	n.d	
	2	8,1	14,83	2100,0	34,00	572,0	311,0	2457,0	3950,0	60,0	n.d	
Rainwater at El-Dabaa		8,0	335,00	40,5	7,41	24,60	4,7	25,2	9,1	132,0	n.d	1,96
Mediterranen Sea		7,1	55,05	10,7	94,20	1.03	1,52	21,4	2,9	138,0	n.d	49,10

The main sources of surface irrigation water from the Revier Nile are El-Nubaria canal and El-Nasr canal. Chemical composition of surface water represented El Nubaria and El-Nasr canal showed in Table 8.The main irrigation systems are surface, dripping, and sprinkler center pivot. Surface water has moderate concentration of salts, slight alkalinity and sodium bicarbonate is the dominant salt in the irrigation water.

Table 8: Chemical composition of surface water (meq^{-1})

Location	pH	ECc	Cations				Anions				SAR
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	HCO_3^-	CO_3^{--}	
El Nubaria Channel	7,50	0,39	1,90	0,10	1,30	0,60	1,10	1,30	1,50	n.d	1,90
El-Nasr Channel	7,90	0,77	3,40	0,20	2,60	1,50	2,30	2,50	2,90	n.d	2,40

3.6. Natural Vegetationand and Land use

The area in the western Mediterranean coastal zone of the country is an example of the different affected coastal ecosystems in Egypt, as well as the other Arab countries. "*Egypt is a part of the arid region and despite the fact that the natural plant cover of Egyptian deserts is quite low and scattered; the flora in the North West Coast is relatively rich and diverse*" (El-Morsy and Ahmed, 2010). The natural range is considered the basic source of animal feedstuff in the Northwestern Coast. The coastal strip of the western coast is recognized as one phyto-geographical region, i.e., Mediterranean; and about 50% of the number of species that constitute the Egyptian flora (~ 2000 species) are found in this area (Mohamed A.G.M., 2002).

El-Hammam canal extension zone is a flat strip of shallow and very shallow soils with fairly rich shrubby vegetation Figure 21. The vegetation of rocky ridges may be related to two associations along of the northwestern coastal plain of Egypt, the first is co-dominated by Thymelaea hirsuta and Gymnocarpos decandrum. It includes a fairly large number of characteristic species, among which are Helianthemum ellipticum, Lotus corniculatus, Herniaria hemistemon, Scorzonera alexandrina, Stipa capensis and Dactylis hispanica. The second association occurs on deeper soils and is co-dominated by Plantago albicans and Asphodelus microcarpus, and its characteristic species are Centaurea glomerata, Lolium perenne, Reseda Alba and Medicago littoralis (Ayyad, 1973) and (Ayyad and Ammar, 1974)

Figure 21: Shrubs by vegetation of the study area (Draft et al., 2005)

The natural vegetation cover of the study area is dominated by woody shrubs, particularly Thymelaeon hirsute, in addition to Anabasis oropediorum, Noaea mucronata, Lycium europaeum Figure 22 .Salsola tetragonal, Astragalus spinosus and Asphodelus microcarpus. According to (Fehlberg and Stahr, 1985) mobile livestock production (camels, sheep and goats) is the essential element of nomadic land use in the investigated area. Therefore most of this area is used as a pasture for sheep and goats which means dangers of overgrazing and consequently desertification.

Figure 22: Lycium Europaeu (Draft et al., 2005)

Within the irrigated area adjacent to the El-Hammam, canal now-a-days agriculture is composed of croplands, vegetable gardening and fruit tree cultivation. As fruit trees (especially fig, olive, mango, apples, guava and different types of citrus are used Figure 23. The most important vegetables are (tomato and onion whereas on the fields (barley, wheat and maize are grown).

Figure 23: Apple trees of El-Hammam Canal (Julie 2011)

In General, The main land uses of El-Hammam canal extension are rain-fed farming and grazing, addition to some sand dunes located around El-Hammam canal Figure 24.The main annul crops area barley and wheat. Figs are successful on calcareous coastal dunes and olives, almonds and pistachio in land alluvial. Irrigated agriculture of grain crops, fruit trees and pasture is spreading after the extension of irrigation canals from the River Nile. **Transport services**: Network Services consist of roads in the area such as;The Alexandria northern coastal road from the intersection of Cairo, Alexandria desert region west of Alexandria Al-Ajami westward to Marsa Matrouh, and then to Sallum on the Libyan border, through tourist villages parallel main coastal road and through Wadi al-natrun to El-Alamein.

Figure 24: Grazing of the North western coast of Egypt, (Julie 2011)

As for the railway station, airports and shipping, there is line of Alexandria - Marsa Matrouh and Salloum. There is in the scope of Alexandria Governorate Alexandria International airport and Burg El-Arab Airport. El-Alamin, Siwa and Matruh International airports are located in Matrouh Governorate Figure 25. As for the railway station, airports and shipping, there are located along the coast of the Mediterranean Sea. Water and electricity servicescommunications and other services, covering coastal part of the Mediterranean Sea

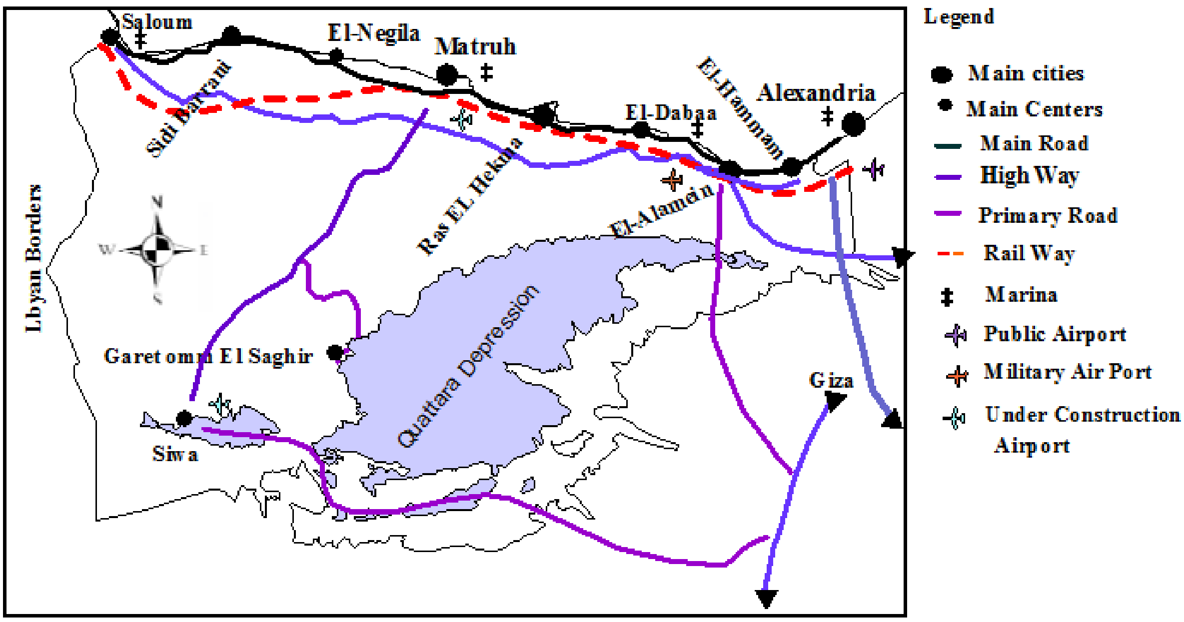


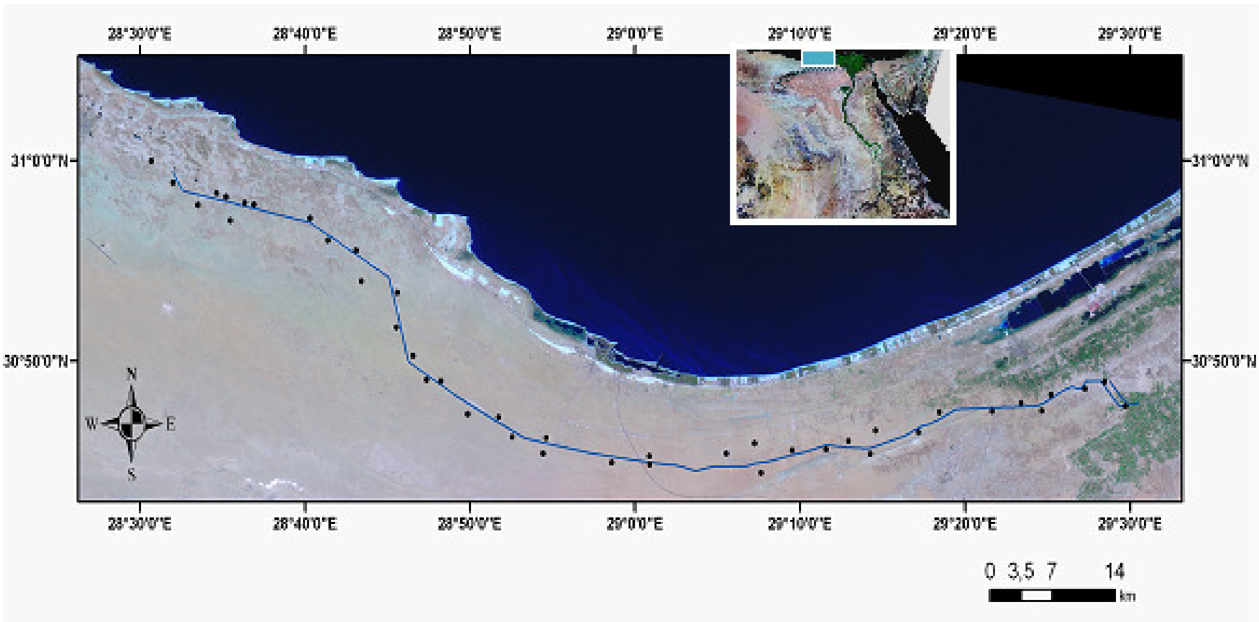
Figure 25: Infrastructure service of north western coastal zone

CHAPTER IV: MATERIALS AND METHODS

Fieldwork and laboratory analysis were determined in the present chapter. Soil classification is carried out according to World reference base for soil resources (2006) and key to soil taxonomy (2010). The most applied of land evaluation methodologies has reviewed, such as the USDA land capability classification, parametric methods and tools for land evaluation systems.

4.1. The Field work

Forty-three soil profile represent the area under study were chosen on the basis of available geomorphologic information. These profiles, which are located at El-Hammam Canal and El-Hammam Canal extension (Figure 26) were dug wide open to a depth of 150 cm unless opposed by bedrock or extremely hard layer. Soil profiles were expected to reflect the wide variations in both geomorphology and soil in the coastal plain. Then, transect sampling methods are applied to cross the different mapping units in the area. Two transects (A) and (B) have been done; transect (A) includes profiles number 1 to 22; transect (B) includes profiles number 23 to 43. Moreover, some check points were done outside the sampling area to validate different mapping boundaries.



.Soil profile

Figure 26: Location map of the soil profile

Morphological description of the soil was undertaken according to the criteria established by Field Book for Describing Sampling soils, (Schoeneberger et al., 2002) and (Schoeneberger, 2011) and FAO (Guidelines for soil description 1990, 1998 and 2006). (FAO, 1990); (FAO, 2006) and (Schoeneberger and National Soil Survey, 1998) Pedological classification was carried out following World reference base for soil resources (WRB, 2006)and the Soil

Taxonomy system (Edition, 2010).The collected soil samples, amounted 102, represented the consequent morphological variations throughout the entire depths of the soil profiles.

4.2. Laboratory analysis

The collected soil samples (disturbed samples) are air dried; ground gently; and sieved through 2 mm sieve. Then, physical and chemical properties are determined for the soil samples as following:

Parameter	Description	Reference
Soil depth	Soil profiles were expected to reflect the wide variations in soil in the coastal plain. And the depth were very deep to very shallow (>150,0 to 10 cm).	Guidelines to soil description, (1990)
Soil description	Morphological description of the soil was undertaken according to the criteria established by Guidelines to soil description, (1990),Field Book for Describing Sampling soils (1998) and the Guidelines for soil description, (2006)	FAO (1990) FAO (1998) FAO (2006)
Soil Classification	Soils under classify with the World Reference Base for Soil Resources (FAO 2006), and Soil Taxonomy system (2010)	WRB (FAO 2006). Key to Soil Taxonomy (2010)
sample preparation in the field	The samples were air-dried, crushed and sieved through a 2 mm sieve, then subjected to the following analyses.	
color	at the fine earth: with MUNSEL SOIL COLOR CHART, on wet and dry material	
particle-size distribution (PSD)	For coarse-textured samples, the dry sieving method was applied, Piper (1950).	Piper, C.S.(1950)
pH-value	Soil reaction (pH) was determined electrometrically in the soil paste using a Beckman bench-type pH –meter.	Allison, L. E., L. A. Richards, et al. (1954)
Electrical conductivity§ Cationic and anionic compositions	Total salinity (ECe) in the soil saturation extract was determined Conductimterically. Cationic and anionic compositions of the soil saturation extract were determined following the methods described by Richards (1954) and Jackson (1963)	Allison, L. E., L. A. Richards, et al. (1954)
Gypsum content	Gypsum content was determined quantitatively by precipitation with acetone	Allison, L. E., L. A. Richards, et al.

Parameter	Description	Reference
	as recommended by Richards (1954)	(1954)
Total amount of nitrogen (TN)	A fine-ground sample (about 0.7 g) is combusted at high temperatures (900 °C) with oxygen, the released gases are separated and cleaned from water, and the NOx is reduced to N2. The N2 is measured by thermal conductivity (vario MAX, Elementar Analysensysteme).	SSLMM- 6B4a, pp. 227; ISO 13878
Total amount of carbon (TC)	A fine-ground sample (about 0.7 g) is combusted at high temperatures (900 °C) with oxygen, the released gases are separated and cleaned from water, and the CO is oxidized to CO_2. The CO_2 is measured by thermal conductivity (vario MAX, Elementar Analysensysteme).	SSLMM- 6A2e, pp. 223
Amount of inorganic carbon (TIC)	If inorganic carbon occurs (pre-test with HCl) 0.2 to 2 g of fine ground sample are weighted in a 50 ml glas bottle closed with a septum. 10 ml of HCl (10 %) are injected, mixed and stored in room temperature overnight. A gas sample is analyzed gas-chromatographically.	
AC exchangeable cations	5 g of air-dried fine-earth are extracted with ammonium acetate two-fold (25 ml each, brought up to 50 ml as the final volume). For each step of extraction the sample is shaken (30 min) and centrifugated (2000 rpm for 10 min). The extracted cations are quantified by atomic absorption and atomic emission spectroscopy (AAS).	Helmke & Sparks (1996)
Plant available P and K	Water soluble P was determined spectrometrically, Jackson (1973). Available K was determined by flame photometry	Jackson, M. L. (1973).
ESP	Exchangeable sodium percentage, calculated with the exchangeable cations from CEC or AC method see natric horizon definition in the WRB	WRB & PSA, pp. 57
Total Element (XRF)	X-ray fluorescense analysis (XRF) - Part 2.The total concentration of the elements	DIN 51418-2 1996

Parameter	Description	Reference
	Al, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S, Si, Ti and Zn is determined by X-Ray spectroskopie.	
Exchangeable cations and cation exchange capacity (CEC)	The exchangeable cations are removed with an excess of ammonium (5 g of air-dried soil, five extractions with 25 ml 1 M NH_4Cl each) and are quantified by atomic absorption and atomic emission spectroscopy (AAS). The ionic strength of ammonium is reduced to 0.01 M NH_4Cl and the adsorbed NH_4 extracted with 1 M KCl afterwards. The concentration of NH_4 is measured by photometry; the CEC is corrected for the soluted proportion of NH_4.	

4.3. Soil classification and evaluation systems

Land Evaluation is the process of assessing the performance of land when used for a given purpose. Land Evaluation may be operated for a specific kind of use (maze, potatoes) or for a more general utilization (agriculture, grazing) and is than referred as land suitability or land capability evaluation respectively. Land Evaluation may be qualitative or quantitative. Land Evaluation involves the execution and interpretation of survey and studies of landforms, soils, vegetation, climate and other aspects of land in order to identify and make comparisons of promising kinds of land use in terms applicable to the objectives of the evaluation. The values allocated to those properties can then be intergraded into categoric, parametric and computerized systems (Verheye, 2002).Some systems group the classes into a series of levels of importance (order, class, subclass, type, etc.), and are thus hierarchical systems. Other systems have one category, and these are frequently parametric. Land Capability Classification. Evaluation systems use mapping methods to represent the results of the soil evaluation. Various systems for land evaluation have been introduced; Sys and Verheye (1978), Storie (1978, 2008), land suitability for crops (Sys et al., 1993), the automated land evaluation system (ALES) and Mediterranean land evaluation information system MicroLEIS (1991). In combining the factor ratings of several individual factors in order to decide the appropriate land suitability class to assign, the possibility of interactions should be taken into account. In a broad interpretation of the meaning of the word ‘interaction’ it can be readily appreciated that many factors interact in the resultant land index which is the integral of their effects (Bagherzadeh and Mansouri Daneshvar, 2011) Some classification systems use the term 'land capability' to express the inherent capacity of a land unit to support a defined land-use for a long period of time without deterioration. 'Land suitability' is meant to describe the adaptability of land to a specific land-use. The Importance of **land capability** and **land suitability** studies lies in its application for the purpose of agricultural land-use planning.

4.3.1. Current (actual) land capability and suitability system

4.3.1.1. Land capability classifications (USDA) system

This system has developed by the Soil Conservation Service of the US Department of Agriculture (1961) provides conceptual definitions of capability classes according to the limitations imposed by permanent properties of land. "The USDA Land Capability Classification is an example of the most traditional land evaluation system that provides conceptual definitions of capability classes according to the degree of limitation to land use imposed by land characteristics on the basis of permanent properties", (Rosa and van Lanen, 2002). The USDA method has three levels in its capability classification structure: classes, subclasses, and units. Soil mapping units are the foundation of the capability systems. The capability classes are the broadest category and indicate the degree of limitation. Soils are placed into one of eight capability classes which are distinguished on the basis of the range of alternative uses, with priority for arable cropping (I, II, III…etc). The soil limitation risk becomes progressively greater from class one to class eight (see chapter II, Table 2) This System is-based on permanent physical land characteristics that limit land use or impose risks of erosion or other damage that can easily be identified. Important characteristics for interpretation are slope, soil texture, soil depth, permeability, water holding capacity and type of clay (Nwer, 2005) Land capability classification consists of soil components, soil map units, and land capability classes (LCC), land capability subclasses (LCS). The land capability classes (LCC) are groups of soil map units with the same relative degree of limitations, based on their soil characteristics, for crop land and pasture uses, Figure 27 (Sinclair and Dobos, 1977)

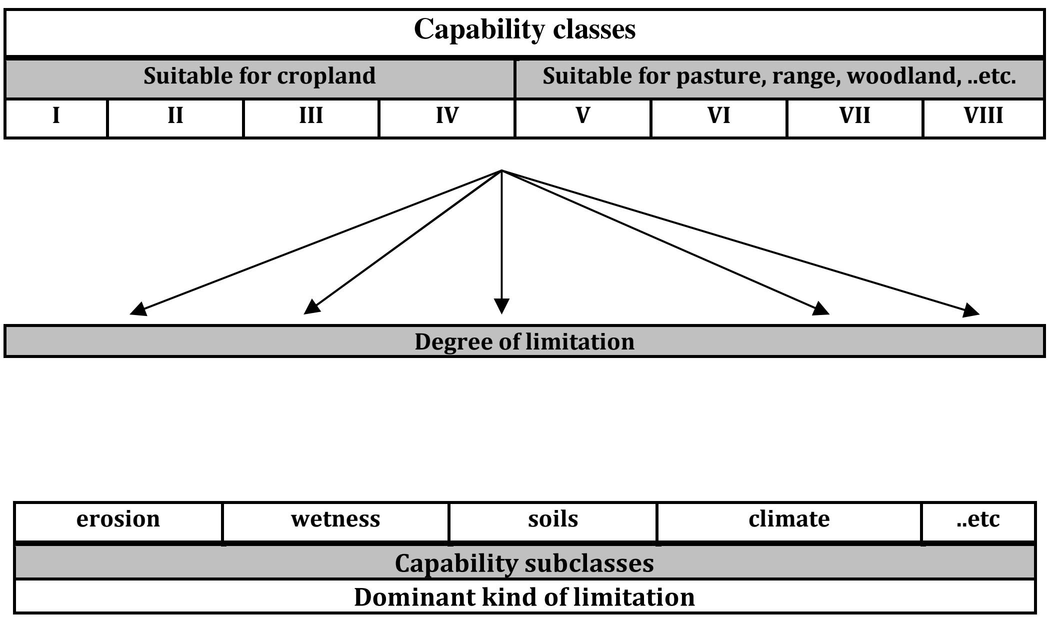


Figure 27: Levels of the land capability classification system

4.4.1.2. The parametric approach

The parametric approach combines the various soil and site properties (parameters) that are believed to influence yield using mathematical formula. Some parametric systems are simple whilst others can be extremely complex. Semi-quantitative land evaluation methods such as parametric assessments are positioned halfway between qualitative and quantitative methods. These are derived from the numerical inferred effects of various land characteristics on the potential behavior of a land-use system. The parametric land evaluation consists in numerical rating of different limitation levels of land characteristics according to a numerical scale between the maximum (normalized as 100%) and the minimum valus. In our case, the indices were calculated following two alternative procedures:

4.4.1.2.1. The Storie -Index Method (Storie index, 1978 and 2008)

In these systems, mathematical formulae are applied so that the final result is expressed in numerical terms. These can be additive (Index = A, B, C, X...) or with a multiplicative scheme (Index = A x B x C x X x...) Figure 28, the latter offering better results for following the minimum law. Storie Index ratings (1978) have been generated by soil survey staff and collaborators. These ratings can be highly subjective because no singl person has generated Storie ratings for the entire state, and because of the inherent biases associated with the design of the classification system. So, the Storie Index has developed a revised version to generate ratings digitally from USDA Natural Resources Conservation Service (NRCS) and National Soil Information system (NASIS).

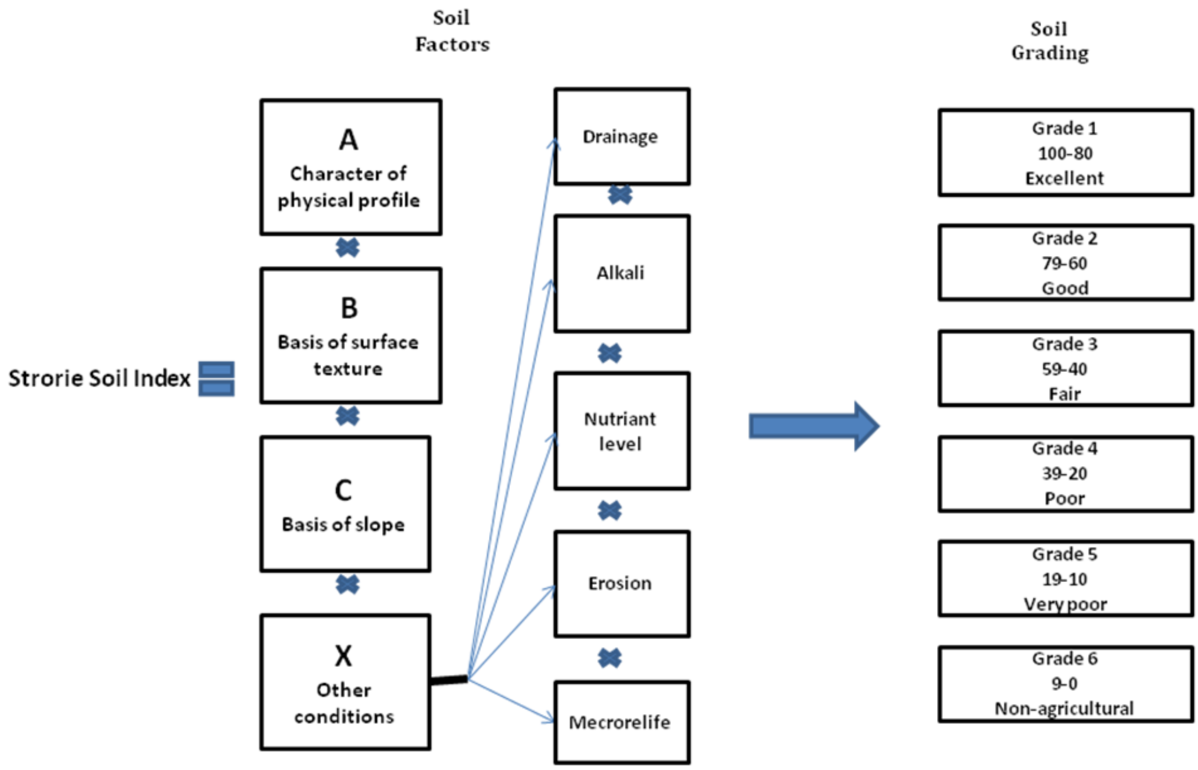


Figure 28: Flow chart for Storie Index (1978) system

This revised Storie index is generated from a wide range of soil profile and landscape characteristics to those in Storie (1978) (O'GEEN, 2008). The soils of the study area evaluated according to the structure of Storie Index (2008) which is programmed through 'Excel Visual Basic'.

4.4.1.2.2. The Sys and Verheye (1978) system

Based on the number and intensity of limitations, Sys and Verheye (1978) suggested definitions of suitability orders and classes Figure 29.The suitability index for irrigation (Ci) is calculated, and this value is also integrated in the definition where: Suitability evaluation does not identify a single Farm-use as best on each unit .Suitability classes for different uses cannot be compared in routine automatic manner. Land-use planning depends on physical, chemical, soil fertility properties and economic aspects to develop the border between classes and sub- classes. Land suitability classes indicate the degree of suitability within an order. Arabic numbers reflect a sequence of decreasing suitability: Class SI land is highly suitable for the defined land-use; Class S2 land is less suitable than SI land, and so on (FAO, 1976).

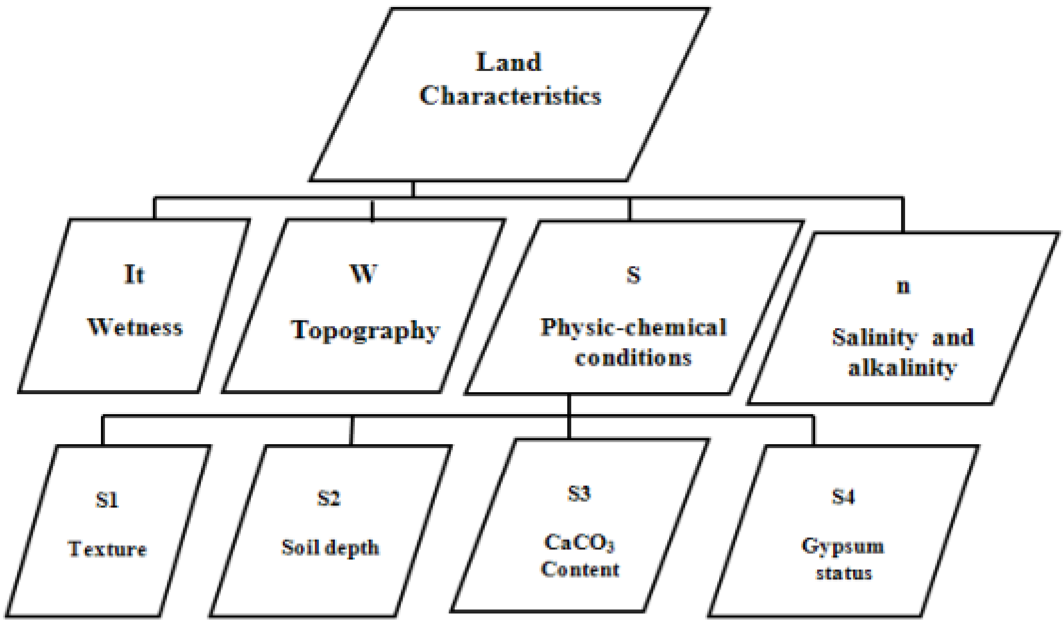


Figure 29: Flow chart for Sys and Verheye (1978) system

4.4.1.2.3. Land suitability for specific crops: (Sys, 1993) system

This method depends upon three phases as follow:

1- Collection of the necessary characteristics provided from the profile description and the analytical data, e.g., slope, drainage, soil physical characteristics, fertility characteristics, salinity and alkalinity.
2- Determination of the requirements of the land utilization types: Soil requirements and landscape for each land use type (LUT) were applied from (Sys, 1993)

3- Evaluation procedure: Evaluation procedure was achieved by comparing the land characteristics /qualities with the crop requirement (LUT) using limitation method with a criteria number and intensity of limitation. Degree of limitations, intensity of limitations and classes are presented in Table 9. Different land suitability classes and indices 13 crops were selected and evaluated according to their requirements with the land characteristics of the mapping units to recognize the current suitability, limiting factor.

Capability index for irrigation (Ci) =

$$\left[A \times B \ / \ 100 \ \times C \ / \ 100 \ \times D \ / \ 100 \ \times E \ / \ 100 \ \times F \ / \ 100 \right] \quad \textbf{Equation 2}$$

Where Ci = Capability index for irrigation; A = soil texture rating, B = soil depth rating, C = $CaCO_3$ status, D = electro-conductivity rating, E = drainage rating, F = slope rating.

Table 9: Degree of limitations, intensity of limitations and classes

Defined classes	Suitability classes	Intensity of limitation	Degree of limitations
Very suitable	S1	No	**0**
Moderately suitable	S2	Slight	**1**
Marginally suitable	S3	Moderate	**2**
Actually unsuitable and potentially suitable	N1	Severe	**3**
Actually unsuitable and potentially unsuitable	**N2**	**Very severe**	**4**

4.4.1.3. Tools for land evaluation systems

There is several computerized land evaluation systems used worldwide. In Egypt land evaluation systems ALES (The Automated Land Evaluation System) and MicroLEIS (Mediterranean Land Evaluation Information System) main tools used in Egypt.

4.4.1.3.1. The Structure of an ALES evaluation

In the study area only land capability model applied, which depend on soil characteristics (slope, effective depth, drainage, texture class, cation exchangeable capacity, exchangeable sodium percentage and calcium carbonate content). In light of soil characteristics, the classes of lands can be distinguished as follows:

Class 1 = highly Capability. Class 2 = moderately Capability.

Class 3 = marginally suitable. Class 4 = limited capability, and

Class 5 = Not Suitable.

Current land capability assessment: Land capability model was built and using ALES software d by (Mahmoud et al., 2009) and the soil characteristics rates in El-Hammam area in Table 10.

4.4.1.3.2. Mediterranean land evaluation information system (MicroLEIS DSS)

Microcomputer Land Evaluation Information System (MicroLEIS) include of 12 model show in (A). In the study area only two were used (Land capability model "CERVATANA" and Land suitability model "ALMAGRA"), see (B) and (C) respectively.

Table 10: Soil Characteristics of the soil which used in the capability (Mahmoud et al., 2009b)

Soil Characteristics		Class 1 High Capability	Class 2 Moderate Capability	Class 3 Marginal Capability	Class 4 Limited Capability	Class 5 Not Suitable
Erosion hazard	**Slope %**	<2	2-5	5-8	8-16	>16
	Effective depth (cm)	≥ 120	90-120	60-90	25-60	<25
Wetness	**Drainage [1]**	good	moderate	imerfect	Poor but drainable	Poor but not drainable
Rooting Conditions	**Texture class[2]**	L, SL, SCL, CL, SC	SiL, SiCL, SiC, Si, light C	F. S, C	S, G.S	Extremely G. sand
	$CaCO_3$ %	<10	10-20	20-40	40-50	>50
Fertility status	**CEC ($cmol_c/kg$)**	≥30	15-30	10-15	5-10	<5
	EC (dSm^{-1})	<4	4-8	8-16	16-32	>32
Salinity and alkalalinity hazard	**ESP**	<15	15-20	20-30	30-40	>40

(1)According to (Shalaby et al., 2006)

(2)Texture classes: L: Loamy, SL: Sandy loam, SCL: Sandy clay loam, CL: Clay loam, SC: Sandy clay, SiL: Silty loam, SiCL: Silty clay loam, SiC: Silty clay, Si: Silty, F.S.: Fine sand, C: Clay, S: Sandy, G.S.: Gravely sand

4.4.1.3.2.1. General land capability model (CERVATANA)

The CERVATANA (land capability model) works interactively, comparing the values of the characteristics of the land-unit to be evaluated with the generalization levels established for each use capability class. Following the generally accepted norms of land evaluation (FAO, 1976) and (Dent and Young, 1981), the CERVATANA (land capability model) forecasts the general land use capability for a broad series of possible agricultural uses.The methodological criteria refer to the system designed earlier by De La Rosa and Magaldi (1992) and modified for computing purposes by (De La Rosa et al., 2004), (Ibrahim and Nahry, 2010) . Land Capability evaluation orders and classes of lands can be distinguished as follows:

Classes	Subclasses
Class S1 = Excellent	Slope =t
Class S2 = Good	Soil=I
Class S3 = Moderate	Erosion risks=r
Class N = Marginal	Bioclimatic deficit=b

4.4.1.3.2.2. Agricultural soil suitability model (ALMAGRA)

The soil suitability Almagra model is based on analysis of edaphic factors which affect the productivity of twelve traditional crops: wheat, maize, melon, potato, soybeans, cotton, sunflower, and sugar-beet, alfalfa, peach, citrus and olive. The edaphic factors including the effective depth (p), texture (t), drainage (d), carbonate content (c), salinity (s), sodium saturation (a) and degree of profile development (g) are used as diagnostic criteria Figure 30.The main limitations factors for Suitability classes are calcium carbonate, soil texture, soil depth, drainage, soil alkalinity and salinity.

4.4.2. Potential land capability and suitability for irrigation

The most soil properties were studied in arid and semi arid soils were soil texture, soil depth , drainage , calcium carbonate content and salinity by (Hamied, 2009) and (Abdel-Hady et al., 2011), (Albaji et al., 2010a; Landi et al., 2008; Mehdi et al., 2012) ,(Kalkhajeh and Amerikhah, 2012) and (Dengiz, 2006) in Egypt , Iran and Turkey, respectively. However, the soils under study are coarse texture, well to poor drainage and non-saline to highly saline. Due to major improvements of rating of soil texture, soil depth, drainage, calcium carbonate content and salinity tables for potential land suitability and modification of rating land suitability for irrigation Sys and Verhye (1978). "*The potential land suitability classification relates the suitability of land for the use in question at some future date after major improvements have been effected where necessary*" (Shalaby et al., 2006). The Micro LIES depend on the soil is virgin and does' not cultivated but the Sys and Verhye (1978) system depend on the soils cultivated for long time (Hamied, 2009). The soils under investigation which are adjacent to the El-Hammam Canal which has been cultivated, however the soils which are along the El-Hammam Canal Extension are virgin, for this reason to apply and modification Sys and Verhye (1978) and ratings in MicroLIES model.

Sys and Verhey system (1978), the limitation (severe) is used when the characteristics are very marginal. The relative limitation scale is transferred to a parametric approach using the ratings for the different limitation levels set out inTable 11 and land index for soil class in Table 12. The dominant limiting parameter for irrigation suitability of most investigated soil is soil texture. Potential land suitability for irrigation in arid and semi-arid soils with surface irrigation is different than drip irrigation with coarse texture soils (Abdel-Hady et al., 2011) Table 13, Table 15 and Table 16 shows the rating of soil properties classes for irrigation suitability, these values in the case of possible soil uses drip irrigation and irrigation surface.

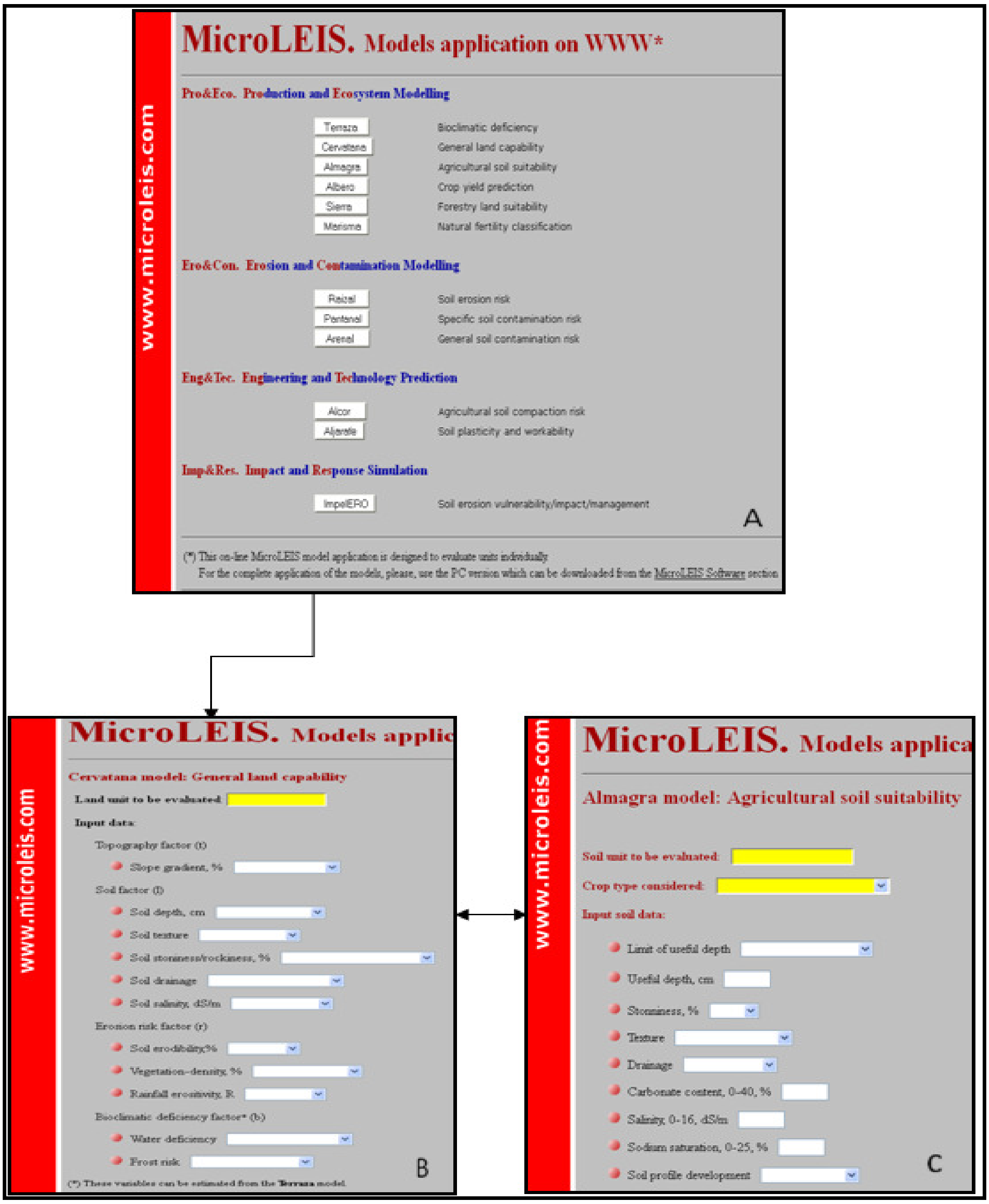


Figure 30: General scheme of the MicroLEIS, Cervatana and Almagra model (http://www.evenor-tech.com/microleis/microlei/microleis)

Table 11: Land suitability classes according to degree of limitations (Modification Sys and Verhey, 1978)

Soil class	Intensity of limitation	Rating %
S1	Without limitations	95-100
S1	Slight limitations	85-95
S2	Moderate limitations	60-85
S3	Severe limitations	40-60
N1	Very severe (modifiable)	25-40
N2	Very severe (non modifiable)	0-25

(Bagherzadeh and Mansouri Daneshvar, 2011)

Table 12: Land suitability classes according to land index (Modification Sys and Verhey, 1978)

Soil class	Intensity of limitation	Land index
S1	Highly suitable	75-100
S2	Moderately suitable	50-75
S3	Marginally suitable	25-50
N1	Currently not suitable	12,5-25
N2	Permanently not suitable	0-12,5

Table 13: Texture class ratings for irrigation suitability

Soil texture	Rating for surface irrigation					Rating for drip irrigation				
	Fine gravel			Coarse gravel		Fine gravel			Coarse gravel	
	< 15	15 - 40	40 - 75	15 - 40	40 - 75	< 15	15 - 40	40 - 75	15 - 40	40 - 75
Clay Loam	**100**	**90**	**80**	**80**	**50**	**100**	**90**	**80**	**80**	**50**
Silty Loam	**100**	**90**	**80**	**80**	**50**	**100**	**90**	**80**	**80**	**45**
Sandy Clay Loam	*95*	**85**	**75**	**75**	**45**	**95**	**85**	**75**	**75**	**45**
Loam	**90**	**80**	**70**	**70**	**45**	**90**	**80**	**70**	**70**	**45**
Silty Loam	**90**	**80**	**70**	**70**	**45**	**90**	**80**	**70**	**70**	**45**
Silt	**90**	**80**	**70**	**70**	**40**	**85**	**95**	**80**	**80**	**44**
clay	**85**	**95**	**80**	**80**	**45**	**90**	**80**	**70**	**70**	**45**
Silty Clay	**85**	**95**	**80**	**80**	**40**	**85**	**95**	**80**	**80**	**40**
Sandy Clay	**80**	**90**	**75**	**75**	**35**	**95**	**90**	**85**	**80**	**35**
Silty Loam	**75**	**65**	**60**	**60**	**35**	**95**	**85**	**80**	**75**	**35**
Loamy Sand	**55**	**50**	**45**	**45**	**25**	**85**	**75**	**55**	**60**	**35**
Sandy	**30**	**25**	**25**	**25**	**70**	**65**	**50**	**35**	**35**	**35**

Table 14: Soil electric conductivity classes rating for irrigation suitability

Soil Salinity dsm^{-1}	Rating for surface irrigation		Rating for drip irrigation	
	C, SiC, S,SC texture	Other texture	C, SiC, S,SC texture	Other texture
< 4	100	100	100	100
4 – 8	90	95	95	95
8 – 16	80	50	85	50
16 – 30	70	35	75	35
>30	60	20	65	20

C: Clay, SiC: Silty clay, S: Sand, SC: Sandy clay

Table 15: Drainage classes rating for irrigation suitability

Drainage classes	Rating for surface irrigation		Rating for drip irrigation	
	C, SiC, S,SC texture	Other texture	C, SiC, S,SC texture	Other texture
Well drained	100	100	100	100
Moderately drained	80	90	100	100
Imperfectly drained	*70*	80	80	90
Poorly drained	60	65	70	80
Very poorly drained	40	65	50	65
Drainage status not known	70	80	70	80

C: Clay, SiC: Silty clay, S: Sand, SC: Sandy clay

Table 16: Soil depth and calcium carbonate content classes rating for irrigation suitability

Soil depth (cm)	Rating for surface irrigation	Rating for drip irrigation	$CaCO_3$ %	Rating for surface irrigation	Rating for drip irrigation
< 20	30	30	< 0.3	90	90
20 – 50	60	70	0.3 – 10	95	95
50– 80	80	90	10– 25	100	95
80 – 100	90	100	25 – 50	90	80
>100	100	100	>50	80	70

CHAPTER V: SOIL PROPERTIES

This chapter shows the results of the fieldwork and laboratory analysis like the description of the major soil properties and description of references profiles. Based on relevant soil properties the soil could be classifed according to the World Reference Base for soil resources (2006), the key to soil taxonomy (2010) and by a cluster analysis. A discussion of soil properties and the development of integrating soil indices are presented.

The north-western Mediterranean coastal zone can be differentiated into two main provinces. These are the elevated tableland in the south and the coastal zone to the north, where the study area is located. The main formation of geomorphology of the western coastal zone is nine ridges separated by eight depressions that run parallel to the present Mediterranean coast (Figure 31).

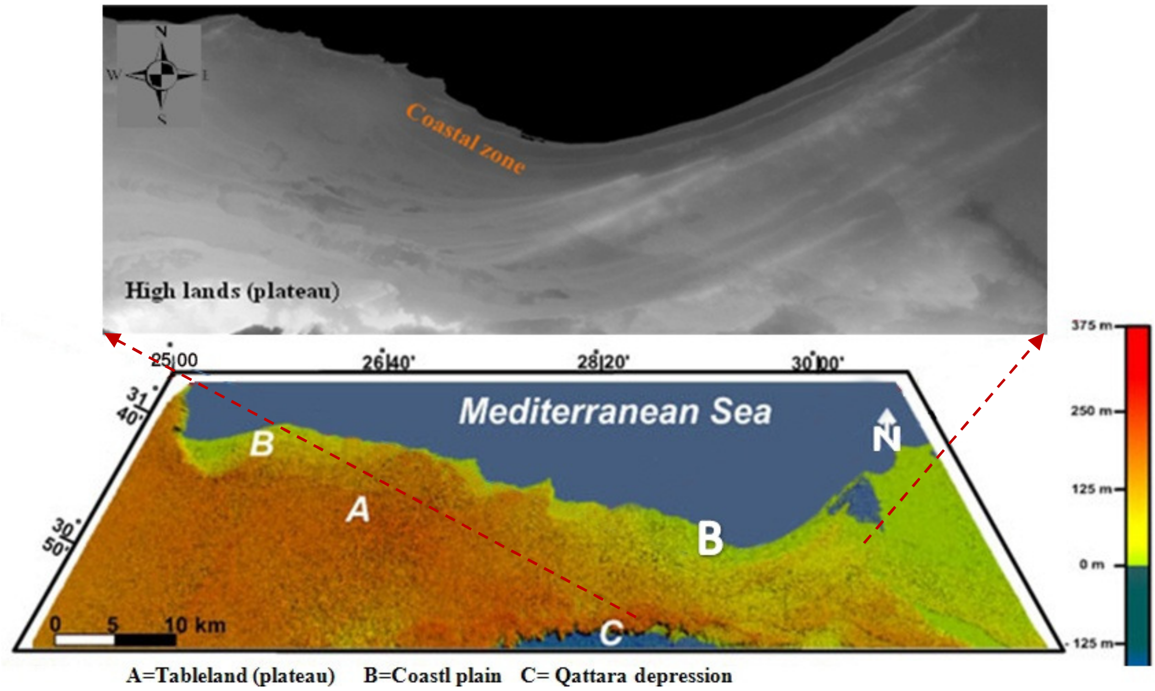


Figure 31: Geomorphology units of North Western of Egypt (Yousif and Bubenzer, 2012)

5.1. *Overview of the studied soil properties*

Soil is composed of minerals and soil organic matter, water and air; soils can be enormously complex systems of organic and inorganic components. The composition and proportion of these components of soils greatly influence soil physical properties including rooting depth, capacity for water storage and aeration. Most of the studied soil profiles are situated in an almost leveled terrain and the top surface is flat to almost flat with few undulating surface.

5.1.1. Soil Depth

Most of the cultivable soils in the north-western coastal area are of alluvial origin. The sediments have been transported by water to alluvial fans and flood plains. However, aeolian sediments in some locations are being cultivated. The subsoil layers are formed locally from marine limestone. The soil depth varies accordingly, being shallow in the sloping and plateau landscape, and deep in the coastal plain and alluvial fans. The studied soil profiles represent the cultivated lands surrounding El-Hammam canal while few profiles are dug in the area under natural vegetation at the end of this canal. Accordingly, soil profiles are deep along the canal but are less deep at the end of the canal. On the contrary, the soils representing the El-Hammam canal extension are deep at the western end but are rocky to very shallow at the eastern start of the canal (Figure 32).

The effective soil depth is an essential requirement in land suitability classification. It is identified as a key for many soil characteristics, such as soil drainage, irrigation conditions and yields for all crops. Soil profiles located in sand dunes are deep and represent most of the area adjacent El-Hammam canal. The relationship between calcareous soils and rooting depth is not difficult to isolate from effects of coarse texture and good physical properties. Around El-Hammam canal, tree growth of citrus, apple and guava indicates a positive relationship to the depth of carbonate rocks in the soil profile. Rooting depth for almost all grown trees was at least 100 to 120 cm and carbonate rocks occurred at a depth of 150 cm.

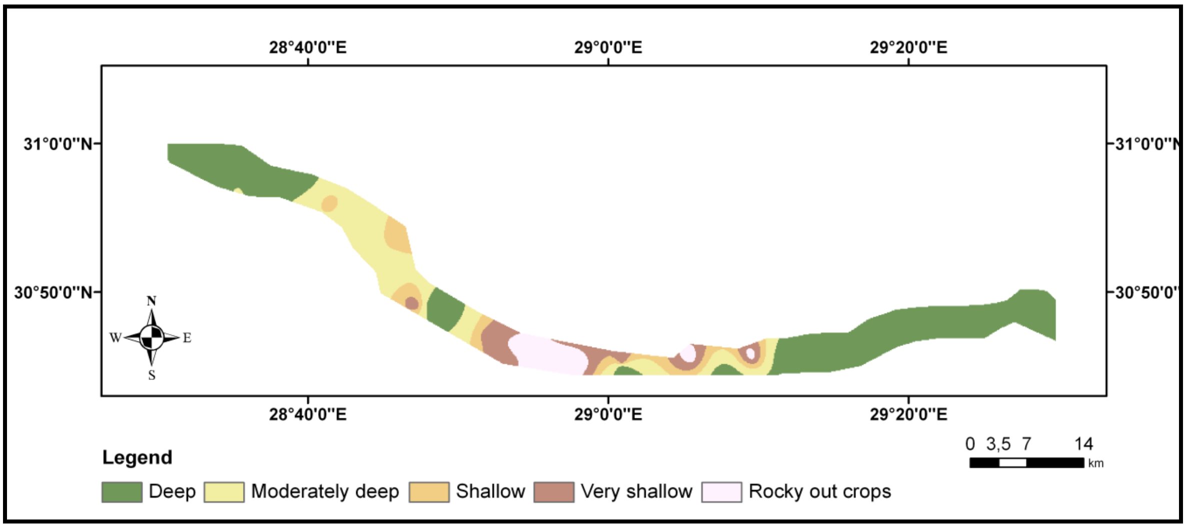


Figure 32 : Distribution of soil depth of the study area

5.1.2. Soil colour

Climate has important influences on soil formation and soil characteristics. In arid areas, wind and occasional water erosion are severe so that gravelly desert plains, sand dunes, and sand sheets are prevalent (Armitage and others, 1985). Soil colour is one of the important basic properties which help to identify the kinds of soils and recognize the successions of soil horizons / layers in soil profiles. The soil colour of an area, often relates to specific chemical, physical and biological properties of the soils in that area. Colour can be a useful indicator of some of the general properties of a soil, as well as some of the chemical processes occurring beneath the surface. The top of the fourth ridge close to the area of study is composed of pink to pale-brownish red paleosols (Pink limestones), which the Miocene deposits. Lower Cretaceous and Miocene formations which have solid light-brown sandy marl and soft yellowish marly limestone were dominated by 10 YR 7/3 and 10 YR 8/4, respectively. Mineral composition of Lower Cretaceous formation was dominated by calcite > quartz >~ kaolinite, and calcium carbonate content was 34.8 %. In contrast, for Miocene formation the calcium carbonate content value was 68,5 % and mineral composition was dominated by dolomite > quartz >~ palygorskite (Shadfan et al., 1985).

The dominant soil colour in the studied soil profiles is very pale brown (10 YR8/4, dry) to very pale brown (10YR 7/4, moist) or very pale brown (10YR7/4, dry) to light yellowish brown (10YR6/4, moist), however, yellow (10YR 8/6, dry) to yellow (10YR7/6, moist) is also detected (Figure 33). In general, the soil colour is seemingly affected by calcium carbonate content and soil depth.

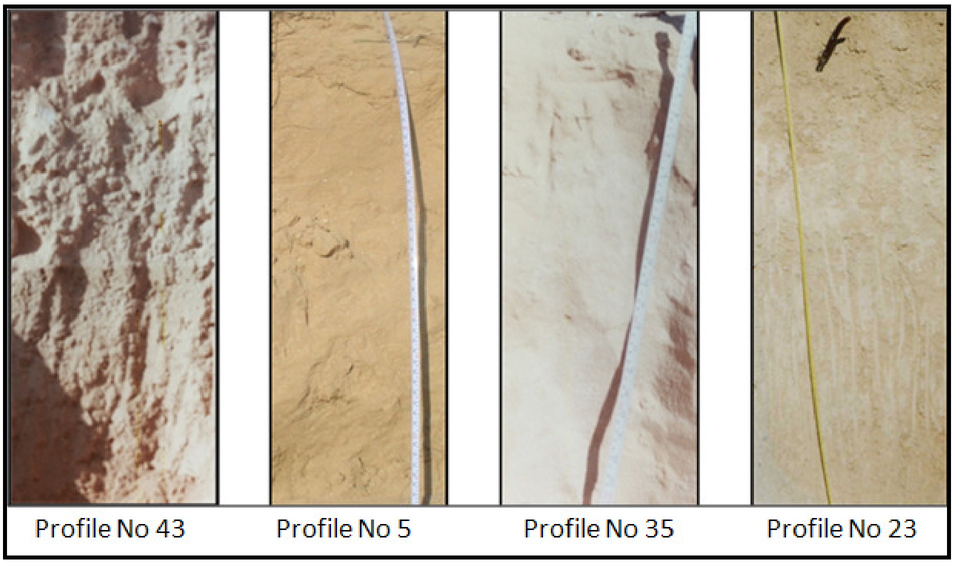


Figure 33: Soil coloure distribution of soil profiles

5.1.3. Soil Texture

Soil texture is considered one of the most important soil criteria affecting soil behavior and land management, and it influences a number of physical and chemical soil characteristics. Also, growth and development of the plant is primarily based on the soil texture and root penetration, nutrition absorption through soil particles, water holding capacity, water infiltration and percolation. Results of particle size distributions of the soil samples represent the consequent layers of the studied soil profiles indicate that the soil is coarse in texture especially in the surface samples and most soils representing El-Hammam canal. The particle size distribution of the soil samples shows that, medium and fine sands contributed the major part of the soil in both habitats. Gravel content is very few to few (0.5 - 10.0 %) fine and medium sized throughout the entire depth in the soils adjacent El-Hammam canal. At the end, gravel content ranges from 14.5 to 25.9 %, the higher contents are mostly detected in the deepest layer of this canal. On the other side of El-Hammam canal extension, gravel content is widely variable, being very few to many in variable size gravels (0.9 to 38.5 %), the highest contents are also detected in the deepest layers.

Soil texture throughout the entire depth of these soil profiles are coarse-textured and sometimes medium to coarse textured where soil texture varies between coarse sand to sandy loam except for some layers which are silt loam on the front El-Hammam canal and at the end of the canal extension. Sand fractions are dominated by fine sand (more than 50%, see Figure 34).

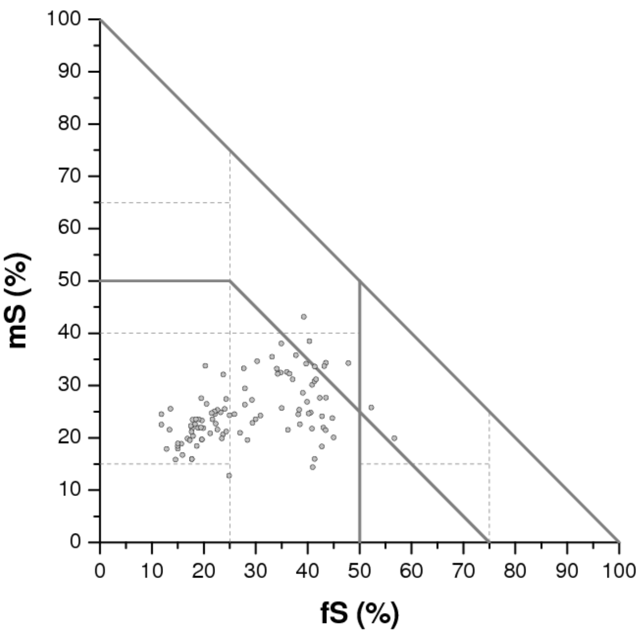


Figure 34: Results of fine sand to medium sand relations (% of all grain fractions)

5.1.4. Soil structure

Soil structure is just as important as soil texture in governing, how water and air move in soils. Structure fundamentally influences the suitability of soils for the growth of plant roots. Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. Most of the investigated soils have no observable aggregation or no definite orderly arrangement of natural lines of weakness, such as: massive structure, while the entire soil layers appears cemented in one great mass; single-grain structure (non-coherent) or the individual soil particles show no tendency to cling together, such as pure sand. Soil structure is different with depth, being single grains in the top surface layers of all soil profiles and massive to week subangular blocky in the subsoil layers. Wet consistence agrees well with soil texture, being non-sticky and non-plastic to slightly sticky and slightly plastic.

5.1.5. Soil reaction

In general, soils are chemically different from the rocks and minerals from which they are formed in that soils contain less of the water soluble weathering products calcium, magnesium, sodium, and potassium, and more of the relatively insoluble elements such as iron and aluminum. Soil chemistry is the interaction of various chemical constituents that takes place among soil particles and in the soil solution. The variation in soil reaction was related to parent material, rainfall and topography. A pH greater than 8 indicates possible high levels of exchangeable sodium, calcium or magnesium, and therefore a tendency for the clay to disperse (production of poor soil structure). Soil reaction is important because it affects nutrient availability, microbial activity and plant growth.

From the data presented in this study, it is clear that soil reaction varies considerably between 7.4 and 9.4, indicating slightly alkaline to very strongly alkaline soil reaction (Figure 35). High pH indicates that the soil is fully saturated with exchangeable cations and free $CaCO_3$ is present in the soil. The dominant part of the investigated soils have pH values in the range of 8.0 to 8.7, only few profiles exhibit pH values more than 8.7 due to the dominance of $CaCO_3$ and presence of $MgCO_3$ or Na_2CO_3.

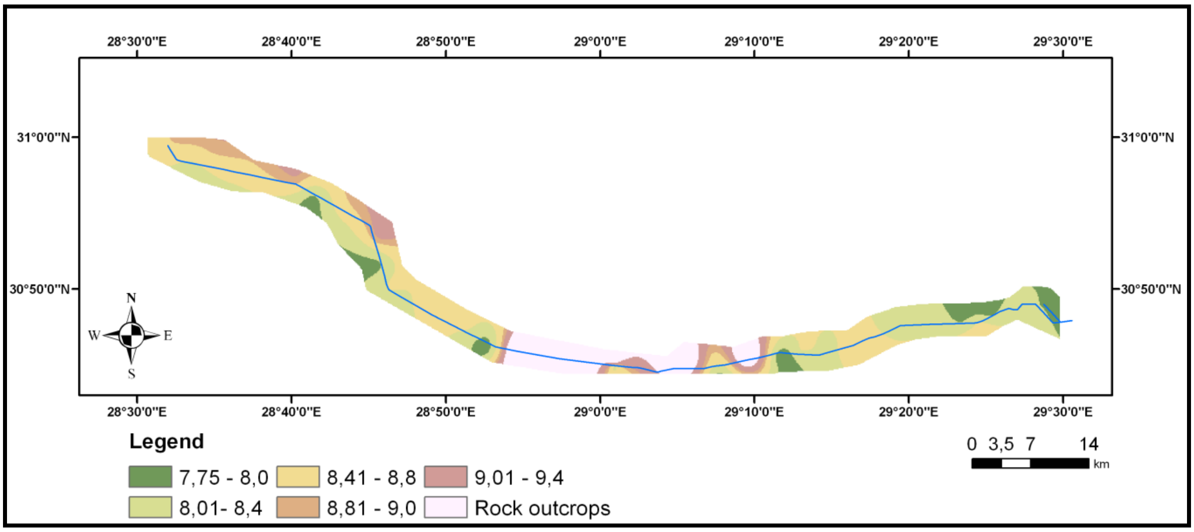


Figure 35: Distribution of soil reaction (pH) in the studied area

5.1.6. Soil salinity

Salinity is one of the main edaphic factors which limits the distribution of plant communities in their natural habitats and which is causing increasingly severe agricultural problems. Electrical conductivity is a measure of the concentration of water-soluble salts in saturated soil paste.

Soil salinity values ranged widely between 0.82 and 33.1 dSm^{-1}, with an average value of 6.2 dSm^{-1} (slightly saline). Most values of soil salinity (EC) indicate non-saline or slightly saline soils. The soil profiles representing cultivated soil along El-Hammam canal are slightly saline except soils represented in profile 43. The dominant soluble cations are Na^{+1}, Ca^{+2} and Mg^{+2} in a descending order, while soluble anions are dominated with Cl^{-1} and SO_4^{-2}. For soil profiles, electrical conductivity weighted mean values ranged between 0.91 and 26.4 dSm^{-1} indicating non-saline and strongly saline soils, respectively. High concentrations of neutral salts, such as sodium chloride and sodium sulfate, may interfere with the absorption of water by plants because the osmotic pressure in the soil solution is nearly as high as or higher than that in the plant cells. Salts may also interfere with the exchange capacity of nutrient ions, thereby resulting in nutritional deficiencies in plants and the possible toxic effect of individual ions.

Distribution of soil salinity is shown in Figure 36. The pattern of soluble anions and cations indicates that NaCl, $NaSO_4$, $MgSO_4$ and $CaCl_2$ / $MgCl_2$ predominate the soluble salts in the studied soil profiles. The soils profiles have high concentrations of more soluble neutral salts than Ca and Mg carbonate. Alkaline soils which have exchangeable sodium percentage more than 15 % and high pH values > 8,5 indicates to highly content of sodium carbonate (Na_2CO_3). In general, the dominance of salt composition in soils is Ca and Mg carbonates and sometimes Na in sodic soils. The cationic composition of the soil saturation extract of most soil layers is dominated by Na^+ followed by Ca^{+2} /or Mg^{+2} and K^+. Exceptional cases are found in some soil profile Ca^{+2} exceed Na^+. The anionic composition is characterized by the dominance of Cl^- followed by SO_4^{-2} /or HCO_3^- while CO_3^{-2} in entirely absent.

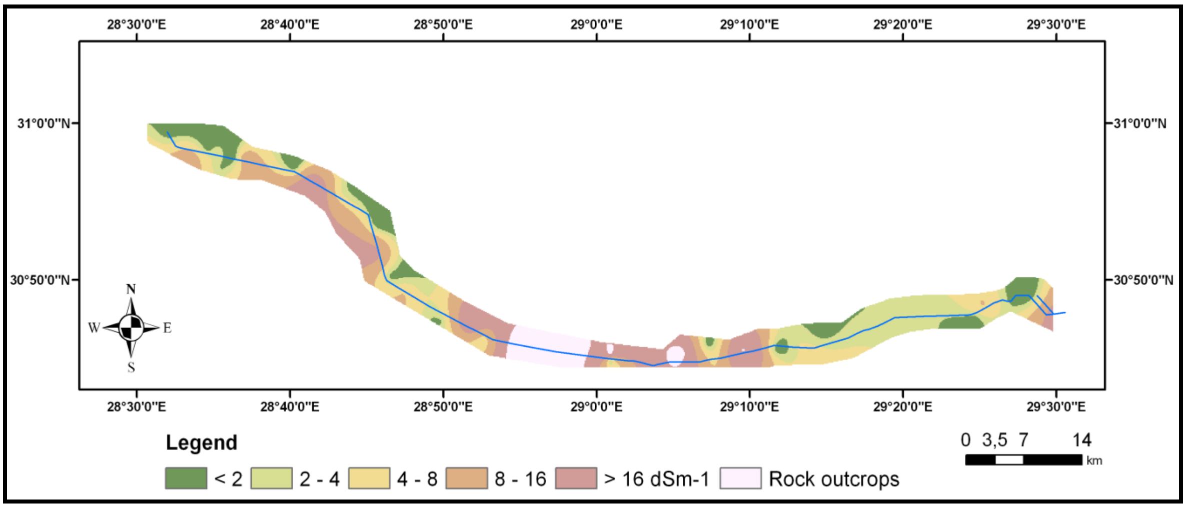


Figure 36: Distribution of soil salinity (EC) in the studied area

5.1.7. Calcium carbonate content

Soils under arid or semiarid conditions in the northern Mediterranean zone are mostly Calcisols. Consecutive mudflow occurrences have been responsible for the development of

Calcisols with variable contents of secondary carbonate (lime) accumulation. Durisols contain cemented secondary silica (SiO_2) in the upper one meter of the soil. Their typical feature is the presence of a hard-cemented layer identified as the "duripan phase". In the Mediterranean coast, they occur on level and slightly sloping alluvial plains, terraces and gently sloping piedmont plains. The coastal zone to the north of the Miocene plateau is covered by Quaternary deposits, which rest with conformable and/or unconformable relation of the Tertiary deposits.

These deposits are mainly represented by the Holocene deposits of coastal sand dunes, lagoonal and alluvial deposits as well as the Pleistocene oolitic limestone ridges and old lagoonal deposits. The chemical analyses of carbonate rocks of the studied ridges have indicated that calcium carbonate is the main component of these rocks. However, magnesium carbonate shows a marked increase toward the oldest ridge which is attributed to dolomitization of calcite by aging. This is related to increasing content of insoluble residue and to leaching processes that took place after deposition of these rocks. This process may be enhanced by groundwater movement and leaching process by rain water (Zahran, 2008).

Soil $CaCO_3$ is identified as an important soil criterion for agricultural crops in Mediterranean region. This criterion affects soil moisture regime and availability of nutrients to plants, pH, dispersion-flocculation and organic matter stabilization. Pedogenic carbonate formation requires a calcium source, which may be, mineral weathering, evaporative concentration of Ca from ground water, and/or Ca input via dust and/or precipitation. Calcium carbonate accumulation depend on a balance among, geomorphic age or landscape stability, soil water movement at both profile and landscape scales, soil texture, and vegetation type and quantity. These accumulations follow a sequence of morphologic development starting as horizon features such as carbonate coats, masses, and fine nodules (Schoeneberger et al., 2002) and (Schoeneberger, 2011). Calcareous soils originate mainly from carbonate-rich parent materials such as limestone.

Soil adjacent El-Hammam canal and their extensions are shown to be extremely calcareous, where $CaCO_3$ contents range between 27.1 % and 69.5 % with an average value of 46.4 %. The highest $CaCO_3$ content is formed in the soils profiles representing El-Hammam canal extension and some profiles, located in the northern side of El-Hammam canal. In addition, weighted mean values of $CaCO_3$ content in soil profiles (31.1 - 64.5 %) indicate an extremely calcareous mature (Figure 37) and (Appendix, Table 43). The lowest values characterize the soils around El-Hammam canal, which have a fine and medium sand dominated texture. Carbonate contents in the surface layers of the studied are formed from calcareous parent materials through the weathering of high tableland formations (Miocene plateau) in the south and the re-precipitations of carbonate.

The overall reaction for the dissolution and re-precipitation of $CaCO_3$ is

$$\mathbf{CaCO_3 + H_2CO_3 \leftrightarrow CO_2 + {}_2H_2O} \qquad \textbf{Equation 3}$$

Calcium and Magnesium carbonates are among the least stable and most reactive soil constituents. Correlations between $CaCO_3$ content and the particle size fractions of soil samples indicates positive correlation between coarse sand and calcium carbonate content as well as with the very fine sand, silt and clay. On the other hand, negative correlation is observed between calcium carbonate content and medium (r=-0.259) and fine sand (r=-0.449). In general, total calcium carbonate contents are mostly associated with coarse and moderately coarse textured soils, suggesting the role of physical weathering.

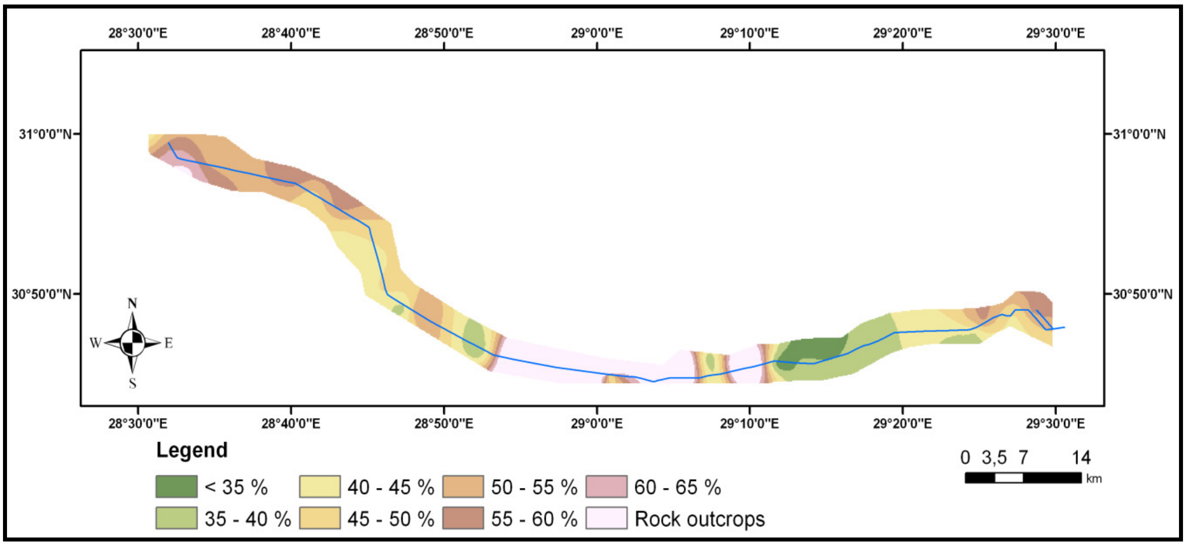


Figure 37: Distribution of calcium carbonate content in the studied area

In general, carbonate minerals constitute more than 60% of minerals in the coastal area and the most carbonate minerals are calcite, aragonite, Mg-calcite and dolomite. The non-carbonate fraction is mainly composed of quartz, feldspars and clay minerals such as, kaolinite, ilite and attapulgite.

5.1.8. Organic Carbon

Soil organic matter is considered the main source for many elements in soil and helps to maintain the aggregates of soils and increase resistance to erosion. Increasing organic matter in soils will increase the amount of water for plant growth. Organic carbon influences many soil characteristics including colour, nutrient holding capacity (cation and anion exchange capacity), nutrient turnover and stability, which in turn influence water relations, aeration and workability. Organic matter contributed much to the cation exchange capacity (CEC) of soils and plays a major role in retaining potassium, calcium, magnesium and others.

Soil organic carbon (SOC) contents are very low, being in the range of 0.07 to 0.98 %. The surface and subsurface layers have the highest values of SOC especially in soil profiles representing the cultivated lands along El-Hammam canal. Organic matter contents are very low and ranged between 0.12 and 1.69 %, the highest content is found in a topsoil horizon of the profile No 43 which represents old cultivated lands. Weighted mean values of organic carbon and organic matter are very low (SOC: 0.15 - 0.78 %, organic matter 0.26 - 1.34 %).

5.1.9. Exchange characteristics

5.1.9.1. Cation exchange capacity (CEC)

The cation exchange capacity is used as a parameter for the buffering capacity for fertilizers. The natural fertility level and the buffering capacity do not strongly interact in their influence on the crop and are treated as separate components of the land quality. Cation exchange capacity (CEC) of soils is closely related to the contents of organic carbon and clay content. The exchange characteristics of the soils under study dictate that CEC values are low and coincide well with soil texture, being in the range between 2.0 and 8.6 meq/100 g soil with an average 3.2 meq/100g soil and coincide very well with texture classes. In general, the values of CEC were higher in soil layers containing high fine material and /or high organic carbon. The presence of carbonate minerals associated with silicate minerals lead to a diminished cation exchange capacity.

5.1.9.2. Exchangeable cations

Accordingly, the soils of the study area are base saturated and the cations on the exchange complex are in the order: $Ca^{+2} > Mg^{+2} \geq Na^{+} > K^{+}$. The high values of exchangeable Ca^{+2} and Mg^{+2} reflect the presence of carbonate minerals such as calcium carbonate (calcite) or magnesium carbonate (dolomite). The order of exchangeable cations follows two distinct patterns, being dominated with Ca^{+2} followed by Mg^{+2}, Na^{+} and K^{+} for soils of low salinity while for some extremely saline layers exchangeable cations are dominated with Ca^{+2} followed by Na^{+}, Mg^{+2} and K^{+}.

5.1.9.3. Exchangeable sodium percentage (ESP)

The level of exchangeable sodium percentage (ESP) ranges from 0.7 to 39.8 %, the highest percentages are associated with subsurface layers. For most soil profiles low ESP values indicate a low sodicity hazard. The highest ESP values are associated with high salinity and dominance of soluble sodium in the soil extract. The major issue arising from high sodium levels relative to the other exchangeable cations is on the physical properties of soil. In surface soil layers, this imbalance in the ratio of cations results in poor soil structure. This is evidenced by surface soil crusts or the setting of soil into large blocks on drying. Additionally, the poor soil structure leads to a decreased permeability to water and thus poor soil drainage. However, most of the soil profiles under study are coarse textured, which facilitate the possibility to decrease exchangeable sodium percentage if an efficient drainage system is established. It is also clear that the soils adjacent to El-Hammam canal extension have exchangeable sodium percentage (ESP) higher than 15 % (Figure 38). Here, three soil profiles

(14, 19 and 25) have ESP >15 %, pH > 8.5 and salinity > 4.0 dSm[-1]. In this part of the studied area the ESP values is range from 15.6 to 26.8 % combined with and alkaline pH values (8.6).

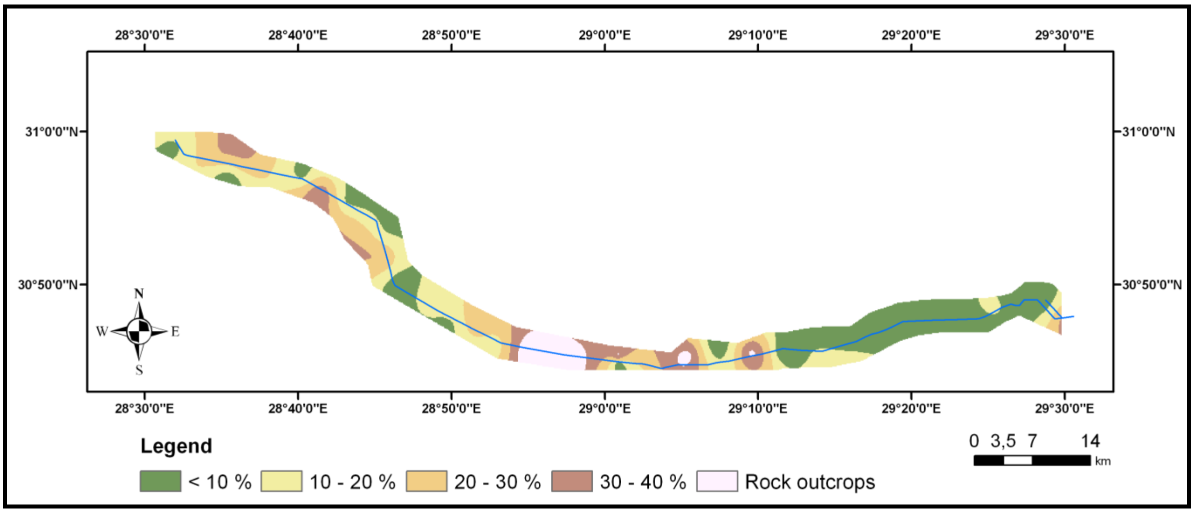


Figure 38: Distribution of exchangeable sodium percentage (ESP) in the studied area

5.1.10. Vertical distribution of soil properties

The vertical distribution of soil reaction (pH), soil salinity (EC), and calcium carbonate content ($CaCO_3$), cation exchangeable capacity (CEC) and sodium exchangeable percentage (ESP) in the soil profile are shown in (Figure 39) for six selected profiles (no. 1, 4 and 41 from El-Hammam canal and no. 16, 24 and 31 from El-Hammam canal extension).

In most cases for soils adjacent to El-Hammam canal the pH values in the subsoil samples are slightly lower than those measured in the topsoil samples. On the other hand in soils adjacent to El-Hammam canal extension pH values in the subsoil samples are higher than those measured in the topsoil, except most of shallow soil profiles that are increased with soil depth. Soil reaction values have a negative correlation with ECe (r = -.0527), ESP (r= -0.367) and CEC (r= -0.400). Within the studied soils pH value is positive correlated with $CaCO_3$ content (r= 0.054), indicating that soil reaction slightly associated with calcium carbonate content

Soil salinity is one of the great problems in arid and semi-arid environments. The lowest values of EC are found in the deep coarse textured and well-drained soils. The highest EC values mostly are measured in the topsoil of irrigated soils adjacent to El-Hammam canal and decreasing with depth.

On the contrary, low values of EC are also found in the surface horizons of El-Hammam canal extension. From the abovementioned results, it is clear that the distribution of EC values is associated with ESP, CEC and calcium carbonate content. Correlation coefficient between soil salinity and soil properties, indicates that EC values have positive and strongly significant correlation with ESP (r= 0.872) and CEC (r = 0.894).

Within the El-Hammam canal extension area, results show that vertical distributions for calcium carbonate in most of the soil profiles increases with depth. However, there is no clear distribution of calcium carbonate contents for soil profiles near the ridges.

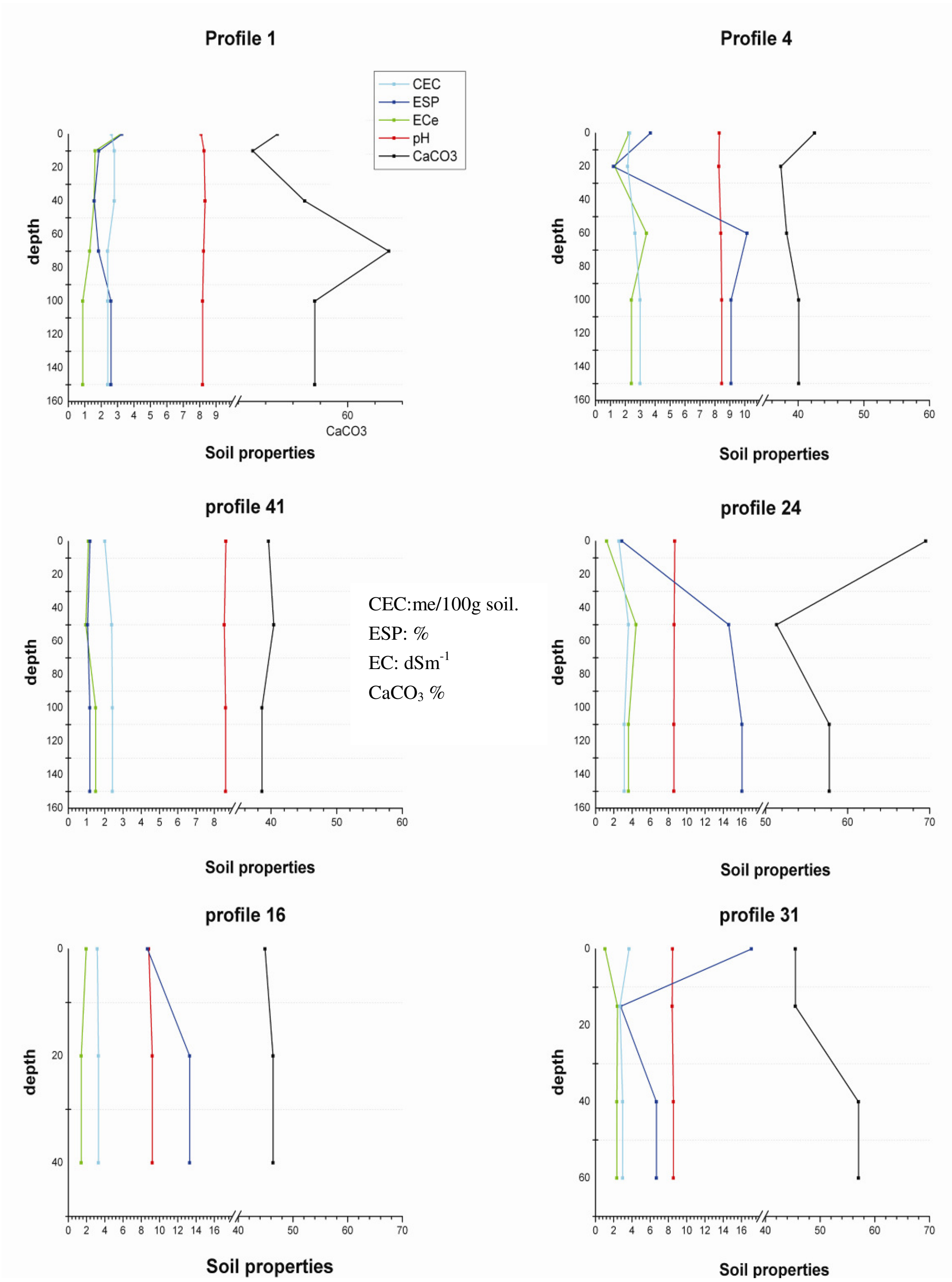


Figure 39: Vertical distribution of main soil properties of six selected profiles

As to the exchange characteristics of soil profiles, the lowest exchangeable sodium percentages are presented in the surface layer and increases with depth of the soil profiles adjacent to El-Hammam canal extension. Sodium exchangeable percentage have a positive and strong correlation with EC (r = 0.872) and CEC (r = 0.888), this indicates that ESP is mainly associated with soil salinity and CEC.

5.1.11. Elemental composition

The current work is carried out to study the total contents of nutrient elements in the soils of the studied area using the classification of essential nutrients units as a guide. To assess the relationship between content of elements and their influencing factors, the levels and distribution of total nutrient elements in the representative soil profiles will be discussed. Moreover, an attempt is made to shed light on their status and the factors controlling their behavior in the soils of El-Hammam canal and its extension. The essential plant nutrients may be divided into macronutrients (primary and secondary nutrients) and micronutrients

5.1.11.1. Macronutrients

Macronutrients include C, H, O, N, P, K, Ca, Mg, and S. They are further subdivided into primary and secondary nutrients.

5.1.11.1.1. Primary macronutrients

Primary macronutrients are nitrogen, phosphorus and potassium (**NPK**). The soil factors which influence the contents of these nutrients are soil texture, soil depth, organic matter content, soil reaction, calcium carbonate content and amount and composition of clay minerals. Soils in the study area are coarse textured and poor in organic matter content. Total N and P are very low, the higher contents of N and P contents are formed in cultivated soils and particularly in the surface layers. Total **nitrogen** content of all soils, depending on organic matter, are very low and range between 0.010 and 0.060 % with an average 0.016 %.

Total **Phosphorus (P_2O_5)** content ranges from 0.03 – 0.1 %, the highest content is found in surface layers, while the lowest content is found in deepest layer. Weighted means of P_2O_5 are low and range between 0.03 and 0.10 %, the lowest contents are shown in soil profiles representing medium and coarse sand textured and cultivated soils adjacent to El-Hammam canal such as profiles no. 5, 35 and 36. The highest contents of P_2O_5 are measured in El-Hammam canal extension profiles.

Potassium (K) sources in soils are organic matter and minerals, the minerals considered as original source of K are feldspars, orthoclase, microcline, muscovite, biotite and also secondary silicate clays like illite, vermiculite and chlorite. K_2O content ranges from 0.31 to 1.33 %, and weighted mean values are ranged from 0.34 to 1.26 %. The highest values are presented in the soils adjacent El-Hammam canal extension. Parent materials of the studied area are limestone, basalt, marine and alluvial sediments. The availability of K_2O is based on the parent material, here the contents of K_2O in basalt rocks are higher than in other materials, may be due to mica content of basalt rocks (Irmak et al., 1999).

5.1.11.1.2. Secondary nutrients

Secondary nutrients include calcium, magnesium and sulphur. Contents and distribution in the study area is given as follows:

Calcium

Typically, arid soils have high calcium content which is attributed to low rainfall and hence little leaching. The studied soils are strongly enriched in calcium and the major sources of calcium are the weathered products of rocks and Ca containing minerals such as calcite, apatite, dolomite, aragonite and gypsum. Calcium (CaO) contents ranges from 11.79 to 38.35 %, with an average of 24.70 %. Calcium weighted mean content is high and range between 14.92 and 37.01 % with an average of 24.25 %. The lowest CaO contents characterize the deep coarse textured soils and the irrigated soils, whereas, the highest values are found in soil profile representing El-Hammam canal extension. Calcium contents increase in all soil profiles, particularly in El-Hammam Canal extension as a result of its proximity to the plateau attaining weathered minerals.

Magnesium

Magnesium also increases in the soil profiles located near to plateau. The source of magnesium is related to weathering products of biotite, dolomite, hornblende, olivine, chlorite, illite, montomorillnite and vermiculite. MgO values range between 2.1 and 5.82 %, weighted mean content range between 2.10 and 5.82 % (Figure 40). The Mg/Ca ratios range from 5.0 to 32.0 % with an average 13.2 %. The origin of Mg is related to the parent material dolomite or to the underlying saline ground water. This is reflected in the increase of Mg/Ca ratio in some soil profiles relative to those in the depression in coastal plain. Here the sediments are composed mainly of aragonite, high-magnesium containing calcite and low-magnesium calcite in that order of abundance (El-Bastwasy, 2008).

Sulfates

Sulfates of Ca, Mg, Na and K tend to predominate in arid zone. SO_3 values are low and range from 0.06 to 0.27 %; the highest weighted mean are found in soil profiles representing El-Hammam canal extension near plateau. The depth distribution of SO_3 shows an increase with depth especially for soil profiles representing the area adjacent El-Hammam canal extension. The highest value was found in the topsoil of profile 43 (0, 78 %), where the source of sulfate is organic and inorganic fertilizers. Inorganic forms are soluble, adsorbed and insoluble sulfate co-precipitated with calcium carbonate and reduced inorganic sulfate compounds. It is worth to mention that SO_4 is prone for leaching when associated with Na, medium losses when bound to divalent Ca or Mg and minimum losses when bound to Al or Fe and that sulfate may precipitate with calcium which is an important fraction in calcareous soils which are characteristic for the study area

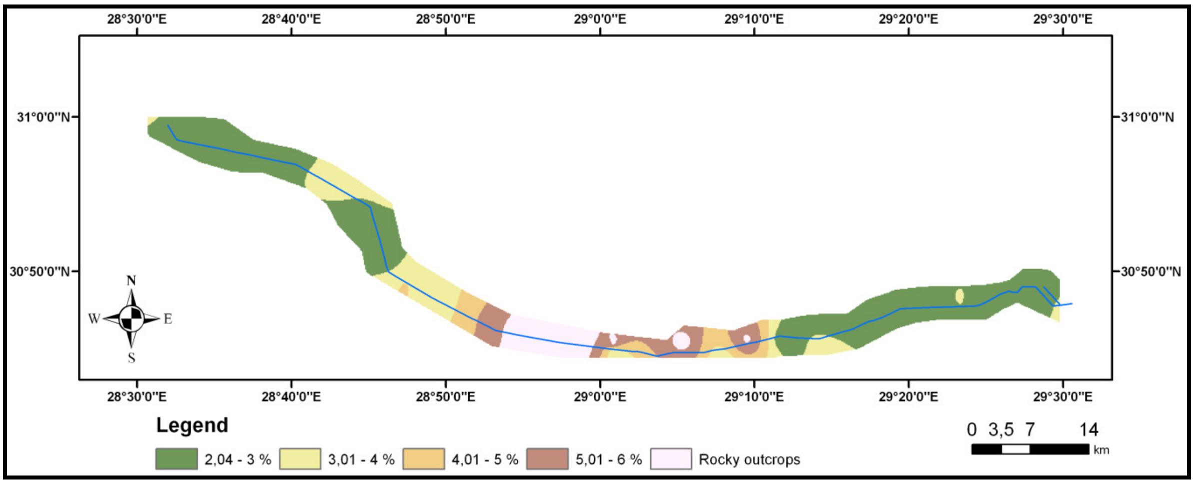


Figure 40: Distribution of MgO content in the study area

5.1.11.2. Micronutrients

The micronutrients essential for green plants are Fe, Cu, Mn, Zn, Mo and Cl, the main source of micronutrients in soil is mostly the parent material. In this regards, the factors leading to micronutrient deficiencies in soil and thus plant growth are parent material, soil reaction (pH), calcium carbonate content, soil texture (clay content) and interaction with macronutrients. The main source of micronutrients in soil is the parent material.

The X-Ray diffraction mineralogical analysis revealed the following composition: calcite (65 %), gypsum (22 %), dolomite (7%), feldspars and quartz (6 %) (Hassouba, 1995). The micronutrients content of the soil entirely depends on the rocks from which the parent material is derived.

The total content of **Fe_2O_3** ranges from 0.65 to 3.1 %. Figure 41 show that the weighted mean of total Fe_2O_3 ranges from 0.66 % and 3.10 %, with an average of 1.59 % .The lowest values are found in soils rich in medium sand that constitute the major portion of cultivated soils along El-Hammam canal. In contrast, the highest values are measured in soil profiles representing the El-Hammam canal extension area, especially in the very shallow soil profiles which have moderately coarse texture.

Total **Zn** contents ranged between 6.1 mg kg^{-1} and 41.0 mg kg^{-1}, with an average of 19.9 mg kg^{-1}. The spatial distribution of total Zn reveals that the lowest values are found in soils along El-Hammam canal while the highest values are detected in the very shallow soil profiles of El-Hammam canal extension.

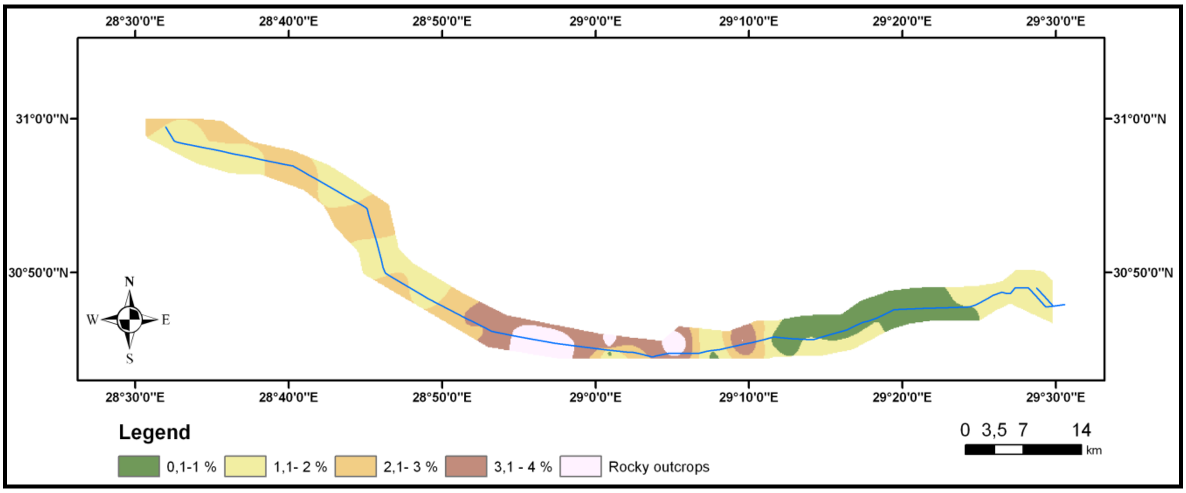


Figure 41: Distribution of Fe_2O_3 content in the study area

Total **MnO** contents are also very low with the highest values in the very shallow soil profiles of El-Hammam canal extension. The MnO values range from 0.02 % to 0.05 %, with an average of 0.03 %. Total **Cu** contents range from 1.0 mg kg^{-1} to 11.0 mg kg^{-1}, with an average of 5.5 mg kg^{-1}. Very shallow soil profiles have highest values of most of the elements. Total **Ni** content ranged from 3.2 mg kg^{-1} to 25.80 mg kg^{-1}, with an average value of 12.77 mg kg^{-1} (Figure 42). The highest contents of total Ni are detected in the finest textured and very shallow soil profiles representing El-Hammam canal extension.

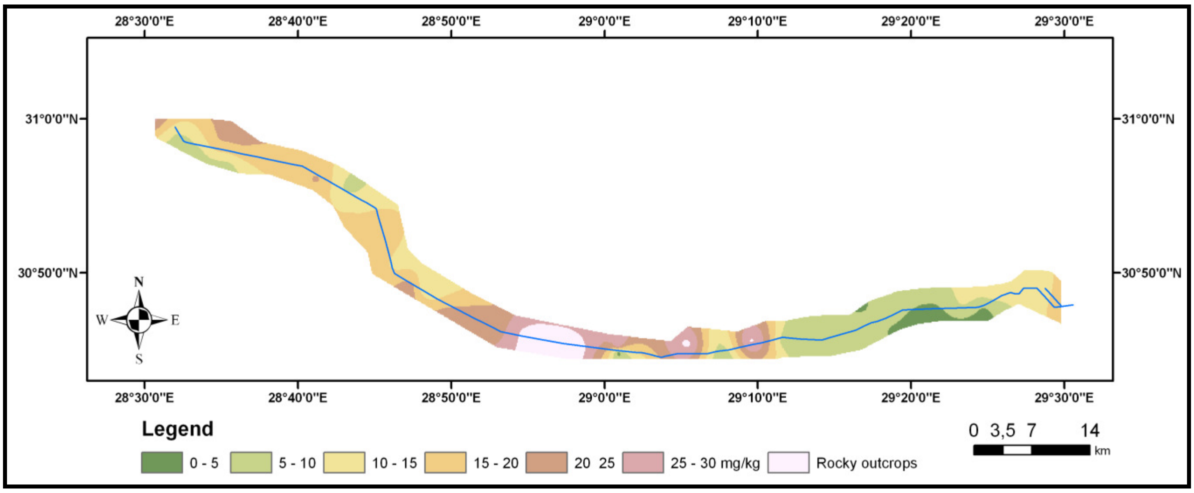


Figure 42: Distribution of Ni content in the study area

5.1.11.3. Heavy metals

According to (Nassef et al., 2006) the results of the heavy metal contents in most of the studied soil samples and their weighted means in soil profiles are in the normal range. **Lead** (Pb) content ranges between 1.0 mg kg^{-1} and 17.0 mg kg^{-1}, the weighted means of Pb in soil profiles ranged from 1.0 to 13.0 mg kg^{-1}, with an average of 6.4 mg kg^{-1}. Pb content in the studied soil profiles are not indicative of pollution and are within the global acceptable range for soils.

Cobalt (Co) contents range from 9.0 to 121 mg kg^{-1}, with an average of 33.7 mg kg^{-1}. Cobalt weighted mean contents range from 0.2 mg kg^{-1} to 66.8 mg kg^{-1} with an average of 33.6 mg kg^{-1}. The highest contents are found in coarse, medium sand textured soils. Co is a chalcophile element that is expected to be associated with mafic minerals such as pyroxene, biotite, and hornblende. The **Silicon** (SiO_2) content ranges from 21.9 % and 67.5 %, with an average of 41.7 %. The weighted means ranges from 22.3 % to 67.5 % with an average value of 41.9 % (Figure 43). It is also apparent that coarse textured soil profiles have high content of SiO_2.

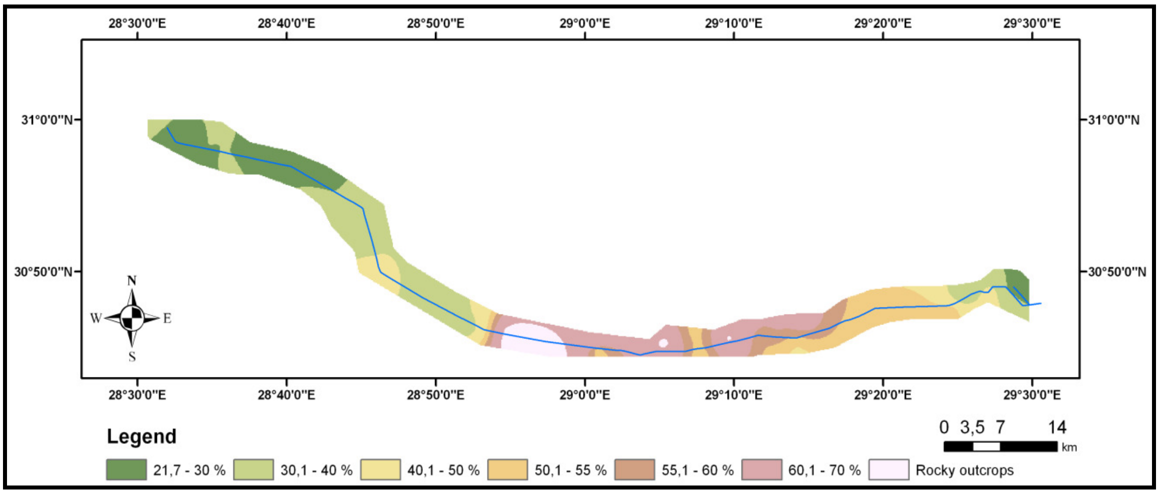


Figure 43: Distribution of SiO_2 content in the study area

Aluminum (Al_2O_3) lowest contents are detected in soil profiles representing coarse textured soils and along El-Hammam canal. On the other hand, the highest values of (Al_2O_3) are presented in very shallow soil profiles, which are located along El-Hammam canal extension (Figure 44). As Figure 45 shows, the highest weighted mean values of Sr occur around the end of El-Hammam canal extension with an apparent decrease from the west to the east direction. Most of the strontium released by the dissolution of aragonite has gone into the pore waters, to be deposited as celestite. Sulfate ions, which are necessary for the precipitation reaction with the strontium to produce the celestite ($SrSO_4$), have probably been provided by the water of the Lake Maryut which occurs landwards of the second ridge.

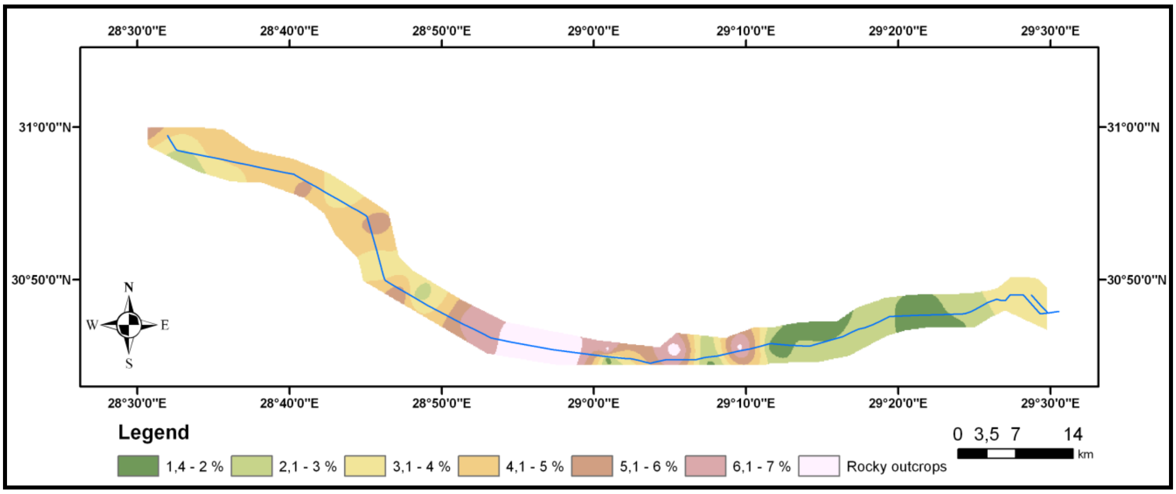


Figure 44: Distribution of Al_2O_3 content in the study area

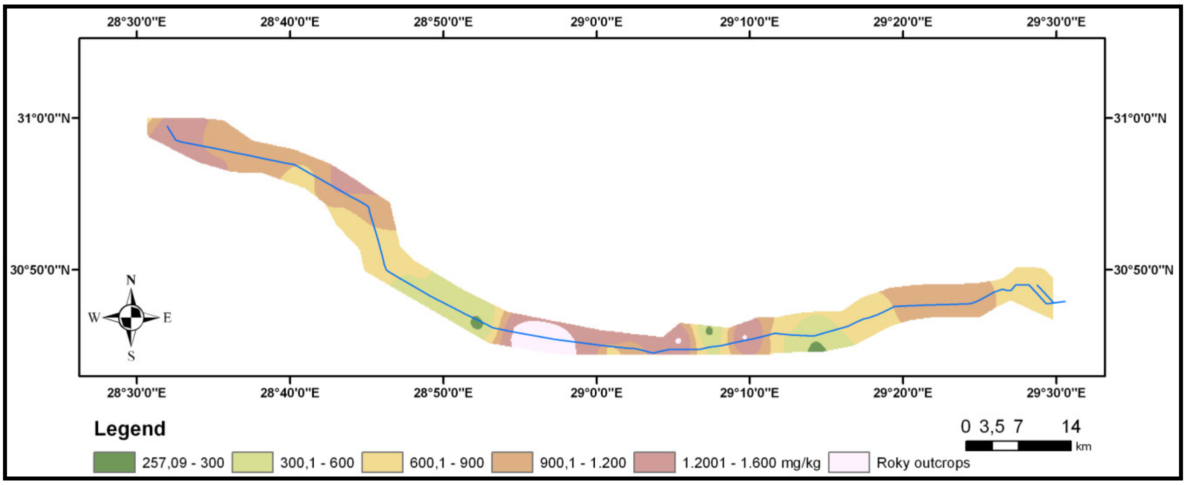


Figure 45: Distribution of Sr content in the study area

5.2. Soil mapping unit

The study area may be characterized as a coastal plain landscape with an area of about 63,000 hectares. The soils of this area are represented by 43 profiles along to El-Hammam canal and its extensions. In the zone adjacent to El-Hammam canal, most of the area is cultivated with the dominant field crops (wheat), fodders (alfalfa), vegetable crops (tomato) and fruit trees (appel, guava and citrus), except for small locations between the ridges and the canal. In contrast, most of the area around El-Hammam canal extension is uncultivated especially in the eastern part where rocky outcrops are exposed, except very small area irrigated manual in the front of El-Hammam canal extension. Some few fields adjacent to El-Hammam canal extension are cultivated with field crops (dominated by wheat and barley) which depend on the rainfall (rainfed agriculture).

Based on the specific soil attributes depth, texture and gravel content, the soils of studied area were classified to ten mapping units. The respective divisions of the soil attributes are given in Table 17.

Table 17: Divisions of soil depth, texture and gravel content

Depth	**divisions**	**Texture**	**divisions**	**Gravel**	**divisions**
cm		classes		%	
0-25	Very shallow soils	Coarse sand	Sand	< 15	No texture adjective is used
25-50	Shallow soils		loamy sand	15 to < 35	Gravelly
50-100	Moderately deep soils	Moderately coarse	Sandy loam	35 to < 60	Very gravelly.
100-150	Deep soils		Silty loam		

For the allocation of the texture classes to the soil profiles, the dominant texture within the soil depth was indicative, the gravel content was used as a weighted mean for the soil profile. The definitions of the mapping units are shown in Table 18, the distribution in (Figure 46) The morphological, physical and chemical properties of each unit are given in the following chapters.

Table 18 : Soil mapping definations units based on soil depth, texture and gravel content

Location	**Soil unit**	**Soil profiles**	**Area (10^3 ha)**	**Area (acre)**
El-Hammam canal	Deep coarse to moderately coarse-textured soils	1, 2, 38 and 43	6.9	~ 16,900
	Deep coarse-textured soils	3, 4, 5, 6, 35, 36 , 37 , 39 , 40, 41 and 42	11.9	~ 29,500
	Moderately deep course-textured soils	8	1.2	~ 3,000
El-Hammam canal extension	Deep coarse-textured soils	23	2.3	~ 5,600
	Deep coarse-textured soils with very gravelly subsoil	18, 19 and 25	8.4	~ 20,700
	Deep coarse-textured soils with gravelly subsoil	14, 24 and 26	5.3	~ 13,000
	Moderately deep coarse-textured soils	17, 28, 29 and 31	11.1	~ 27,500
	Shallow coarse- textured soils	11, 15, 16 and 27	6.2	~ 15,400
	Very shallow coarse-textured soils	13, 30 and 32	4.8	~ 11,900
Rocky outcrops		7, 9, 10, 12, 33and 34	7.1	~ 21,100

5.2.1. El -Hammam Canal

5.2.1.1. Deep coarse to moderately coarse-textured soils

This soil mapping unit occupies an area of about 17,000 acres, their morphological description and analytical data are given in the appendix tables (Table 44 and Table 45). The topography of the landscape is generally flat (< 0.5 %) to almost flat (0.5 – 2.0 %) with nearly level sloping (0.5- 1.0 %) to gently sloping (0.5 -2.0 %) surface. The surface is generally covered with field crops, except in few areas where very few scattered desert shrubs are found near ridges. The common features of this soil mapping unit are depth (>150 cm), a sandy to silty loam texture with extremely high calcium carbonate content and moderately well drained. The dominant soil colour is very pale brown (10YR 8/4, dry) to very pale brown (10YR 7/4, moist). The soil colour is affected by calcium carbonate content in the deepest horizons. Gravel content throughout the entire depth varies from 0.98 to 14.2 % and a size of fine to medium. The highest contents are detected in subsoil horizons in profiles near to the ridges.

Soil structure and dry consistence are massive to weak subangular blocky and soft to very hard in the surface and deepest layers, respectively. Moreover, wet consistency agrees well with soil texture and calcium carbonate content, being non-sticky and non–plastic with medium sand and very fine sand, while being slightly sticky and slightly plastic with moderately coarse texture.

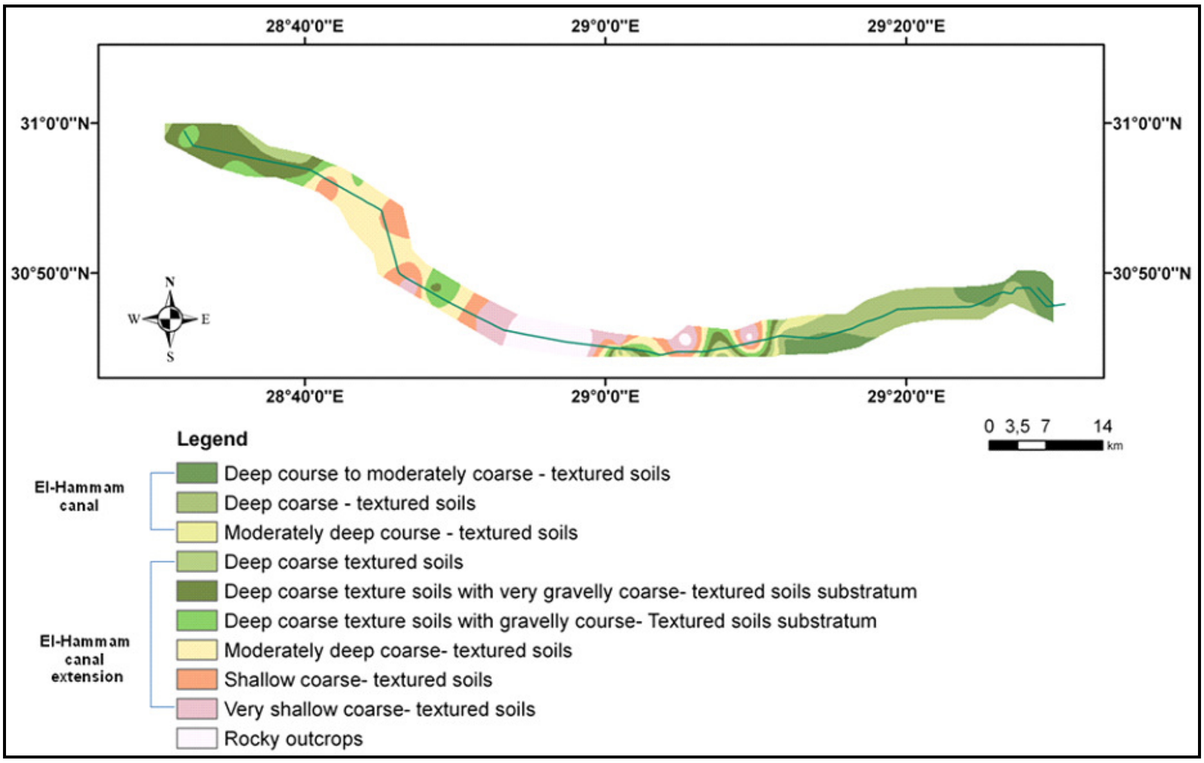


Figure 46: Soil mapping units of the study area

These soils are extremely calcareous soils, where calcium carbonate varies between 40.1 and 63.0 %. The lowest contents are mostly detected in the deepest layers. Gypsum content is not detected to very low (<0.01 to 2.29 %).

Soil reaction is slightly alkaline to moderately alkaline, as indicated by pH values which range from 7.4 to 8.4, except for the deepest layer of profile 38 (strongly alkaline, pH 8.8). Electrical conductivity values ranges widely between 0.9 and 33.6 dSm^{-1}, the highest values are mostly detected in the topsoil and decrease throughout the entire soil depth. As **for** the exchange characteristics of the soils in this mapping unit, CEC values range from 2.25 to 8.57 meq/100g soil and coincide well with the soil texture. The highest value is detected in surface layer and lowest values in deepest layers. Exchangeable cations are dominated with Ca^{++} followed by Mg^{++} and K^{+} or Na^{+}. The exchangeable sodium percentages varies widely between 1.3 to 34.89 % and is associated to soil salinity. Salinity may become a problem when salts accumulate in the rooting zone to negatively affect plant growth, however, these soils are irrigated from El-Hammam canal and by a surplus of water the accumulation of salts can be avoided.

With regard to the levels of organic matter and macronutrients in the uppermost surface layers, the obtained data show that organic matter content is very low (0.32 to 0.88 %), total N content is also very low (0.01 to 0.06 %), and available P and K contents are in the range of 0.27 to 0.88 mg kg^{-1} and 244.28 to 950.0 mg kg^{-1}, respectively. These levels indicate that the soils are poor in N and P while being sufficient supported with K.

5.2.1.2. Deep coarse-textured soils

This mapping unit covers an area of approximately 29,500 acres. The topography of the landscape is generally flat (< 0.5 %) to almost flat (0.5 – 2.0 %) with nearly level sloping (0.5- 1.0 %) surface. The land is generally used for cropping. The common soil features of the unit depth are (>150 cm) (except for soil profile 42 depth is 120 cm), the coarse texture, the high calcium carbonate contents and the moderately to well drainage. Soil colour is yellow (10YR 7/6, dry) to brownish yellow (10YR 6/6, moist), or yellow (10YR 8/6, dry) to yellow (10YR 7/6, moist) and very pale brown (10YR 8/4, dry) to very pale brown (10YR 7/4, moist). Texture throughout the entire depth of the soils of this mapping unit is sand dominated by fine sand. The gravel content is typically very few to few (0.33 to 4.3 %) in fine and medium size, while gravel contents of soil profile no. 42 range from 5.5 to 16.9 %. The common soil structure is massive with single grains at surface horizons. The dry consistency is loose, with a tendency of increasing compaction to soft or slightly hard in some soil profiles. Moreover, wet consistency agrees well with soil texture being non-sticky and non-plastic. Soils are extremely calcareous, where calcium carbonate contents various widely from 28.0 to 58.8 % and the highest contents are detected in the deeper horizons.

Soil reaction in the soil paste mostly is slightly to strongly alkaline, as indicated by pH values ranging from 7.8 to 8.8. Soil salinity varies from 0.82 to 7.92 dSm^{-1} indicating non-saline to slightly saline soils. The higher concentration of soluble salts in some soil layers dictates that leaching or removal of excessive salts throughout the subsequent layers is a must, and this could be practiced quite easily due to the open structure of the soils. The cationic composition of the soil saturation extract of most soil layers is dominated by Na^{+} followed by Ca^{++}/or Mg^{++} and K^{+}. While the anionic compositions are characterized by the dominance of Cl^{-} followed by SO_4^{-2} or/ HCO_3^{-} and CO_3^{-2} is mostly absent. The CEC values in this mapping unit vary from 2.1 to 3.5 meq/100g soil and coincide well with soil texture. Exchangeable cations are dominated by Ca^{+2} followed Mg^{+2}, K^{+} and Na^{+} in most successive soil layers with low in electrical conductively. Exchangeable sodium percentages are very low to moderate (0.7 to 14.5 %). Organic matter content is very low (0.15 to 0.72 %), the same is true for total N content (0.01 to 0.03 %) and available P (0.23 to 2.58 mg kg^{-1}). These levels indicate that the soils are poor in N and P while the available contents of K are high (184 to 355 mg kg^{-1}) and being seemingly sufficient in most soil profiles.

5.2.1.3. Moderately deep coarse-textured soils

This mapping unit covers an area of about 3000 acres. The topography of the landscape is generally flat with nearly level sloping surface. The surface is generally covered with many boulders and stones and sometimes with gravels of different size. The common features of this soil mapping unit are a moderate depth (50 – 100 cm) and a texture of sand or loamy sand. The soil colour is yellow (10YR 7/6, dry) to brownish yellow (10YR 6/6, moist). Throughout the entire soil depth the sandy soil texture is dominated by very fine sand. Gravel contents range from 14.5 to 25.9 %, the highest content is detected in the deepest layer. Soil structure is massive with single grains surface. The dry consistence is loose, with a tendency of increasing compaction to slightly hard in the subsurface layer. Calcium carbonate contents various from 29.6 to 32.8 %. The soil reaction is strongly alkaline, as indicated by pH value (8.6). EC ranges from 1.3 to 1.5 dSm^{-1} with the highest value being measured in the deepest layer. The CEC values vary from 2.35 to 2.93 meq/100g soil and coincide well with soil texture. Exchangeable cations are dominated with Ca^{+2} followed Mg^{+2}, K^{+} and Na^{+} in the topsoil while in the subsoil exchangeable cations are dominated by Ca^{+2}, Mg^{+2}, Na^{+} and K^{+}. ESP are 1.5 and 6.5 % in the surface and deeper layers, respectively. With regard to the levels of organic matter and macronutrients, the obtained data show that organic matter content is 0.07 and 0.39 % in the topsoil and the deeper layer, respectively. Total N content is very low (0.006 and 0.012 %), and the available P and K contents are in the range of 0.12 to 0.43 mg kg^{-1} and 198 to 363 mg kg^{-1}, respectively. These levels indicate that the soils are very poor in N and P while being sufficient supplied with K.

5.2.2. El-Hammam Canal Extension

5.2.2.1. Deep coarse-textured soils

The total area represented by this mapping unit is about 5,700 acres. The morphological description, physical, chemical and nutritional characteristics are given in the following appendix tables (Table 44 and Table 45). The topography of the landscape is almost flat (0.5 – 2.0 %) with gently sloping (2.0- 5.0 %) surface. The land-use is generally plowed fields and olive plantations. The common features of this soil mapping unit are depth (>150 cm), the coarse texture, the high calcium carbonate contents and a moderately well drainage. The soil colour is mostly different in entire soil depth from surface to deepest layer: the surface layer is yellow (10YR 7/6, dry) to brownish yellow (10YR 6/6, moist), the deepest layer is very pale brown (10YR, 8/4dry) and very pale brown (10YR, 7/4 moist). Soil texture is loamy sand to sandy loam in the deepest horizon; gravel contents are low (0.50 to 1.10 %) and of very fine size, the highest content is detected in the surface layer. Soil structure is weak subangular blocky and massive in the deepest layer. The dry consistency is slightly hard, wet consistency agrees well with soil texture being slightly sticky and non-plastic. These soils are extremely calcareous (40.6 to 44.4 %), the highest carbonate content is detected in the subsoil.

The soil reaction is moderately alkaline in the topsoil (pH 8.2) and strongly alkaline in the deeper layers (pH 9.0). EC values indicate a non-saline to very slightly saline soil (1.4 to 3.0 dSm^{-1}). Whereas the soil salinity decreases with soil depth, the soil reaction increases. Cation exchangeable capacity values are low (3.1 and 3.4 meq/100 g soil) and coincide well with soil texture. Exchangeable cations are dominated by Ca^{+2} followed Mg^{+2}, Na^{+} and K^{+}. ESP is in the range between 10.9 to 18.2 % with the highest value being measured in the deepest layer. Organic matter content ranges from 0.22 to 0.67 % in the topsoil and subsoil, respectively. Total N content is very low (0.012 - 0.017 %). Available P and K contents are in the range of 0.42 to 0.62 mg kg^{-1} and 427 to 450 mg kg^{-1}, respectively.

5.2.2.2. Deep coarse-textured soils with very gravelly subsoil

This soil mapping unit covers an area of about 20,700 acres which is not cultivated. The topography of the landscape is generally almost flat with a very gently sloping to gently sloping surface. The common features of this soil mapping unit are depth (100 to 150 cm), the coarse texture and the occurrence of a very gravelly subsoil layer. Additionally, high calcium carbonate content are obvious. The dominant soil colour is very pale brown (10YR, 7/4 dry) to light yellowish brown (10YR 6/4, moist). Gravel content is 3.0 to 38.5 % and in heterogeneous size, the highest values were detected in the deepest layers. Soil structure mostly is massive. The soil horizons are extremely calcareous (48.3 to 65.3 %), the lowest contents are mostly detected in the surface layers and increase with depth. Soil reaction is mostly strongly alkaline, as indicated by pH values which range from 8.6 to 9.0. For profile no. 18, EC values vary from 1.4 to 1.8 dSm^{-1} indicating a non-saline soil. For the profiles numbers 19 and 25, EC values are in the range of 3.6 to 22.7 dSm^{-1}, which is very slightly to extremely saline, here increasing with depth.

The CEC values range from 2.6 to 7.7 meq/100g soil. Exchangeable cations are dominated by Ca^{+2} followed by Na^{+}, Mg^{+2} and K^{+}. ESP range from 5.1 to 36.2 %. The levels of organic matter contents are very low (0.35 - 0.67 %), also total N content is also very low (0.017 - 0.027 %). Available P and K contents range between 0.17 to 0.54 mg kg^{-1} and 350 to 386 mg kg^{-1}, respectively. These levels indicate that the soils are very poor in N and P while being sufficient supplied with K.

5.2.2.3. Deep coarse-textured soils with gravelly subsoil

This mapping unit covers an area of about 13,000 acres. The topography of the landscape is generally flat with nearly level sloping surface. The land use is wheat cropping or olive and fig plantations with some areas of scattered desert shrubs. Soil colour is very pale brown (10YR 8/4 or 8/3, dry) to very pale brown (10YR 7/4/,or 7/3, moist) or very pale brown (10YR 7/4, dry) to light yellowish brown (10YR 6/4, moist). Soil texture throughout the entire depth is coarse sand to gravelly coarse sand sometimes with very fine sand to loamy sand at the soil surface. The common soil structure is massive and the dry consistency is soft for surface layers and slightly hard or hard in deeper layers of the studied soil profiles. Gravel content ranges from 2.0 to 18.4 %.

The soils are extremely calcareous (calcium carbonate 49.6 - 69.5 %). Soil reaction is mostly moderately to strongly alkaline, as indicated by pH values (8.3 to 8.8). EC values vary between 1.2 and 7.3 dSm^{-1}, indicating non-saline to slightly saline soils. The high concentration of soluble salts in some soil horizons dictates that leaching or removal of excessive salts throughout the subsequent layers is a must, and this could be practiced quite easily due to the open structure of the soils. CEC values are range from 2.2 to 3.9 meq/100g soil and coincide well with soil texture. ESP values (2.2 and 23.8 %) are quit low to moderate with the highest value correlating to the highest soil salinity. The topsoil levels of organic matter (0.26 to 0.56 %) and total N content (0.010 and 0.025%) are very low, the available P and K contents are in the range of 0.30 to 1.35 mg kg^{-1} and 289 to 410 mg kg^{-1}, respectively.

5.2.2.4. Moderately deep coarse-textured soils

This soil mapping unit covers an area of about 27,500 acres uncultivated land. The topography of the landscape is almost flat with a nearly plain to gently sloping surface. The common features of this mapping unit are the moderate depth (50 to 100 cm) and the coarse texture. Typically, high calcium carbonate content and rock outcrops or extremely hard layer in the deepest soil profiles occur which restrict drainage. The dominant soil colour is very pale brown (10YR 8/4, dry) to very pale brown (10YR 7/4, moist) or very pale brown (10YR 7/4, dry) to light yellowish brown (10YR 6/4, moist). Gravel content ranges from 0.9 to 15.0 %.

The gravel has a fine to medium size and the content typically decreases with depth. The soil structure is massive.

The soils are extremely calcareous (calcium carbonate 41.8 to 61.8 %). Soil reaction is moderately alkaline to strongly alkaline (pH values 7.9 to 8.8). The strongly alkaline horizons are found in the topsoil as well as in the deepest layer of profile no. 17. EC values vary widely from 1.1 to 19.3 dSm^{-1}, the highest values being measured in soil profile no. 29. CEC values range from 2.2 to 5.5 meq/100g soil and exchangeable cations are dominated by Ca^{+2} followed by Na^{+} and K^{+} or Mg^{+2}. ESP values are low to high (2.0 - 32.4 %). Organic matter content (0.27 to 0.63 %) and total N content (0.003 to 0.03 %) are very low and available P and K contents are in the ranges of 0.12 to 0.84 mg kg^{-1} and 400 to 592 mg kg^{-1}, respectively. These levels indicate that the soils are poor in N and P while being sufficient supplied with K.

5.2.2.5. Shallow coarse-textured soils.

This mapping unit occupies an area of about 15,400 acres of uncultivated land. The landscape has a nearly flat to gently sloping plain surface, which is generally covered with few to common scattered desert shrubs, low hummocks, boulders and gravel. Aside of the coarse texture, typical feature of this unit is the shallow depth (25 – 50 cm) above a hard rock layer. Soil colour is mostly very pale brown (10YR 8/4, dry) to very pale brown (10YR 7/4, moist). Gravel contents range from 8.0 to 26.8 %, typically increasing with depth. The soil texture varies between very fine sand to gravelly loamy sand. The soil structure is predominantly massive and single grains.

The soils are often extremely calcareous (41.1 to 53.3 %), the lowest values are mostly detected in the surface layers and increase with depth. The soil reaction is moderately alkaline to very strongly alkaline (pH 7.9 - 9.4). The EC values range widely between 0.9 and 27.7 dSm^{-1}. The CEC values vary from 2.2 to 6.3 meq/100g soil, the lowest values were found in a topsoil with very fine sand texture. The organic matter content is very low (0.22 to 0.82 %), the levels of N, P and K content indicate that the soils are poor in N and P while being sufficient supplied with K (total N 0.01 - 0.04 %, available P 0.31 to 0.79 mg kg^{-1} , available K 189 to 487 mg kg^{-1}).

5.2.2.6. Very shallow coarse-textured soils

This mapping unit covers an area of approximately 11,900 acres of uncultivated land. The topography of the landscape is generally flat. The surface is covered by scattered desert shrubs with boulders, stones and many gravel. The common feature of this soil mapping unit is the very shallow depth (< 25 cm). Soil colour is very pale brown (10YR 7/4, dry) to light yellowish brown (10YR 6/4, moist). The soils are coarse-textured with gravelly medium sand and gravelly fine sand. The common soil structure is massive and the dry consistency is slightly hard. Moreover, wet consistency agrees well with soil texture being non-sticky and non–plastic, sometimes being slightly sticky and non-plastic. Gravel contents are 11.6 to 23.7 %; the lowest and highest values are detected soil profiles no. 32 and 30, respectively.

Calcium carbonate contents are mostly very high (37.2 - 40.1 %). Soil pH is slightly to moderately alkaline (pH values 7.8 - 8.3). EC values range between 5.6 and 25.6 dSm^{-1}, indicating moderately to strongly saline soils. CEC values range from 2.6 to 6.2 meq/100g soil. Exchangeable cations are dominated by Ca^{+2} followed Na^{+}, Mg^{+2} and K^{+} in most soil layers. An exceptional case is found in the profile no. 30, where exchangeable cations are dominated by Ca^{+2} followed by Mg^{+2}, Na^{+} and K^{+}. ESP values are low to high (6.6 and 29.1 %). The analysed data of organic matter and macronutrients in the topsoil horizons indicate that the soils are poor in organic matter, N and P while being sufficient supplied with K (SOM 0.37 -0.81 %; total N 0.02 - 0.03 %; available P 0.21 - 0.42 mg kg^{-1}; available K 368 to 708 mg kg^{-1}).

5.3. Classification of the soils

The purpose of soil classification is to provide a basis for memory, to integrate knowledge of soils, to relate soils to each other and to their environments and to enable predictions of the soils behavior and response to anthropogenic intervention in its natural development. In the present study, soil classification is carried out according to US American system, key to soil taxonomy (Edition, 2010) and the FAO World reference base for soil resources (WRB, 2006). Those systems (USDA and WRB) are the most common in the African continent and the world.

5.3.1. US American system (key to soil taxonomy 2010)

A key to Soil Taxonomy is applied. The system used is based on the following criteria:

- Presence or absence of the diagnostic horizons and other soils characteristics
- Soil moisture and temperature regime
- Soil texture
- Soil depth
- Total calcium carbonate content
- Soil salinity
- Other properties such as pedological features, morphological properties, chemical constitution, etc.

With regard to the study area, the soils display common features, but differ in one or more of the following characteristics:

- The mean annual soil temperatures is about 20 °C (measured values are 20.17 and 19.21 °C in Alexandria and Matruh, respectively).
- The soil texture is coarse in all profiles, varying from very gravelly coarse sand to loamy sand.

- Depth of soil profiles in the area is dominantly deep but some profiles are moderately deep (8, 17, 28, 29, 31) and shallow to very shallow (11, 13, 15, 27, 30, 32).
- Total calcium carbonate content varies between 27 and 70 %.
- Soil salinity ranges from non-saline to extremely saline.
- Gravel content ranges between 0.1 % and 39 %.
- Soil alkalinity varying from slightly alkaline to very strongly alkaline.
- Organic Carbon and organic matter ranges between 0.07 to 0.98 and 0.12 to 1.69 %, respectively.

On basis of the soil properties within the profile control section, soils belonging to the taxonomic units could be differentiated into orders, suborders, great groups and subgroups (Table 19).

In the light of the relevant soil properties, two suborders could be distinguished under the order Aridisols, namely Salids and Calcids and one suborder Psamments is related to the order Entisols. At the great group level under Aridisols order, two categories could be distinguished, namely; Haplosalids and Haplocalcids. Under these two great groups, the identified subgroups are Typic Haplosalids and Typic Haplocalcids. Under the Torripsamments great group, the identified subgroups are Typic and Lithic Torripsamments

Table 19: Classification of soils in El -Hammam canal and Extension (Keys to Soil Taxonomy, 2010)

Names of taxa in each category (2010)				
Order	suborder	Great group	subgroup	Profile No.
Aridisols	Salids	Haplosalids	Typic Haplosalids	43 and 19
	Calcids	Haplocalcids	Typic Haplocalcids	1
Entisols	Psamments	Torripsaments	Typic Torripsaments	2,3,4,5,6,8,14,17,18,23,24,25, 26,28,29,31,35, 36,37,38,39,40,41and 42
			LithicTorripsaments	11,13,15,16,27,30 and 32

5.3.2. According to FAO›s World reference base (WRB) for soil resources (FAO, 2006)

From the data that represented soil properties, soils belonging to the former taxonomic groups could be differentiated on the basis of prefix and suffix qualifiers (Table 20).

Table 20: Classification of soils in El -Hammam canal and Extension (WRB, 2006)

Soil group	Prefix qualifiers	Suffix qualifiers	Profile No.
Calcisol	Hypercalcic	(Aridic)	1, 2, 14, 17, 18, 24, and 26
	Hypercalcic, Endosalic	(Aridic)	19,25 and 43
	Endosalic	(Aridic)	29
		(Aridic)	3,4,5,6,20,21,22 ,23, 28, 31,11, 16, 27, 30, 35,36,37,38,39,40,41and 42,
		(Aridic ,Yermic)	8, 13, 15 and 32

5.4. Description of selected reference profiles

Most of the studied soil profiles are situated in a flat terrain where the top surface is slightly undulating or an even plain. The studied soil profiles represent the cultivated lands surrounding El-Hammam canal as well as the area predominantly under natural vegetation around the canal extension. The soil profiles were dug in two transects to represent the soil units on both sides of the canal and its extension. The transects are approximately 105 km length and stretches from El-Hammam canal junction with El Naser canal in the East. The studied area is bordered by the south ridges and plateau, international road or railway in the north. A rapid reconnaissance ground survey was made throughout the investigated area in order to identify the major soil physical, chemical and physico-chemical properties. Forty three soil profiles were dug (22 soil profiles representing North of El-Hammam canal and its extension and 21 soil profiles representing the south of canal) to fulfill the requirements for digital soil mapping. Detailed morphological descriptions of the soil profiles were recorded based on the basis outlined by (FAO, 1990), Field Book for Describing Sampling soils (Schoeneberger et al., 2002) and the Guidelines for soil description (FAO, 2006).The most important feature of these soils is the calcium carbonate content. The common morphological characteristics of these soils are sandy calcareous soils. Most soil profiles representing the soils adjacent El-Hammam canal are deep, whereas those representing the soils adjacent to El-Hammam canal extension differ from outcropping rocky areas to very deep soils. Soil salinity ranges from non-saline to strongly saline, herewith coincides the low salinity of soils with the coarse texture.

The keys to Soil Taxonomy are the most comprehensive soil classification system in the world and developed with international cooperation systems. The WRB classification was originally developed as a reference base for improved communication. Both systems were applied here, additionally a cluster analysis was applied (SPSS) to group the soil profiles based on their physical, chemical and physic-chemical properties. Seven reference profiles have been selected from the mapping units; an overview of their classification is given in (Table 21).

Table 21: Reference of soil profiles guided by mapping unit (soil depth, texture and gravel content), soil Tax, WRB and cluster analysis

Profile No	depth class	Soil Tax (2010)	WRB (2006)	Cluster Group
43	Deep soils	Typic Haplisalid	Hypercalci-Endosalic Calcisol (aridic)	Group 1
5	Deep soils	Typic Torripsamments	Calcisol (aridic)	Group 4
35	Deep soils	Typic Torripsamments	Calcisol (aridic)	Group 4
32	Very shallow	Lithic Torripsamments	Calcisol (aridic,yermic)	Group 2
23	Deep soils	Typic Torripsamments	Calcisol (aridic)	Group 1
12	Rock outcrops			Group 5
8	Moderately deep	Lithic Torripsamments	Calcisol (aridic,yermic)	Group 3
11	Shallow deep	Lithic Torripsamments	Calcisol (aridic)	Group 4

5.4.1. Reference profile 43

The field observation indicates that the landscape is generally flat with an elevation 50 m a.s.l. The common features of the soil profile are deep, moderately coarse texture, and extremely high calcium carbonate content. The main morphological aspects of the studied soil profiles are shown in Figure 47.

The soil color may reflect important clues about the constituents and about the oxidation-reduction status of the soils or their layers, the very pale brown and yellow color dominate most layers of the dry samples. Soil colour is apparently affected by calcium carbonate content. Figure 48 shows the main physical, chemical and soil fertility characteristics. The results of the particle size distribution reveal some minor variations in soil texture classes along the profiles horizons. Coarse sand fraction increases throughout the entire soil depth, while medium, fine sand fractions are of heterogeneous distributions. The low areas between the ridges are highly saline, fed by sea water that infiltrates through the coastal ridges, evaporates and becomes concentrated. Electrical conductivity of the soil saturation extract, therefore, varies from 16.5 to 33.6 dSm^{-1}.

Soil reaction is slightly to moderately alkaline, as indicated by pH values which range from 7.4 to 8.0. Calcium carbonate content, soil reaction and soil salinity increases throughout the entire soil depth. In rooting zone soil texture is sandy loam.

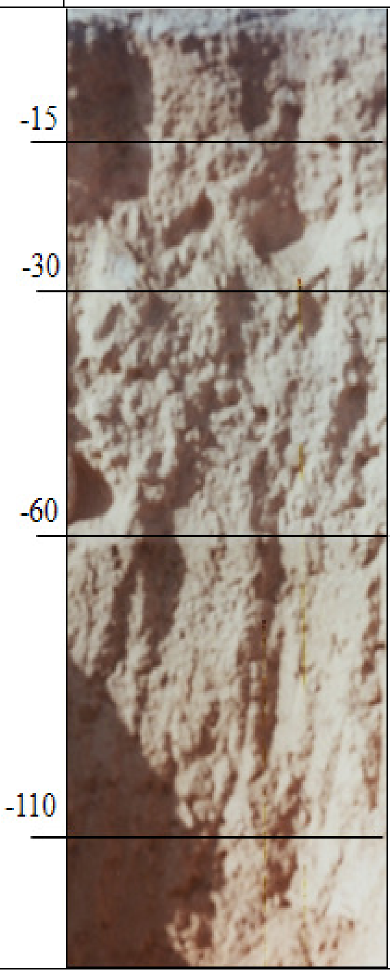
Country	Egypt.	Profile No.	**43**
Governorate	Matruh	Position	30° 47' 46.05" N. 29° 29' 49.75" E
Area	El Hammam canal	Elevation	50 m a.s.l.
Topography	Flat. (0--2%)	Slope	Nearly level. (0.5– 1 %).
Surface cover	Cultivated area	Landform	plain
Vegetation	Field crops	date	24.012.2008
Classification	Typic Haplisalid Hypercalci-Endosalic Calcisol (aridic)	 Site photograph	
		0—15 Yellow (10YR7/6,dry) to brownish yellow (10YR 6/6, moist) loamy sand ; massive ; soft, few fine lime segregation, very few fresh and deed roots , few narrow vertical cracks; clear wavy boundary 15—30 Very pale brown (10YR 7/4, dry) to Light yellowish brown (10YR 6/4, moist) loamy sand ; massive ;slightly hard, few fine lime spots, very fine deed roots ;abrupt smooth boundary 30—60 Very pale brown (10YR 7/4, dry) to Light yellowish brown (10YR 6/4, moist) loamy sand ; massive ;slightly hard, common fine to medium lime segregation , few fine lime spots, very few lime concertinos ; very fine deed roots ; common fine gravels; abrupt smooth boundary, 60—110 Reddish yellow (7,5YR 8/6, dry) to Reddish yellow (7,5YR 7/6, moist) medium sand; massive; hard, non-sticky, non-plastic; extremely effervescence with HCl, many lime segregation, few lime concertinos few fine lime spots; common fine and medium gravels; gradual wavy boundary, 110—150 Reddish yellow (7,5YR 8/6, dry) to Reddish yellow (7,5YR 7/6, moist) loamy sand; massive; hard, extremely effervescence with HCl, common fine to medium lime segregation, few lime concertinos, common fine gravels.	

Figure 47: Description of selected references profile 43

The EC is directly related to the dissolved salts (ions) in the soil saturation extract, such as chloride, sulphate and bio-carbonate. Carbonate ions are not detected in the soil saturation extract while bicarbonates values range from 3.0 to 4.0 me/l. The bicarbonates source could be the dissolution that occurs rapidly on initial infiltration because soil-generated CO_2, which dissociates to carbonic acid, influences the ability of infiltrating groundwater to dissolve calcium carbonate. Exchangeable calcium and soluble calcium contents are increasing with increasing soil reaction values. The cationic composition of the soil saturation extract of most soil layers is dominated by Na^+ followed by Ca^{+2} or Mg^{+2} and K^+.

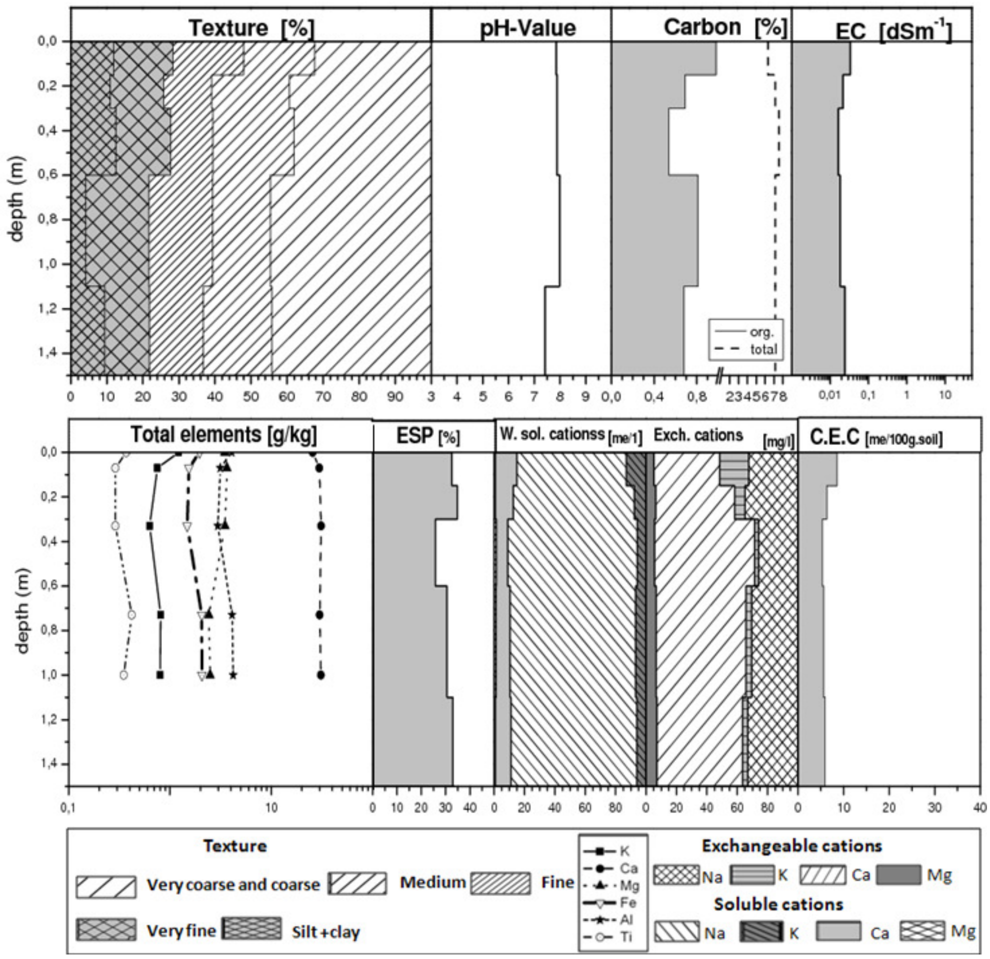


Figure 48: Soil properties of profile 43

With regard to the levels of organic matter and inorganic carbonate in the uppermost surface layers, the obtained data, show that organic carbon content is very low and ranges from 0.69 to 0.98 %. The highest value is found in the topsoil due to the addition of plant residues and organic manures. Total C ranges from 5.9 to 7.2 %. Total N content is very low, being in the range of 0.001 to 0.004 %.

Results indicate that the CEC is low being in the range of 5.4 to 8.6 meq/100g soil, with relatively high exchangeable sodium percentage. Exchangeable cations are dominated by Ca^{+2}

followed Na^{+}, Mg^{+2} and K^{+}. ESP and EC are high, so the land use should take ESP-tolerant crops, e.g. wheat, cotton, alfalfa, barely, tomatoes and beets into account. Values for the ECe and ESP are high in this soil profile, suggesting that proper soil management and drainage techniques are needed to reclaim this soil. The analyses of total nutritive elements contents revealed the nutrient poor character of the parent material limestone and the sandstone-derived materials. Elemental composition reveals that SiO_2 and CaO predominate. The sequence of major elements is Ca > Mg or Al > Fe >K and Ti. Most of these elements decrease downward with depth.

5.4.2. Reference profile 5

The soil morphological description is given in Figure 49. This soil is characterized by the occurrence of sand dunes beach sediments, thus, the soil is characterized by a deep and coarse-textured parent material and having a high calcium carbonate content.

Soil colour is generally light, since these soils have sandy texture and very low organic matter. The surface is covered with field crops, plowed area, citrus crop and some drifting sands. Soil texture throughout the entire depth is very fine sand in a single grains structure for the topsoil and changing to massive structure in the deeper horizons. Calcium carbonate content is considerably high (29.8 to 31.6 %), with a tendency to decrease with depth. From the occurrence of shells and shell fragments it may be suggested, that other sources of calcium carbonate exist. Regarding particle size distribution, the main fractions are very fine, fine and medium sand. The soil EC indicates non-saline condition, where EC values are less than 2.0 dSm^{-1}. EC values tend to decease through soil depth, suggesting the influence of irrigation water on the removal of excess salts. Soil reaction is alkaline as shown by pH value of 8.4. Texture, chemical and physico-chemical properties are presented in Figure 50.

CEC and ESP values are very low, where CEC values ranged from 2.1 to 2.2 meq/100g soil. While ESP values ranged between 1.10 and 2.29 %, the lowest value of CEC corresponds to the lowest value of ESP. The exchangeable cations are dominated with Ca^{+2} followed Mg^{+2}, K^{+} and Na^{+} in most of the successive soil layers. Organic carbon, organic matter and total N are very low, indicating that the soils are poor in N content. The cationic composition of the soil saturation extract of most soil layers is dominated by Na^{+} followed by Ca^{+2}/or Mg^{+2} and K^{+}. While the anionic composition is characterized by the dominance of Cl^{-} followed by SO_4^{-2}/or HCO_3^{-} and CO_3^{-2} is mostly absent. Total elemental composition of soils is dominated by SiO_2 which constitutes around 65 % and increases through the entire depth. Al_2O_3, Fe_2O_3 and K_2O also increase downwords, while CaO, MgO and TiO_2 decrease with soil depth. Most of sand dunes beach sediments are aeolian sands and the distribution of the sand sub factions may suggests the transport of some near shore grains by wind or water (transportation from marine environment) .

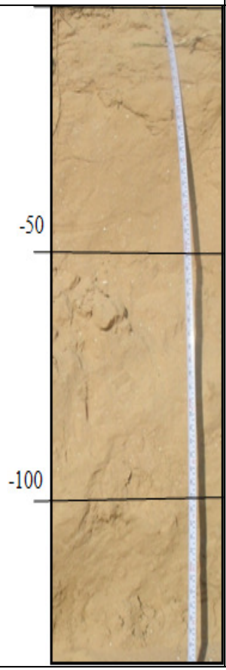
Country	Egypt	Profile No.	**5**
Governorate	Matruh	Position	30° 46' 31.94" N. 29° 14' 36.32" E
Area	El Hammam canal	Elevation	50 m a.s.l.
Topography	Flat. (0--2%)	Slope	Nearly level. (0.5 – 1 %).
Surface cover	Cultivated area ,very few scattered low hummocks	Landform	plain
Vegetation	Fodder crops , fruit trees and desert shrubs	date	26. 12.2008
Classification	Typic Torripsamments Calcisol (aridic)	 Site photograph	
		0—50 Yellow (10YR 7/6, dry) to brownish yellow (10YR6/6, moist), very fine sand , single grains ; losse, non- sticky , non-plastic; extremely effervescence with HCl, few fine lime segregations; few fine shells and shell fragments ; very few fine roots, common fine deed root, very few fine gravels; gradual smooth boundary , 50—100 Yellow (10YR 7/6, dry) to brownish yellow (10YR6/6, moist), very fine sand , massive ; soft, non- sticky , non-plastic; extremely effervescence with HCl , few fine lime segregations ; few fine shell fragments ; very few fine gravels; gradual smooth boundary , 100—150 Yellow (10YR 7/6, dry) to brownish yellow (10YR6/6, moist), very fine sand; very friable; non- sticky, non-plastic; extremely effervescence with HCl , common lime, pockets of sand very friable diffuse in layer.	

Figure 49: Description of selected references profile 5

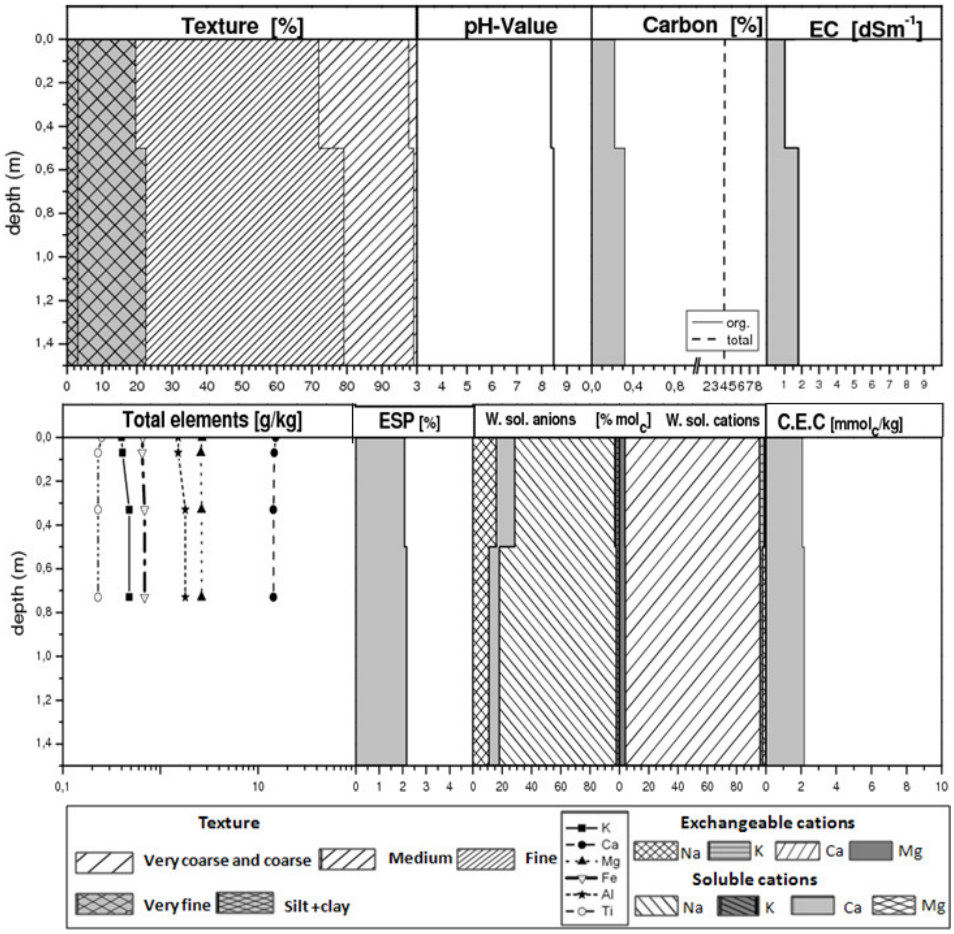


Figure 50: Soil properties of profile 5

The action of transport by wind during strong sand and/or dust storms, lead to deep pits, which are mostly due to the solution of silica along micro fractures in an alkaline near-surface diagenetic sediments. The obtained particle size distribution is fine sand fraction indicating that quartz grains of the coastal dunes is silica precipitates. The smoothness of these grains may be due to the action of the water evaporation during the day/night cycle. Evaporation of pore water in these sediments during the day usually leads to concentration of evaporites and, therefore a rise in the pH value of the water. Under these conditions silica solution from some quartz grain surface is re-deposited in concave areas (Abd-Alla, 1991)

5.4.3. Reference profile 35

At profile no. 35 landscape is gently undulating with drifting sand and scattered low hammocks at the surface (Figure 51). The area represented by this profile is located from the end of El-Hammam canal to the El -Alamein Wadi El-Natrun Road on the West and by a ridge in the South.

Soil colour suggests that the main components of the soils are quartz, limestone (calcium or magnesium carbonates) and low content of organic carbon. Soil texture is dominated by fine sand in the topsoil with increasing proportions of medium sand with soil depth.

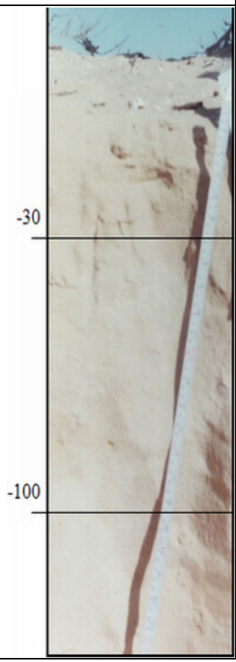
Country	Egypt	Profile No.	**35**
Governorate	Matruh	Position	30° 44' 51.01" N. 29° 00' 54.88" E
Area	El Hammam canal	Elevation	30 m a.s.l.
Topography	Gently undulating (2 - 5 %).	Slope	Gently sloping (2- 5%).
Surface cover	Drafty sand, common shell and many shell fragments, very few low hummocks.	Landform	plain
Vegetation	Few scattered desert shrubs	date	28.12.2008
Classification	Lithic Torripsamments Calcisol (aridic)	 Site photograph	
		0—30 Yellow (10YR8/6,dry) to yellow (10YR 7/6, moist) fine sand, massive; soft, non- sticky, non-plastic; extremely effervescence with HCl, few fine lime segregations; few fine shells and shell fragments; very few fine roots, common fine deed roots ;few fine gravels; gradual smooth boundary 30—100 Very pale brown (10YR8/4,dry) to very pale brown (10YR 7/4, moist) medium sand ; massive ; slightly hard; non-sticky, non-plastic; extremely effervescence with HCl, common lime segregations, many lime spots and patches; diffuse wavy boundary 100—150 Very pale brown (10YR8/4,dry) to very pale brown (10YR 7/4, moist) medium sand; massive; slightly hard; non-sticky, non-plastic; extremely effervescence with HCl, common lime segregations, many lime spots and patches; pockets of sand friable diffuse in layer.	

Figure 51: Description of profile 35

The shift in particle size distribution with depth result from the transport of sand by wind or water (see profile 5). The soil is moderately alkaline (pH 8.3 to 8.4), non-saline to very slightly saline and the inorganic carbon show highly calcareous conditions. The EC, pH and CaO_3 values increase with depth, in contrast calcium carbonate content has the highest content in the topsoil. Shells and shell fragments cover most of the surface area, which might be a relevant source of the carbonate content of the soil.

The levels of organic matter are very low (0.24 to 0.39 %), the highest values occur in the subsurface layer. Total C ranged from 3.5 to 6.3% and is mostly related to calcium carbonate content. CEC values are vary low (2.2 to 2.4 meq/100g soil, Figure 52). Exchangeable cations are dominated by Ca^{+2} followed by Mg^{+2}, Na^{+} and K^{+}. ESP values are quite low (1.2 - 5.0 %), the lowest percentage is observed in case of lowest electrical conductivity. The quality of the soil may be suitable for most of the cultivated field crops in the study area, e.g. wheat, cotton, alfalfa, barely, tomatoes and beets.

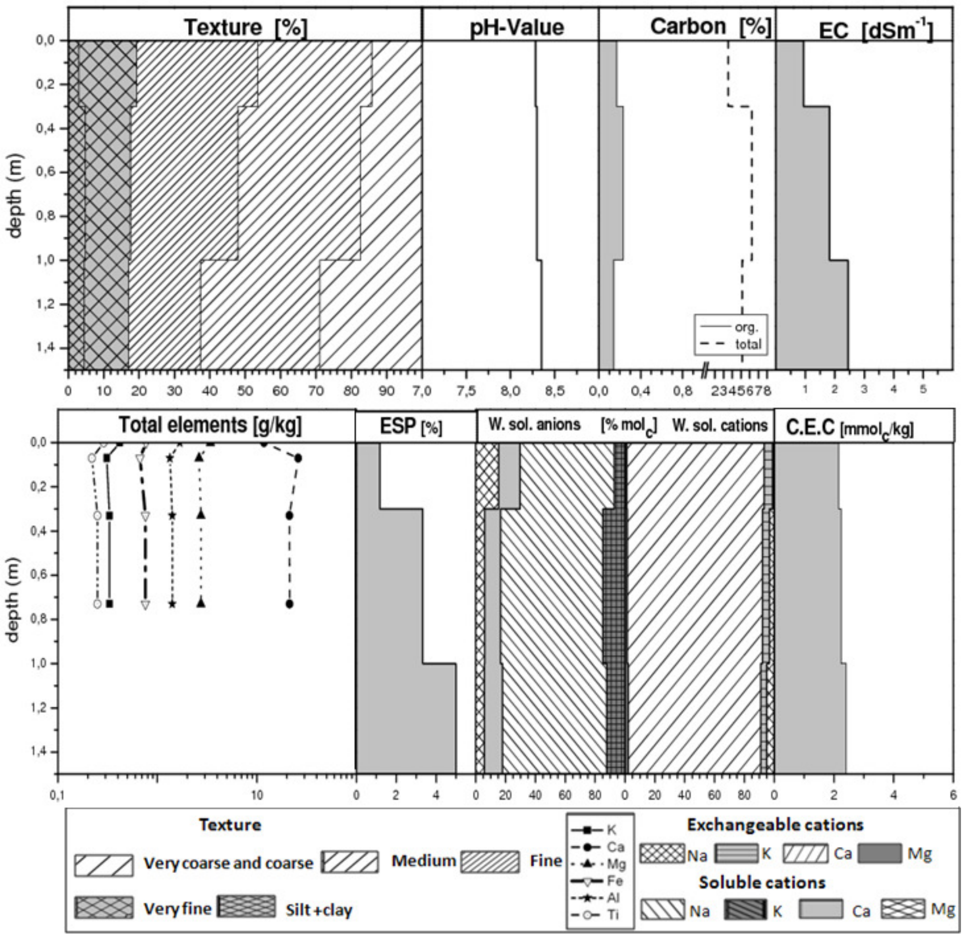


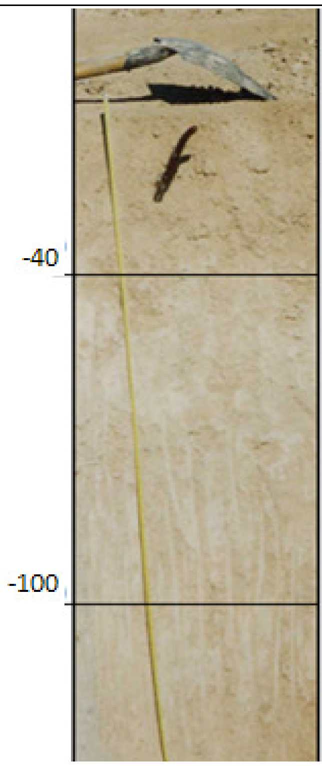
Figure 52: Soil properties of profile 35

The total elemental composition is dominated by SiO_2 followed by CaO, MgO, Al_2O_3, Fe_2O_3, K_2O and TiO_3. Contents of these elements in the subsurface layer are less than in the surface layer, except for CaO that increases with soil depth.

5.4.4. Reference profile 23

This soil profile is located near El-Dabaa town at the end of El-Hammam canal extension. The morphological characteristics are given in Figure 53.

Country	Egypt	Profile No.	**23**
Governorate	Matruh	Position	28° 30' 42.29" N. 30° 59' 57.39" E
Area	El Hammam canal extension	Elevation	22 m a.s.l.
Topography	Flat. (0--2%)	Slope	Nearly level. (0.5 – 1 %).
Surface cover	Few fine and medium gravels, few scattered low hummocks	Landform	plain
Vegetation	Few scattered olive trees and desert shrubs	date	03.01.2009
Classification	Typic Haplocalcid Calcisol (Aridic)	 Site photograph	



0—40 Yellow (10YR, 7/6dry) and brownish yellow (10YR, 6/6 moist) sandy loam; week subangular blocky; slightly hard; slightly sticky, slightly plastic; strongly effervescence with HCl, common fine lime segregation, few fine and medium lime patches. few fine lime spots; very few Schell's, few fine Schell fragments, common fine and medium deed roots, few fine and medium purse; clear smooth boundary

40—100 Very pale brown (10YR 7/4 , dry) to light yellowish brown (10YR 6/4 , moist) loamy sand; week subangular blocky; hard, slightly sticky, non plastic; strongly effervescence with HCl; very few fine gypsum spots; many fine lime segregations, many fine lime spots; clear smooth boundary

100—150 Very pale brown (10YR, 8/4dry) and Very pale brown (10YR,7/4 moist) loamy sand; massive; slightly hard; non-sticky, non-plastic; strongly effervescences with HCl, common fine lime segregation, few fine lime spots.

Figure 53: Description of soil profile 23

Historically, most of studied area was used by nomadic Bedouin tribes. The basic land use in the past was grazing in the natural pasturelands in the south that are dominated by *Thymelaea* *hirsute* and agriculture in the coastal plain where the rainfall is estimated to be about 140 mm annually. Developments of modern methods of water collection helped in the development of the region by e.g. the cultivation of olives and figs.

The landscape is almost flat with gently sloping surface and generally used for cropping and in few areas for the cultivation of olive trees. This soil is coarse-textured with high calcium carbonate content and moderately well drainage. The soil colour differs in all horizons. Particle size analyses (Figure 54) show a significant increase in coarse sand proportion with depth. The soil reaction is moderately alkaline in the topsoil and strongly alkaline in the subsoil (pH 8.2 and 9.0). Soil salinity varies from 1.4 to 3.0 dSm^{-1},indicating non-saline to very slightly saline soil conditions.

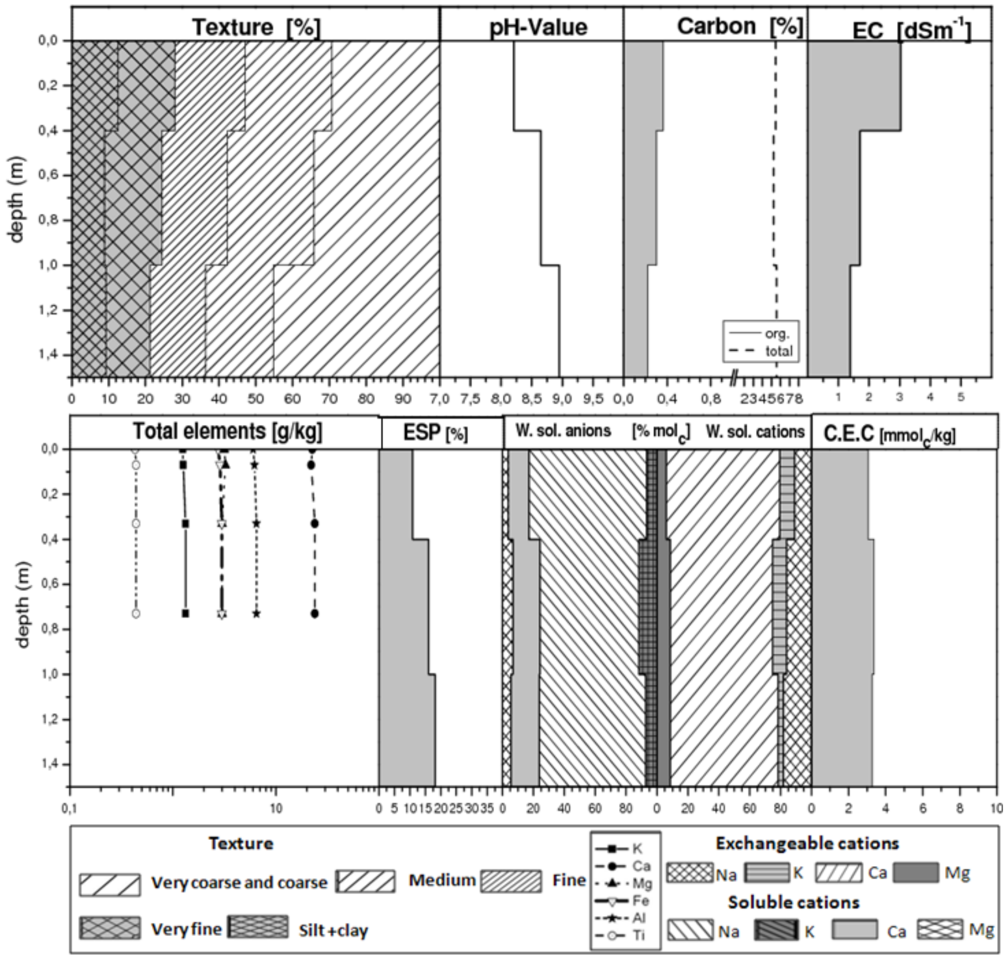


Figure 54: Soil properties of profile 23

Soil salinity has a negative correlation with pH, soil depth, $CaCO_3$ content, coarse sand fraction and CEC, whereas it has a positive correlation with medium, fine and less than 0,063 mm fractions. The cationic composition of the soil saturation extract of most soil layers is dominated by Na^+ followed by Ca^{+2}, Mg^{+2} and K^+. While the anionic compositions is characterized by the dominance of Cl^- followed by HCO_3^- and SO_4^{-2}. The CEC values are low (3.1 and 3.4 meq/100 g soil). Exchangeable cations are dominated by Ca^{+2} followed by Mg^{+2},

Na^+ and K^+, ESP values being in the range between 10.9 and 18.2 %, with the highest value being found in the deepest horizon. Organic carbon, organic matter and total N values are low for soil layers which represented soil profile. Total element composition is characterized by the dominance of SiO_2 followed by CaO, Al_2O_3, MgO, F_2O_3 and K_2O.

5.4.5. Reference profile 32

At reference profile no. 32 the topography of the landscape is generally flat at an elevation of about 20 m above sea level. The surface is covered by scattered desert shrubs and with boulders, stones and numerous gravels (Figure 55).

Country	Egypt	Profile No.	**32**
Governorate	Matruh	Position	28° 50' 31.93" N. 30° 46' 19.72.39" E
Area	El Hammam canal extension	Elevation	20 m a.s.l.
Topography	Flat. (0--2%)	Slope	Nearly level. (0.5 – 1 %).
Surface cover	Few boulders and stones, many vary seized gravels, scattered rock out crops	Landform	plain
Vegetation	Common scattered desert shrubs	date	28.012.2008
Classification	Lithic Torripsamments Calcisol (aridic, yermic)	 Site photograph	
10		0—10 Very pale brown (10YR 8/4, dry) to very pale brown (10YR 7/4, moist) gravely fine sand; massive**;** slightly hard, non sticky, non plastic; extremely effervescence with HCl, many fine lime spots, common fine lime segregations; many gravels, abrupt smooth boundary. 10+ Limestone rocky outcrops	

Figure 55: Description of soil profile 32

The soil has a low depth (10 cm) above a limestone, the texture is a gravel-rich fine sand. The soil structure is massive and the dry consistency is slightly hard. The particle size distributions revealed a dominance of fine and medium sand. The calcium carbonate content is considerably high (40.1 %), the soil reaction is slightly alkaline (pH 7.8). The EC value is 5.6 dSm^{-1}, indicating slightly saline soil conditions. The relatively high concentration of soluble salts gives advice that leaching or removal of excessive salts throughout the areas is a prerequisite for land use, which could be practiced quite easily due to the different elevations of the soils.

The cationic composition of the soil saturation extract is dominated by Na^{+} followed by Mg^{+2}, Ca^{+2} and K^{+}. The anionic composition is characterized by the dominance of Cl^{-} followed by SO_4^{-2} and HCO_3^{-}, while CO_3^{-2} is almost absent. The obtained data of organic matter, organic carbon and total N content, indicates that the soils are poor, as their contents are very low (0.22, 0.37 and 0.029 respectively). Figure 56 shows the exchange characteristics of the soil, the CEC is low (3.8 meq/100g soil), the exchangeable cations are dominated by Ca^{+2} followed by Na^{+}, Mg^{+2} and K^{+}. ESP is moderate (12.4 %). Total elemental composition is dominated by SiO_2 followed by CaO, Al_2O_3, MgO, Fe_2O_3 and K_2O.

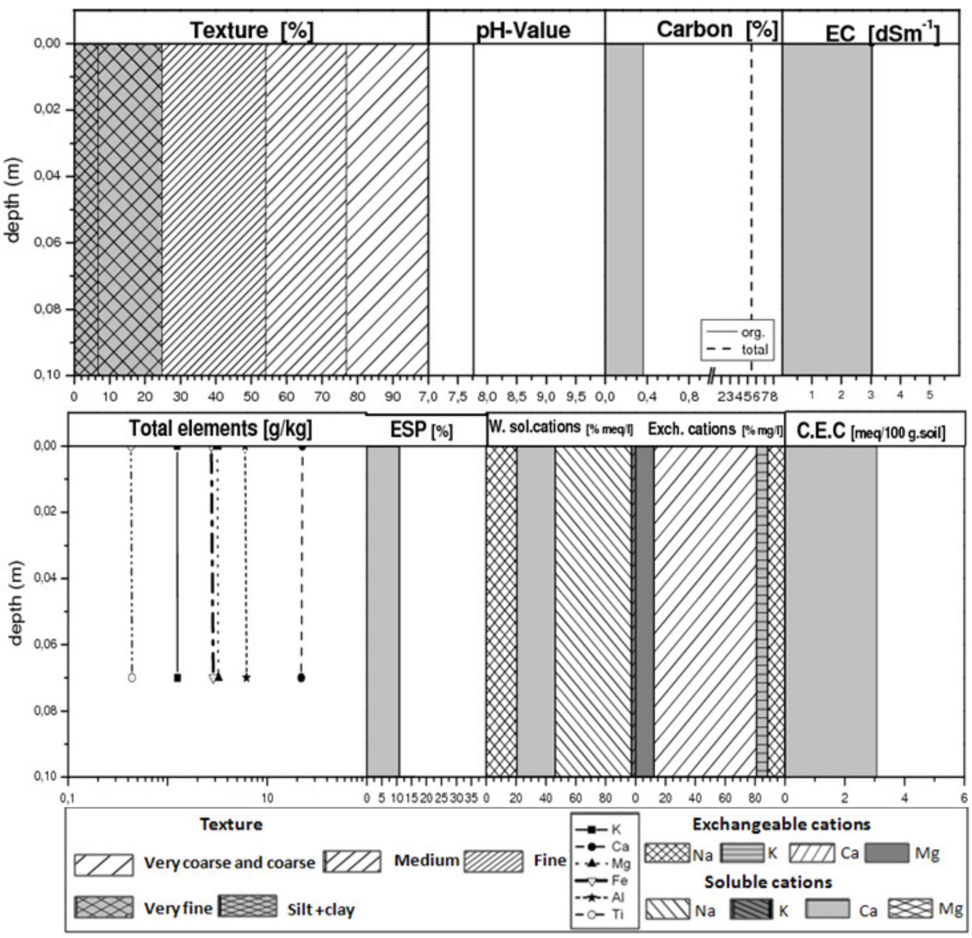


Figure 56: Soil properties of profile 32

5.4.6. Reference profile 12

The soils of the coastal area is build of medium to coarse sand composed of loose to fairly well-indurated deposits of quartz, shell fragments, heavy minerals and other debris. The pleistocene carbonate ridges located along the western coast are the source of most of these sediments. The shoreline is generally undulating and interrupted by rocky headlands, these rocks are mainly oolitic limestone. This profile is situated within an area of limestone rocky outcrops which is characterized by few scattered desert shrubs, boulders and surfaces with few stones. Topography of the landscape is generally flat. Rocky outcrops are located around the highway El-Alamen to Wadi El-Natrun, here profiles no. 9 and 10 are located adjacent El-Hammam canal and nearby El–Alamen pump station, while profile no. 12 (Figure 57) is located around El-Hammam canal extension.

Country	Egypt	Profile No.	**12**
Governorate	Matruh	Position	28° 50' 31.93" N. 30° 46' 19.72.39" E
Area	El Hammam canal extension	Elevation	20 m a.s.l.
Topography	Flat. (0--2%)	Slope	Nearly level (0.5 – 1 %)
Surface cover	Boulders, Few stones, scattered rock out crops	Landform	plain
Vegetation	few scattered desert shrubs	date	28.012.2008
		 Site photograph	
		Rock outcrops	

Figure 57: Soil properties of profile 12

5.4.7. Reference profile 8

The topography of the landscape is generally flat with a height of about 17 m above sea level. The surface is covered with many boulders, stones and sometimes gravels with and with some drifting sand. At the profile, the area was under reclamation at the time of sampling and the surrounding areas were cultivated with vegetables (tomato). This properties of this profile is given in appendix 1 soil properties (Table 44 and Table 45), data a presented in Figure 58.

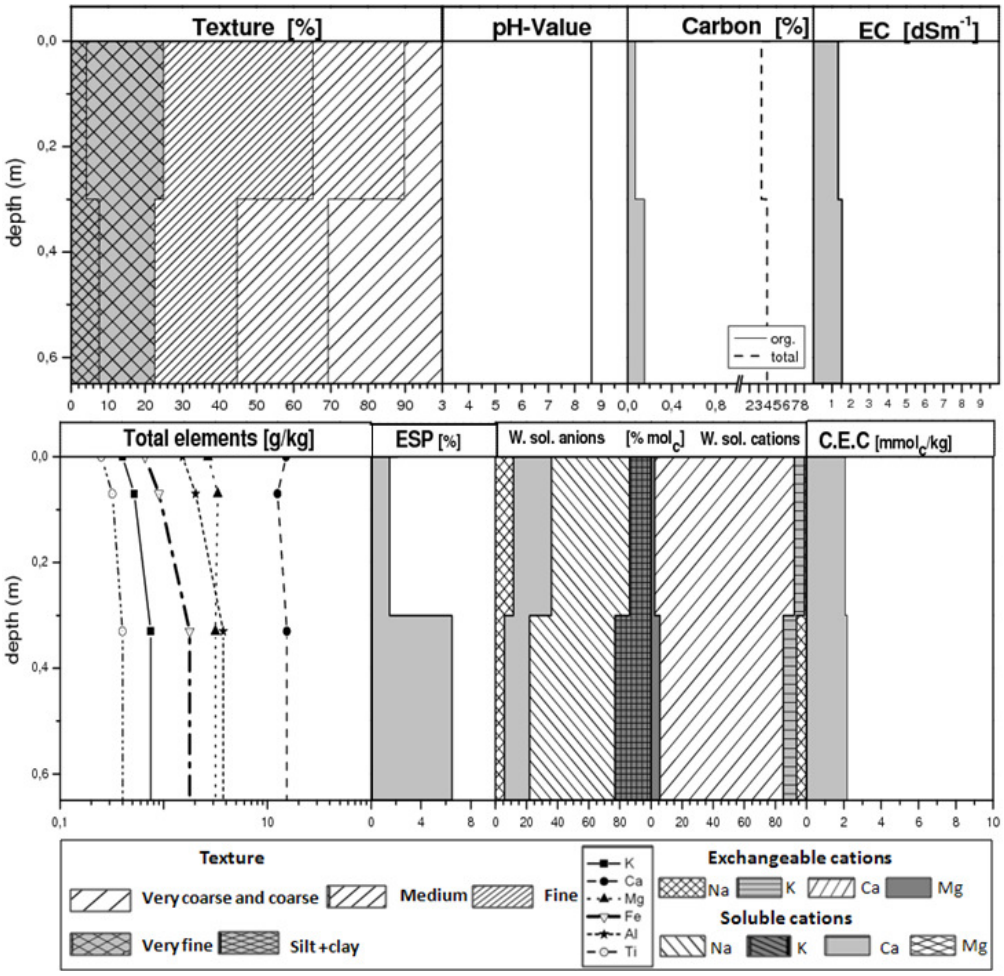


Figure 58: Soil properties of profile 8

5.4.8. Reference profile 11

The landscape is almost flat with a gently sloping surface and an elevation of 23 m above sea level. The surface is covered with few scattered desert shrubs, boulders, gravels and with some drifting sand. The features of this soil are the shallow depth, the coarse texture and the high calcium carbonate content. From the data presented in Figure 59, it is clear that the soil particle size distributions are dominated by the fine, very fine and medium sand fractions. Soil reaction is strongly alkaline to very strongly alkaline (pH 8.7 - 9.4). EC values vary between 0.92 and 1.82 dSm^{-1}.

The CEC is low (2.2 meq/100g soil) and the cations at the exchange complex are dominated by Ca^{+2}, followed by Mg^{+2} and K^{+} or Na^{+}. ESP values are low (0.08 - 2.49 %), the highest value in the subsoil in coincidence to the highest soil salinity. The elemental composition resulted in a dominance of SiO_2 followed by CaO, MgO, Al_2O_3, Fe_2O_3, K_2O and TiO_2.

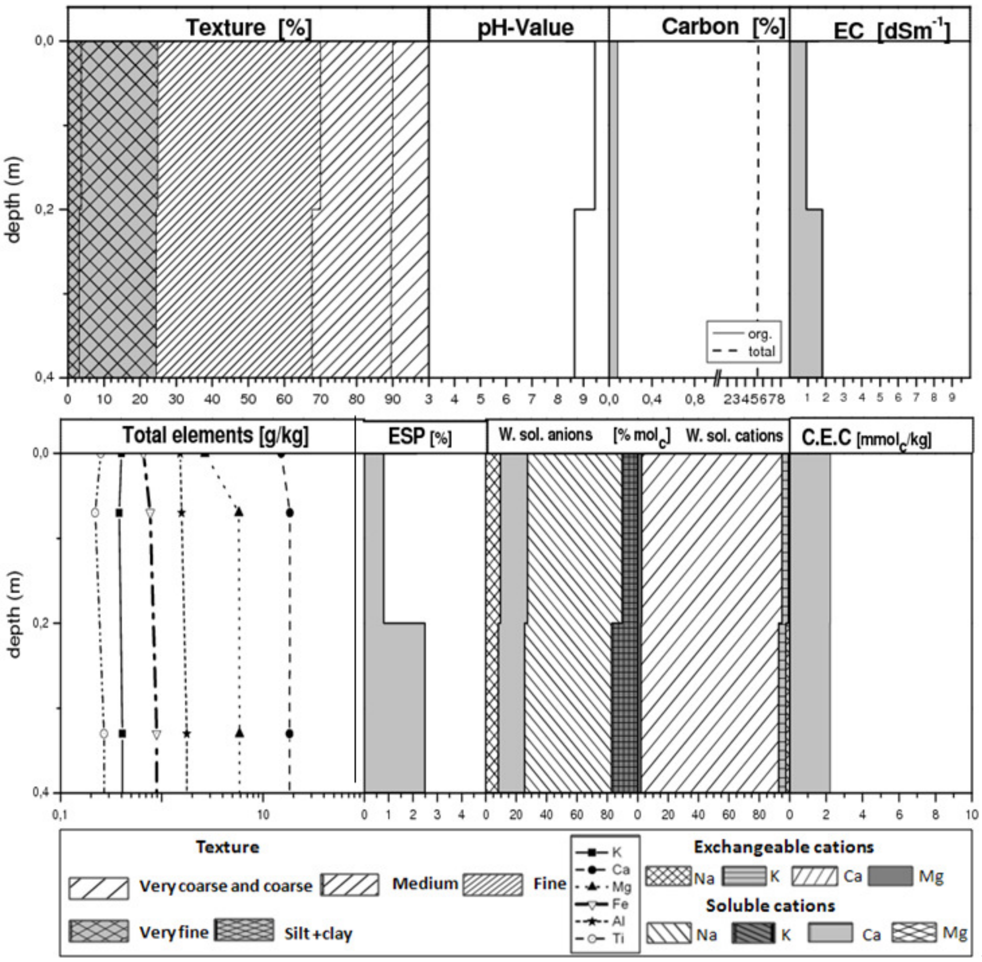


Figure 59: Soil properties of profile 11

5.5. Correlation between the properties of the soil horizons

The correlations between soil properties have been prepared using SPSS.

The **Electric conductivity** (EC) values are directly related to the total dissolved salts (ions) in the soil solution. A significant positive correlation exists between EC and soluble Na^{+} ($r = 0.983$) and Cl^{-} ($R = 0.986$), both ions are also strongly correlated between each other ($r = 0.989$), indicating that the major part of the salinity in the soils is due to halite. Additionally, the correlation coefficient between salinity and sulfate contents is positive ($r = 0.605$). Chloride (Cl^{-}) and sulfate (SO_4^{-2}) are the major anions, while sodium (Na^{+}) and calcium (Ca^{+2}) or (Mg^{+2}) are the major cations. Sulfate ion contents have a positive correlation with chloride (r = 0.467). Bicarbonate ion has a passive correlation with Na^+ (r = 0.244) and K^+ (r = 0.322).

Exchangeable cations are positively correlated with EC (r = 0.920, 0.497, 0.460 and 0.690 for exchangeable Na, K, Ca and Mg, respectively). The salinity and sodicity relations of the studied soils are shown in Figure 60. The data indicate a strong association of saline and exchangeable sodium percentage. Highly contents of Mg^{+2} indicates to that are mostly marine in origin. The dominance of exchangeable and soluble Ca^{+2} over Mg^{+2} may be explained by the lack of ferromagnesian and the abundance of carbonate minerals, by ion exchange processes and by the precipitation of calcite.

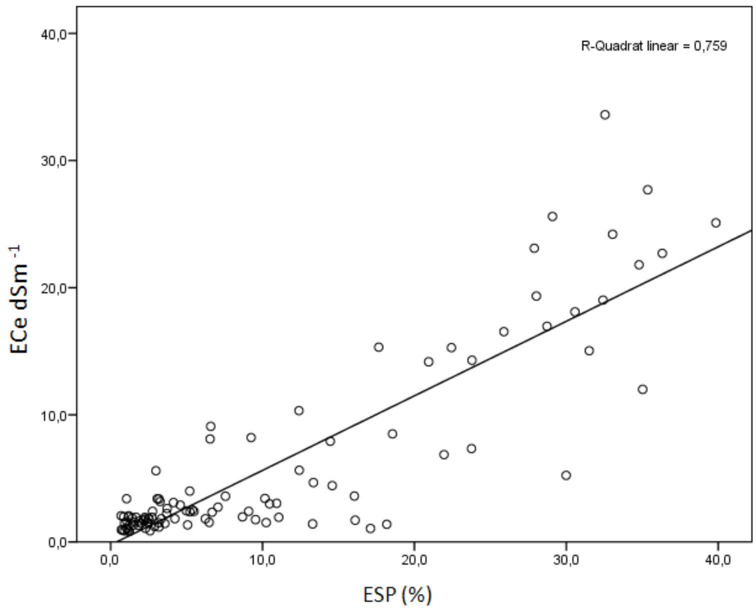


Figure 60: Correlation between soil salinity (EC) and sodicity (ESP)

In alkaline soils, pH usually increases with an increase in salinity due to the presence of sodium bicarbonate. Relationship between concentration of soluble calcium and pH is strongly negative (Al-Busaidi and Cookson, 2003). Within the soils of the studied area pH and soil salinity have a strongly negative correlation (r = -0.503, Figure 61), correspondingly, also between pH and soluble Ca^{+2} concentrations a strongly negative correlation occurs.

Under less alkaline conditions where calcium carbonate dominates the soil mineralogy, soil pH has been shown to drop with an increase in salinity. Reasons for this behavior include ion effects, the variation in ionic strength of soil solutions and the junction potential. The main factors contributing to pH salinity relationships in calcareous soils are concentration in sodium ions, soil aeration and exchangeable calcium contents. Cultivated soils which typically have a coarse texture (e. g. gravelly coarse sand) have a soil reaction less than 8.5. Decreasing of pH values with an increase in soil salinity suggests an increase in NaCl and in the aeration of the soils.

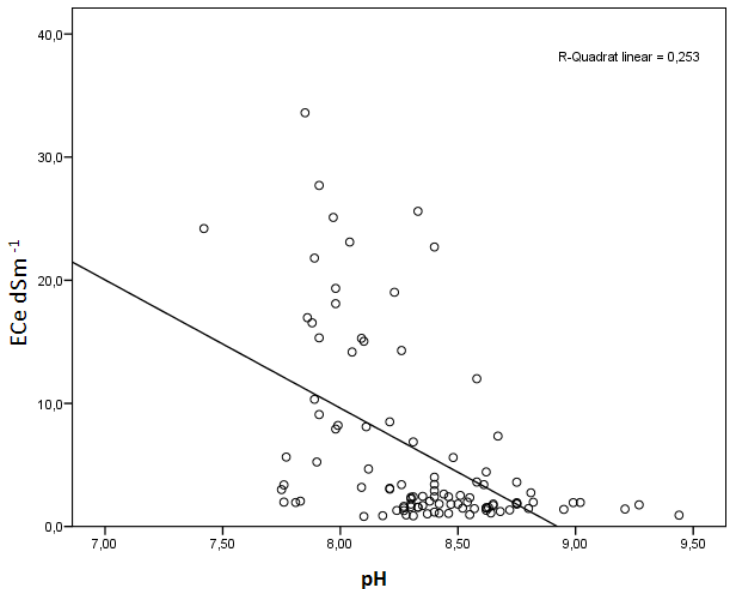


Figure 61: Correlation between pH and soil salinity

Carbonates are common constituents of many soils of arid and semiarid areas. Calcium and magnesium carbonate are reactive soil constituents, which are found in the sand (2.0-0.063 mm) as in the silt+clay (<0.063 mm) fraction. The amount of $CaCO_3$ is significantly correlated to coarse sand (r = 0.503) and silt +clay (0.063 mm, r = 0.322, Figure 62). This data indicated that a source of $CaCO_3$ is the transfer from the limestone in the west by physical weathering. Medium sand and fine sand fractions are negatively correlated with the amount of $CaCO_3$ (Figure 63 and Figure 64; r = -0.285 and -0.495). The relationship between calcium carbonate content and rooting depth is difficult to isolate from effects of fine-textured materials on rooting depth.

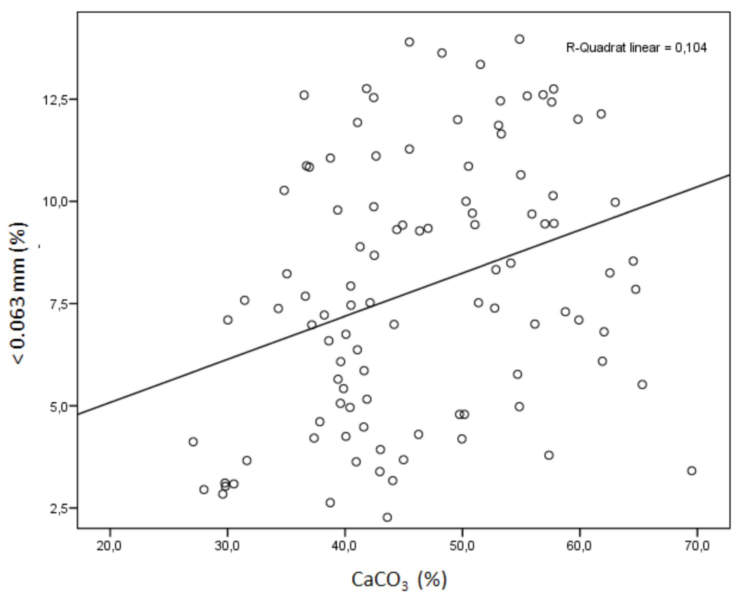


Figure 62: Correlation between $CaCO_3$ and fine fractions (<0.063mm).

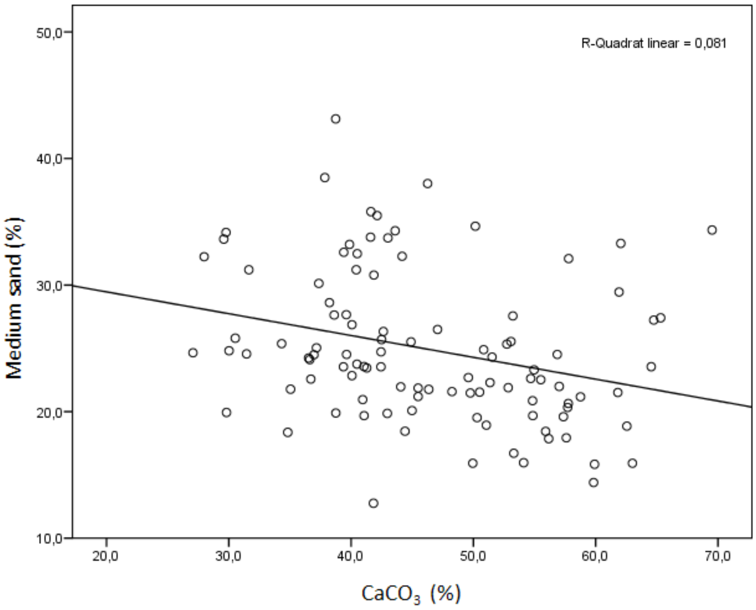


Figure 63: Correlation between $CaCO_3$ and medium sand fraction

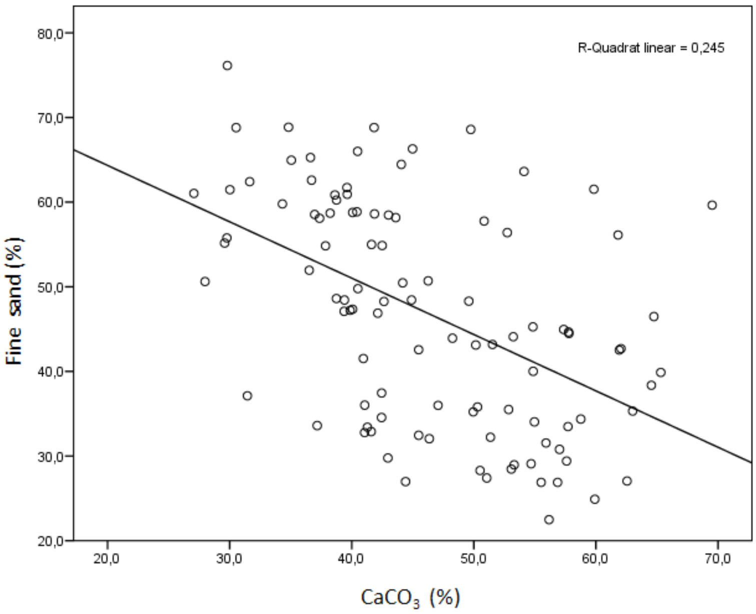


Figure 64: Correlation between $CaCO_3$ and fine sand fraction

The correlation coefficient between **K and Al** is strongly positive (r = 0.962, Figure 65), which means that the predominant proportion of potassium is found in the soils as a component of the silicates and not in secondary precipitates. Also, the correlation coefficient between Zn and Al is strongly positive (r = 0.914, Figure 66). The relationship between total Zn and K value is r = 0.858 (Figure 67).

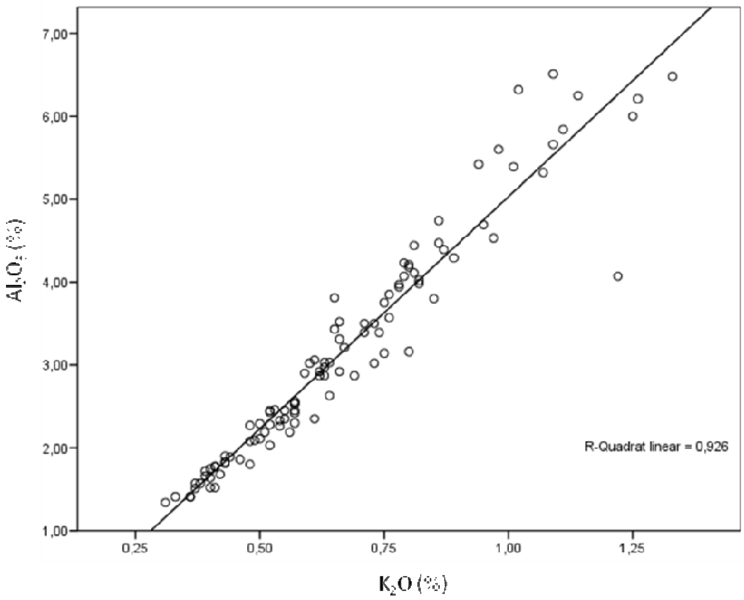


Figure 65: Correlation between K and Al

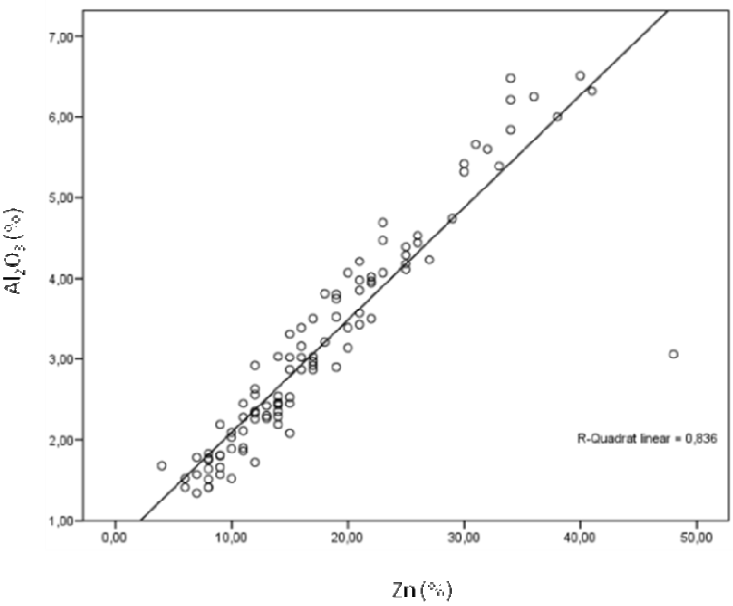


Figure 66: Correlation between Zn and Al

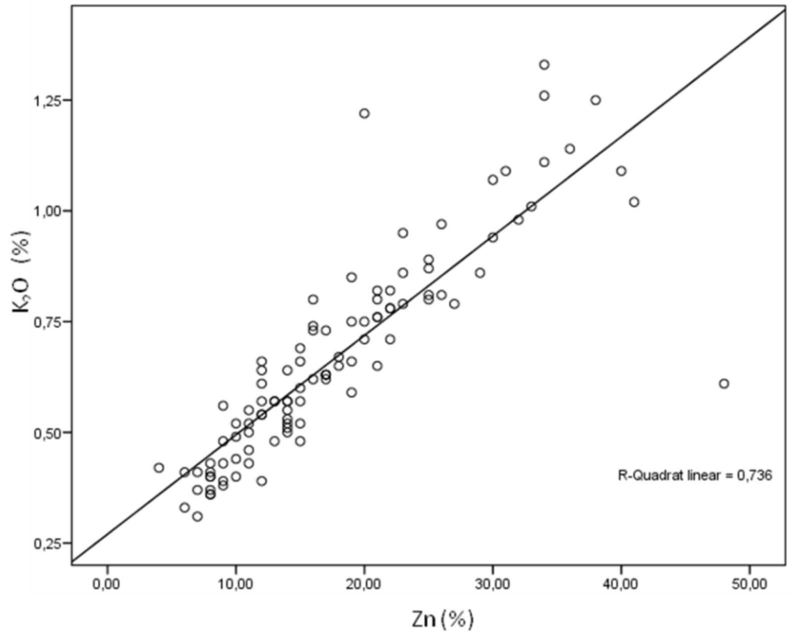


Figure 67: Correlation between Zn and K

The correlation coefficient between **Si and Fe** is negative (r= -0.538, Figure 68), showing that iron originates from silicate minerals with lesser Si content whereas high Si values are associated to quartze. Also, an increasing content of Si is combined with a decreasing concentration of $CaCO_3$ (r= -0.919; Figure 69). By calculating Si as SiO_2 the sum of both components is in the range of 75 to 95 %, which means, that the mineral composition of many soil horizons is dominated by quartze and calcite. The relation can also be interpreted in a way that the amount of quartze minerals in the soil, typically enriched in the sand fractions, can only be enlarged by a loss of carbonates.

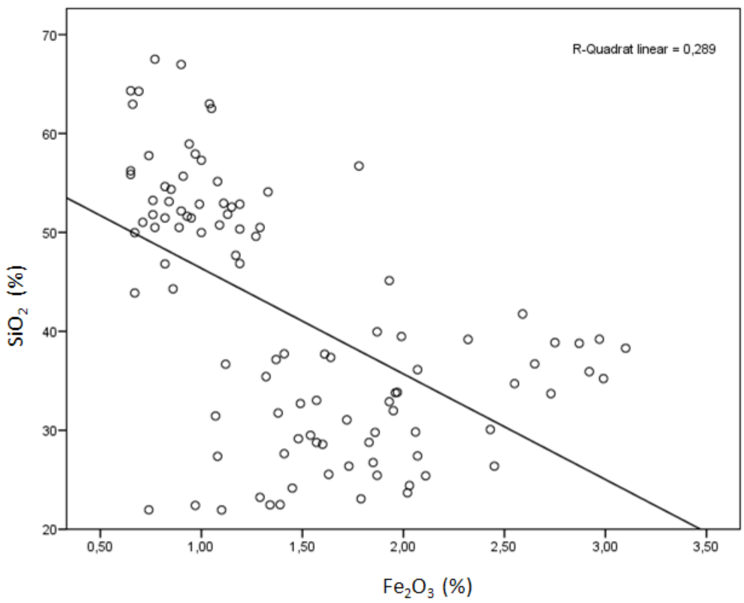


Figure 68: Correlation between Fe and Si

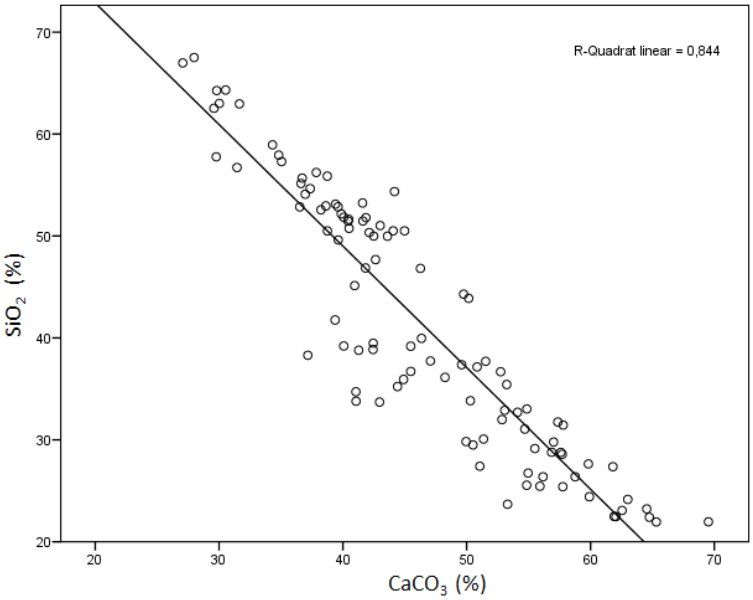


Figure 69: Correlation between $CaCO_3$ and Si

The surface sediments of the coastal plain area are rich in carbonate and carbonate grains from the nearby ridges. Carbonate minerals in the coastal sediments (sabkha surface) were calcite, aragonite, Mg-calcite and dolomite. High magnesium calcite could have been deposed by evaporation of the saline water, dolomite mineral maybe wind-blown detrital material or have been precipitated in situ (Hassouba, 1996).

Concentration of total iron indicating the amount of silicates - and soil reaction (**pH**) – as a measure for sodicity - are not correlated (Figure 70). This means, that the amount of sodicity is not correlated to the amount of silicates, thus soils with higher sodicity may occur in coarse- as well as in fine-grained soils.

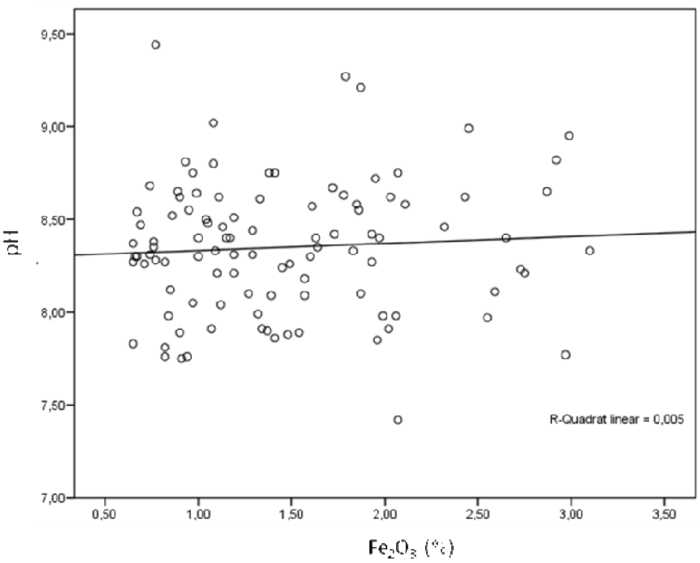


Figure 70: Correlation between Fe and pH

MgO/CaO ratio ranged from 0.05 to 0.32 % with an average 0.13 % (appendix, Table 47), the highest values are detected in shallow soil profile or profiles closed to the ridge such as profile 11, 13 and 38. The Mg concentrations may have been produced from dolomite by water rising to the surface from the underlying saline ground water or the deposition of gypsum. Magnesium-rich clay mineral is Attapulgite, which could be another source of Mg. Higher values of MgO/CaO ratio provided the system with suitable geochemical conditions for the deposition of authigenic attapulgite, (Hassouba, 1995).Values of CaO/MgO ratio are below of rain water (1.12) and above seawater (0.17). Content of $CaCO_3$ and CaO/MgO values indices of carbonate minerals in the groundwater samples of the fissured limestone aquifer and dolomitic limestone and dolomite leading to the increase of Mg in the groundwater (Yousif and Bubenzer, 2012)

Weighted mean of total **Sr** ranges between 224 ppm and 1552 ppm, with an average value of 792 ppm. Sr is strongly positively correlated to the concentration of total Ca (r = 0.640), inorganic carbon (r = 0.616, Figure 71) and negatively to the concentration of total Mg (r= - 0.537), whereas no correlation was found to soil reaction (pH) and soluble SO_4^{-2}. Results indicate that Sr content maybe lost from aragonite lattices to calcite during diagenetic alteration has gone in to the interstitial pore fluid from which some of it has been precipitated as authigenic celestite (reaction between Sr and SO_4^{-2} led to the deposition of celestite). The positive correlation between Sr and calcium carbonate contents indicates that carbonate materials represent the main host of Sr in calcrete rocks.

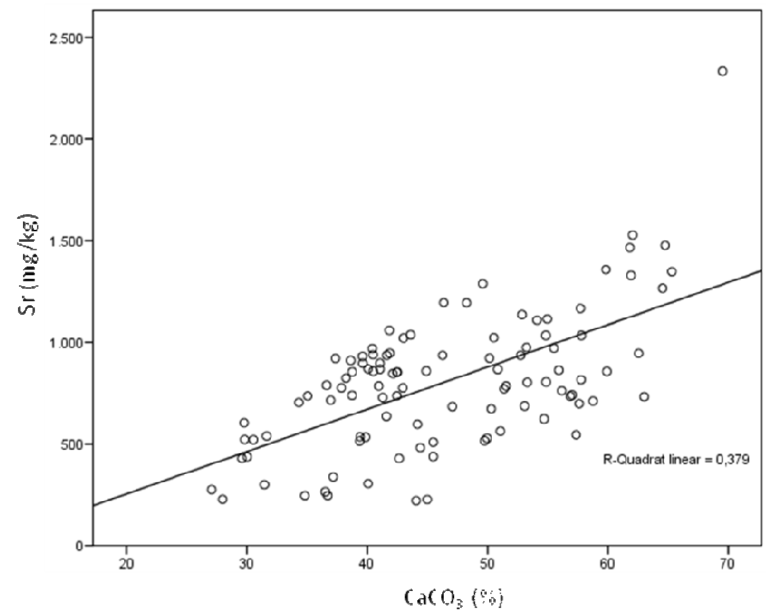


Figure 71: Correlation between $CaCO_3$ and Sr content

High amounts of calcium carbonate may lead to **nutritional limitations.** The Mediterranean area is arid and semi arid and their soils may have extremely high calcium carbonate, high pH values and high concentration of bicarbonate (HCO_3). Most of nutritional problems in tree growth in cultivated area are related to high calcium carbonate contents or excess in nutritional elements such as Ca^{+2}. Soil reaction and calcium carbonate contents have a positive and not to small significant correlation coefficients with total elements; such as Al (r = 0.094, Figure 72), Fe, Mn, K, P and Zn. Total Cu is negatively small significant correlated with soil reaction and calcium carbonate (Figure 73). Total sulfur contents have a negative correlation with soil reaction.

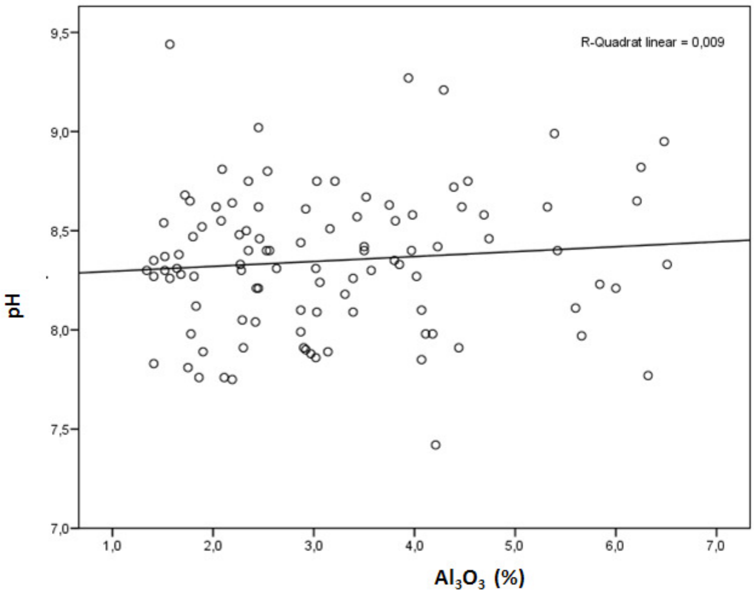


Figure 72: Correlation between total Al and soil reaction (pH)

A high soil reaction may affect the availability of most nutrients in soil solution. Low Fe availability of the extremely calcareous soils reveals to low concentrations of dissolved inorganic Fe at high pH values. In association with high pH values the availability of soil Mn, Zn and Cu are decreased.

The correlation analysis between total contents of cations (Na^+, K^+, Ca^{+2} and Mg^{+2}), the exchangeable cations and the water soluble cation revealed that correlations between total and exchangeable cations are positively with small and medium significance. Water soluble cations correlate positively small to strongly significant with total and exchangeable cations. Except soluble K^+, this has a negative small significant correlation with total and exchangeable K^+. Salinity and soil reaction have a negative correlated with soluble K^+, while they have a positive correlated with total and exchangeable K^+.

The relationships between Al and Fe, K, Na and Ti indicate that, there is a very small scatter of points in the relationship between Al and Fe and a strongly positive correlation (r = 0.995, Figure 74). This indicates that most of the iron is associated with Al in clay minerals and other silicates, also this relationship is nearly the same in cultivated and uncultivated soils.

Relationship between Al and Na is positive but has a medium significant correlation (r= 0.422), data indicates that mineral phases such as plagioclase and K-feldspars have a control on the Al content. Correlation coefficients value are nearly the same in soil profile represented El-Hammam canal extension but soil profiles adjacent El -Hammam canal is strongly positive between Al and Na.

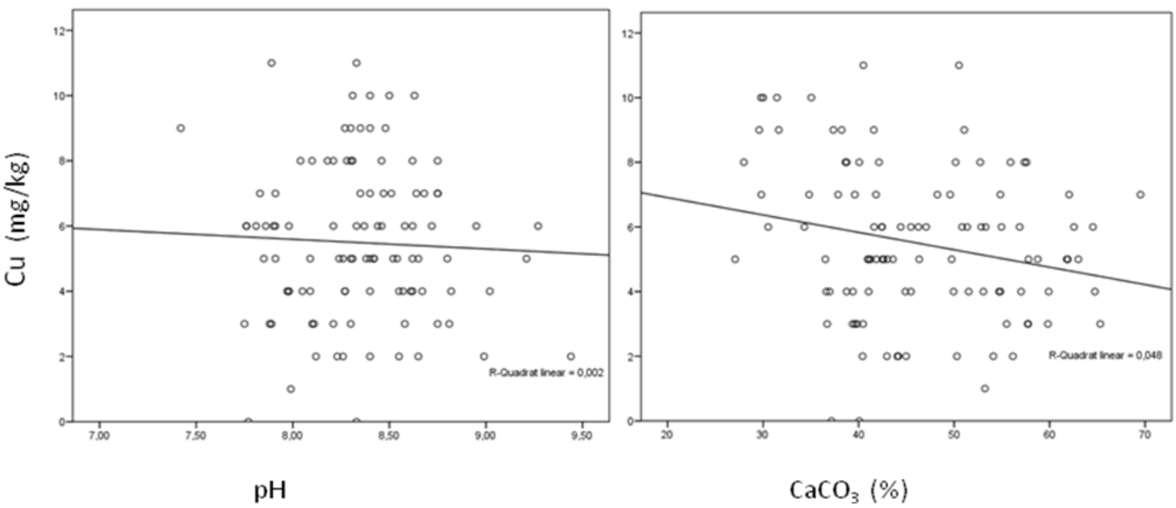


Figure 73: Correlations between $CaCO_3$, pH and total Cu

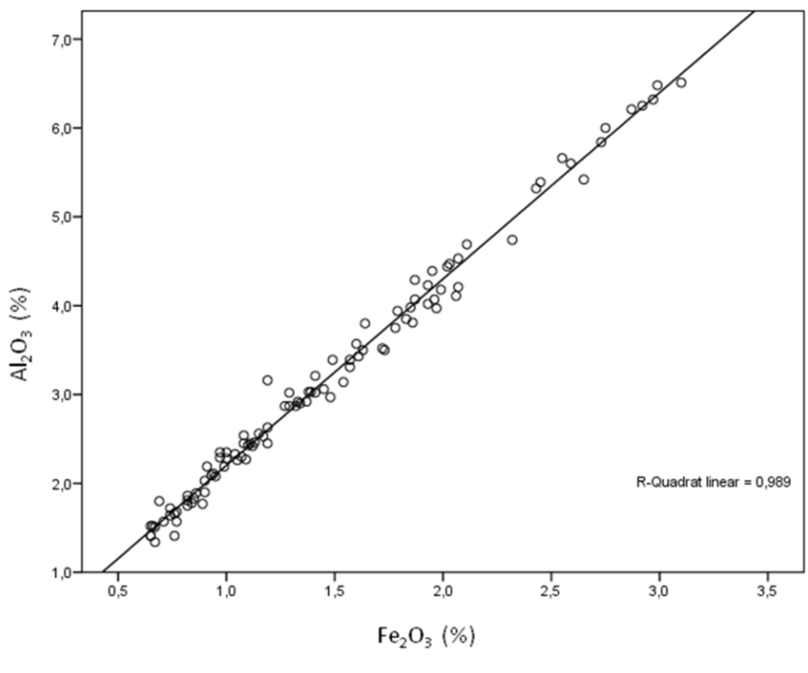


Figure 74: Correlation between Fe and Al

The K_2O/Al_2O_3 ratio of sediments can be used as an indicator of the original composition of ancient sediments. An average K_2O/Al_2O_3-ratio less than 0.3 means that clay minerals are below those specific for feldspars. Titanium is mainly concentrated in phyllosilicates and is relatively immobile compared to other elements during various sedimentary processes and may strongly represent the source rocks. K_2O/Na_2O-ratios range from 0.54 to 3.31. These differences obviously reflect in part the different original compositions of the source rocks. The increase of Ca with the decrease of Na, Mg and K shows the variation in the chemical composition, reflecting changes in the mineralogical composition of the sediments due to the effects of weathering, marine sedimentation and early diagenetic processes.

Ti and Al are positive and strongly significant correlated (r= 0.825). The TiO_3/Al_2O_3 ratio average is 0.103. Ti and Al in general ranked among the most immobile elements during weathering and provenance. The value of ratio indicates that parent rocks of the area are essentially basic rocks, (Abayazeed, 2012). The Al_2O_3/TiO_2 ratio increases from 5.64 to 15.86 for the most soil samples, Thus, the Al_2O_3/TiO_2 ratio of this study suggests that mafic igneous rocks to intermediate rocks, (Nagarajan et al., 2007).

In coarse-textured soils high contents of Si are typical. Al contents are ranged between 1.34 and 6.51 %. The distribution of Al is reverse to that content of Si, however, the SiO_2/Al_2O_3 ratio shows main variations from 4.89 to 42.32 %. The correlation between SiO_2 and Al_2O_3 (r = -0.473) is shown in Figure 75. In all the soil profiles only scarce clay fractions (<10%) have been found.

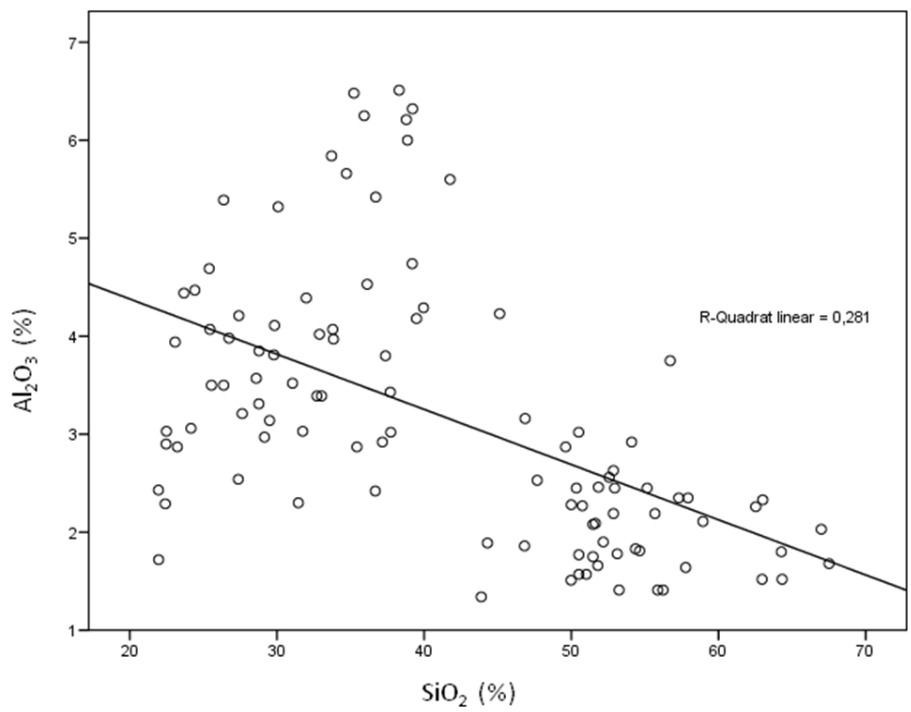


Figure 75: Correlation between Al and Si

The decrease of Al content in the samples with the increase of Si may be related to the parent materials and to physical weathering. The SiO_2/Al_2O_3 ratio is a commonly applied index of sedimentary maturation. Values increase because of increase of quartz at the expense of less resistant components such as feldspar and lithic fragments during sediments transport and recycling. Studied soil samples have values less than 3, this indicates that soils have not basic rocks. Low values of Al_2O/SiO_2 confirm the quartz enrichment in the sandstone, whereas ranged between 0.02 and 0.20 with an average value is 0.09 (Akarish and El-Gohary, 2011). Some soil samples have SiO_2/Al_2O_3 value around more than 5.0 in sedimentary rocks provided evidence of sedimentary maturation. Many elements exhibit positive linear correlation between each other (K with Al, Rb with Al, Rb with K, Figure 76). This correlation supports the interpretation that the absolute abundances of these elements are primarily controlled by illite. During weathering processes Rb with respect to K is preferentially retained in the illite. This is because small cations such as Na, Ca and Sr are selectively leached and removed from the weathering profiles, whereas cations with relatively larger ionic radii, such as K, Rb and Ba, may remain fixed by preferential exchange and adsorption on clays

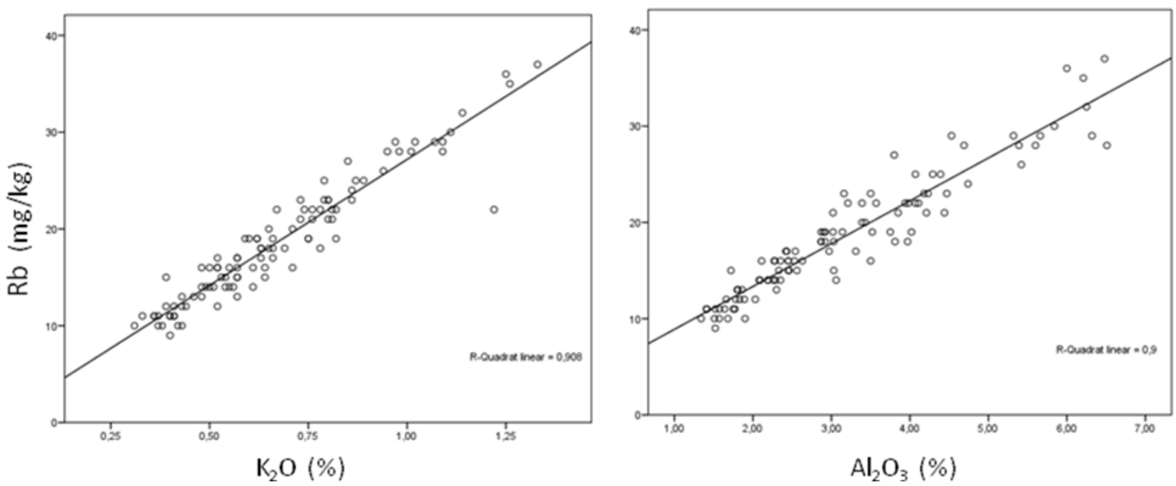


Figure 76: Correlations between Al, K and Rb

The positive correlation between K and Ti and between Al and Na indicate that the elements are associated entirely with the detrital phases. Illite mineral is the dominant clay mineral as based on the ratio of K_2O/Al_2O_3, and phyllosilicates is the main source of Ti. The sources rocks are the origin of most of the immobile elements (Nagarajan et al., 2007). High contents of K and low contents of Al indicate the occurrence of illite and low contents of kaolinite or aluminum minerals. Ti content in the sediments is influenced by the composition of the source rock which contain Ti-bearing minerals such as rutile. The enrichment of Ti and Al and the strong positive correlation (r = 0.816, Figure 77) between both elements could be attributed to the effect of chemical weathering and we suggest that Ti is contained mainly in phyllosilicates rather than Ti-bearing minerals.

The relation between Mg and Ca tends to be reciprocal, the MgO/CaO-ratio ranges between 0.05 and 0.32. An increase in Mg in the parent material thus is accompanied by a drop in Ca. MgO has a percentage from 3.1 to 18.6 % with regard to CaO, whereas the exchangeable values for the exchangeable cations range between 3.7 and 27.9 %. As the exchangeable MgO/CaO ratio is lower than 20% for most of the soil profiles, I suggest that the calcium: magnesium ratios do not adversely affect plant yields. Decreasing the K_2O/Na_2O ratio in the soil profile samples which less than 3.3 indicate a decreasing maturity of the soil materials. The trend of K_2O/Na_2O is interesting and is consistent with the grain size analysis. The variation of the K_2O/Na_2O depth distribution obviously reflects in part the different original compositions of the source rocks. The correlations between Fe, Mg and Al are positive indicating that Mg is originally associated with aluminosilicate phases and assumes a minor association with carbonates during diagenesis.

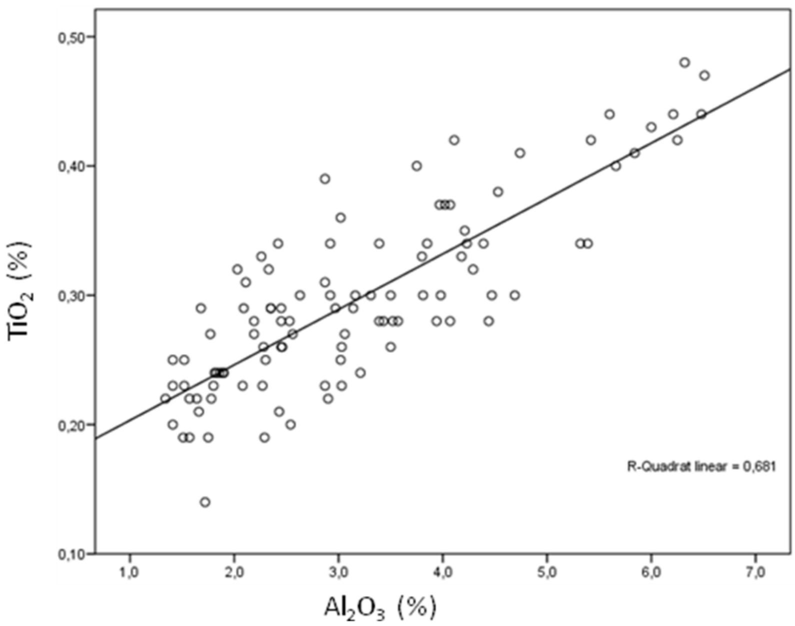


Figure 77: Correlation between Al and Ti

Most of the samples have low P contents which may be explained by the lesser amount of accessory phases such as apatite. Cr, Sc, Ni, and V **trace elements** are positively correlated with Al_2O_3 (r = 0.933, r = 0.173, r = 0.872, r = 0.846, respectively), which suggest that these elements may be bound in clay minerals and concentrated during weathering (Abayazeed, 2012) and (Nagarajan et al., 2007). The average ratio of Cr/Ni is 2.85 with variation among the values between the soil profiles. The higher concentration indicates that the source region was composed of mafic rocks. Both elements are abundant in mafic rocks, but are scarce in rocks of more felsic composition. The Cr/Ni ratio are low in most soil profiles, which ranged from 1.31 and 10.0.

The present study shows that Ba/Sr and Rb/Sr ratios are considerably low (0.033-0.610, 0.006 - 0.095) for Rb/Sr and Ba/Sr, respectively), which may be a result of Ba and Rb loss during weathering. The area under study is close to the seawater, it can be assumed, that within the ridges, and limestone plateau, a greater proportion of Ca and Sr has been recycled in shallow marine carbonates. The high content of Sr in north-western coastal area of Egypt with highly calcium carbonate contents indicates that Sr is associated with calcite minerals. The total Ba content varies between 77 and 214 mg kg^{-1}.

Chemical data reflect the enrichment of chemically immobile elements (Al, Ti, Zr and Sc) and the depletion of mobile elements (Fe, Na, K and Mg). Major elements concentrations reflect the dominant mineralogical composition and the weathering history of the source area. Moreover, the enrichment of trace elements (Sc, Zr and partially Cr) could be attributed to the source rock chemistry and its weathering history. Zr and Cr correlation is positive and medium significant correlated, while correlations between V and Ni is positive and strongly significant (r= 0.831). The positive covariance between Zr–Cr, V–Ni and their concentration demonstrate that at the time of deposition the source area was subject to intense chemical and physical disintegration. Chemical weathering of the mafic ultramafic source rocks would tend to selectively enrich weathering products in Cr and Ni. The Zr contents have a positive and small significant correlation coefficients with V, these indicates that the source rock probably suffered from chemical weathering if they have strongly correlations.

Ratios of La/Sc, Th/Sc, Th/Co and Th/Cr range from 0.4 -21, 0.13 – 6.0, 0.3 – 0.9 and 0.03 to 0.58, respectively (some samples have values below detection limit). These values ratios allow conclusions on the average provenance composition. U contents are generally exerts a strong control on the marine geochemistry, and found in sediments deposited in oxygenated conditions in marine environment. Uranium contents are ranged from 0.5 and 9.0 ppm (some samples are not quantified). U/Th ratio is lower than 1.25 for most soil samples, this indicates that the parent materials was deposed under oxic conditions or in an oxic environment. The authigenic U values are lower than 5, this also indicted to represented oxic depositional conditions.

$$U_{authingenic} = (Total\ U) - Th/3 \qquad \text{Equation 4}$$

In general, climatic factors such as precipitation rate and wind patterns determining aeolian deposition will directly control calcareous soils properties.

5.5.1. Element associations in sediments

Elements may have varying preferential associations with respect to the chemical and mineralogical constituents of sediment. The degree of correlation between major and trace elements and other sediment constituents is often used to indicate the common origin and processes occurring in nature. The examined trace elements are largely detrital in origin and their distributions mainly controlled by the contents of quartz, clays, carbonate and iron oxides.

Regarding to leveled values of Al/Mg ratios, most of soils have coarse fractions and are enriched in silica. Soil profiles representing sand dunes are enriched by silica with Al:Mg ration ~1, while soil profiles representing old cultivated area of El-Hammam canal (no. 1, 2 and 43) and most of soil profile representing El-Hammam canal extension have Al: Mg ration >1. Here, sepiolite is more likely to form than palygorskite. The genesis of the mineral is favoured by formation waters enriched in silica or sepiolite and having a high pH based on Al:Mg ratio (Hassouba, 1980). Marine and non-marine palygorskite-sepiolite deposits occur interbedded with chert, dolomite, limestone, phosphates and other non-detrital sedimentary rocks. The palygorskite and sepiolite deposits suggested that the release of silica by the destruction of ash and montmorillonite are subsequent reconstitution to palygorskite and/or sepiolite, (ISPHORDING, 1973).

The dependence of Sr on carbonate mineralogy probably reflects the existence of aragonite and high Mg-calcite as the main carbonate minerals in the mud fraction of sediments. Enrichment of Sr in the calcrete deposits is most probably due to its liberation during diagenetic dolomitization of the calcite cement. Sr/Ba proportion ranges from 1.6 to 29.9% , trace-element indices indicating shallow marine lithofacies whereas Sr >160 ppm and Sr/Ba > 0.35 (Chen et al., 1997). Cr, Ni and Zn are closely associated with iron (r = 0.942, 0.891 and 0.886, respectively). Ba correlates positively with K (r = 0.802) which may reflect its ability to substitute for K in potassic minerals. Rb occurs in relation to both fine materials and iron contents, as indicated by strongly positive correlation with Fe. Sr has a strongly positive correlation with $CaCO_3$ contents (r = 0.616), that suggested the main source of Sr is calcrete. The distributions of these trace elements mainly controlled by the abundance of quartz, iron oxide, carbonate and total clays.

The silica-sesquioxide ratio ranges from 3.4 to 29.6 with an average of 11.6 %. Samples with coarse and medium sand texture which represent sand dunes and soils adjacent El-Hammam canal have a high silica-sesquioxide ratio. Cation exchangeable capacity values have a negative and medium significant correlation with silica-sesquioxide ratio, (r = -0.464, Figure 78). This correlation indicates that an increase of the silica/sesquioxides ratio leads to a decrease in cation exchange capacity and moisture retention of the soils.

Regarding the levels of **organic carbon (SOC)**, data shows that relation between SOC and concentrations of most elements are positive, except for Si, Mg, Co and Cu. These relations range from small positive to strongly positive correlation (r = 0.02 to 0.74 for Sr and Na contents, respectively). The low SOC observed in the most soil samples may be attributed to the deposition of organic-poor sili-clastic terrigenous materials.

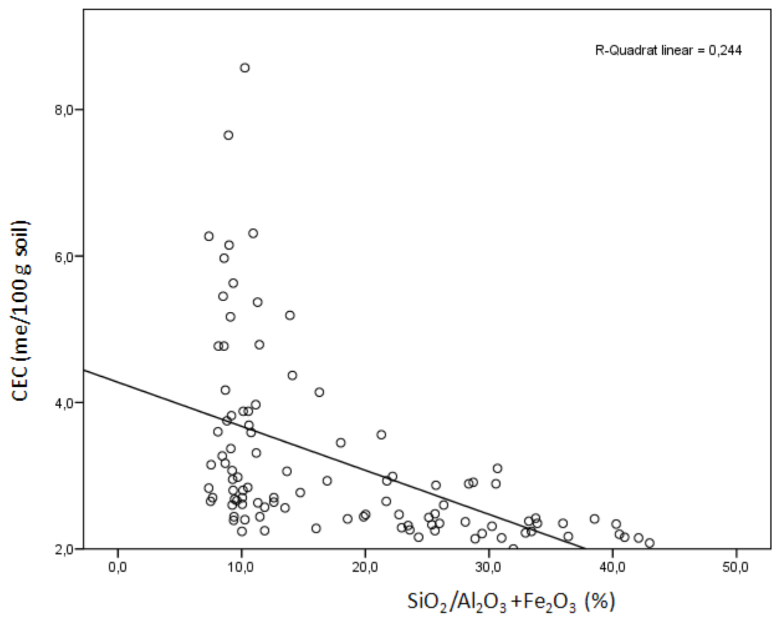


Figure 78: Correlation between silica-sesquioxide ratio and CEC

Si, Mg, Ti, Co, Zr, Cu and Ba contents have a negative correlation with $CaCO_3$ content. The linkage of these results with particle size distribution of soil samples revealed, that $CaCO_3$ and SOC contents are negatively correlated with medium and fine sand fraction, whereas to coarse sand and fine (< 0.063 mm) fraction positive correlations occurred. In addition, most of total elements contents have the same correlations with the particle size fractions (except for Si, Co and Cu that have reciprocal correlations). For example, Al and Fe are positively correlated with silt+clay fractions (Figure 79). Therefore, this suggests that the Al and Fe will depend on clay minerals and other detrital minerals such as mica, chlorite, feldspar and amphiboles. In addition, Al and Fe are strongly positively correlated to the coarse sand fraction (r = 0.704 and 0.731 for Al_2O_3 and Fe_2O_3, respectively).

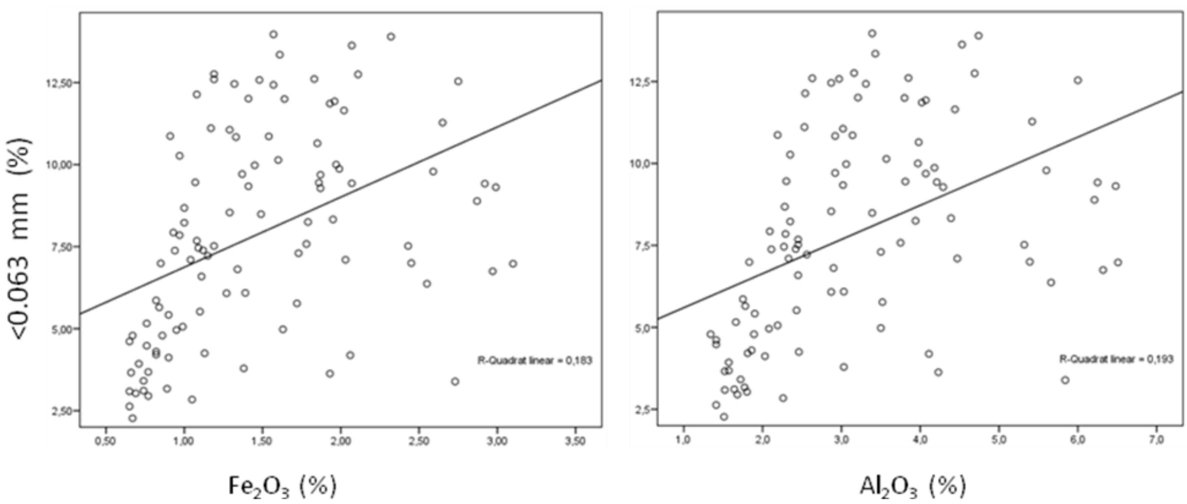


Figure 79 : Correlation between Al, Fe and fine particle fraction (< 0.063 mm)

5.5.2. Weathering effects

The weathering rates on continents are regulated by many factors, including the source rock type, climate regime, tectonic and topographic settings, vegetation, soil development, and human activities. Weathering effects indices are useful tools in characterizing weathering profiles and determining the extent of weathering (Shao et al., 2012) TiO_2 content in the sediments is influenced by the composition of the source rock which contain Ti-bearing minerals (e.g., ilmenite and rutile) and the rate of chemical weathering, (Ghandour et al., 2003). Elemental concentrations in soils result from the competing influences of provenance, weathering, sorting, and sediment diagenesis. Their concentration in sediments is used as a measure of detrital input. Thus, Chemical Index of Alteration (CIA) has been established as a general indicator of the degree of weathering in any provenance regions.

Chemical Index of Alteration (CIA)

$$Al_2O_3 / (Al_2O_3 + CaO^* + K_2O + Na_2O) \times 100 \qquad \textbf{Equation 5}$$

Whereas CaO* is Ca exclusive of carbonates and phosphate. CIA values <50 indicate that the source rock is chemically un-weathered, while those between 51 and 75 and >75 indicate moderate and strong weathering, respectively. The sediments that are enriched in non-silicate Ca (i.e., calcite-rich samples) are excluded from these calculations. Based on the data of the study area CIA values from 59 to 82, with an average of 74 have been calculated, indicating moderate to strong degree of weathering. Highest CIA values occur predominantly in soil profiles located around El-Hammam canal extension and in uncultivated soils.

The index of compositional variability (ICV) is defined as:

$$(CaO^* + K_2O + Na_2O + Fe_2O_3 + MgO + MnO + T_iO_2) \, / \, Al_2O_3 \qquad \textbf{Equation 6}$$

Parent material rocks included Fe, Mg and Mn, the values of ICV are ranged between 4.6 and 24.4 with an average value of 10.9. This values decrease with increasing degree of weathering as shown in Figure 80. The relation between CIW and ICV is negative and medium significant correlated (r = -0,307).

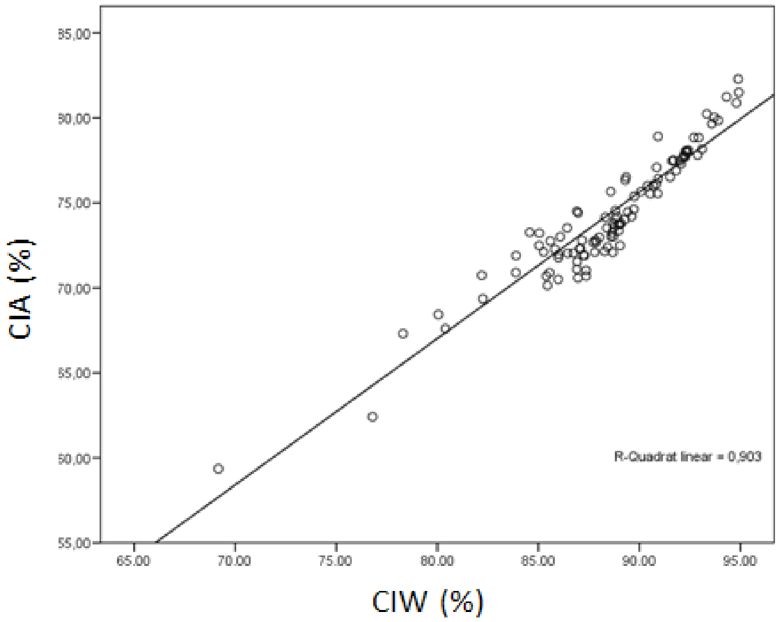


Figure 80: Correlation between CIA and ICV (without CaO)

The studied soils have dominantly detrital features characterized by a low chemical indexes of weathering. The abundance of major and trace elements, considered mainly related to the source rock composition, is in accord with a provenance from the continental crust (limestone rocks, igneous rocks and quartz rich sediments).

5.6. Cluster analysis

Statistical analysis was performed with Statistical Programme for Social Sciences (SPSS) version 16.0 software for the computation of Pearsons' correlation matrix (see correlation between the soil properties) and the hierarchical cluster analysis, which represents a quantitative independent approach of samples and variables classification in environmental studies. The hierarchical cluster analysis was performed to identify groups of soil horizons of most similar characteristics with regard to different parameters (elemental contents and physico-chemical characteristics). Based on soil properties such as particle size fractions (fine sand), alkalinity (pH), lime content ($CaCO_3$), salinity (EC), Organic matter (SOC) and total elements (Al and Co), the studied soil profiles could be arranged into four groups, as well as limestone rocky outcrops (Figure 81).

Soil characteristics of soil profiles representing **group 1** were extermely calcareous , a salinity between 12.0 and 33.6 dSm^{-1}, indicating moderately to strongly saline, a soil reaction between 7.4 and 9.3, moderately to very strongly alkaline, fine sand fractions of 27.0 to 33.6 %,) Al contents are between 3.0 and 6.5 % and Cobalt value between 19 to 43 ppm.

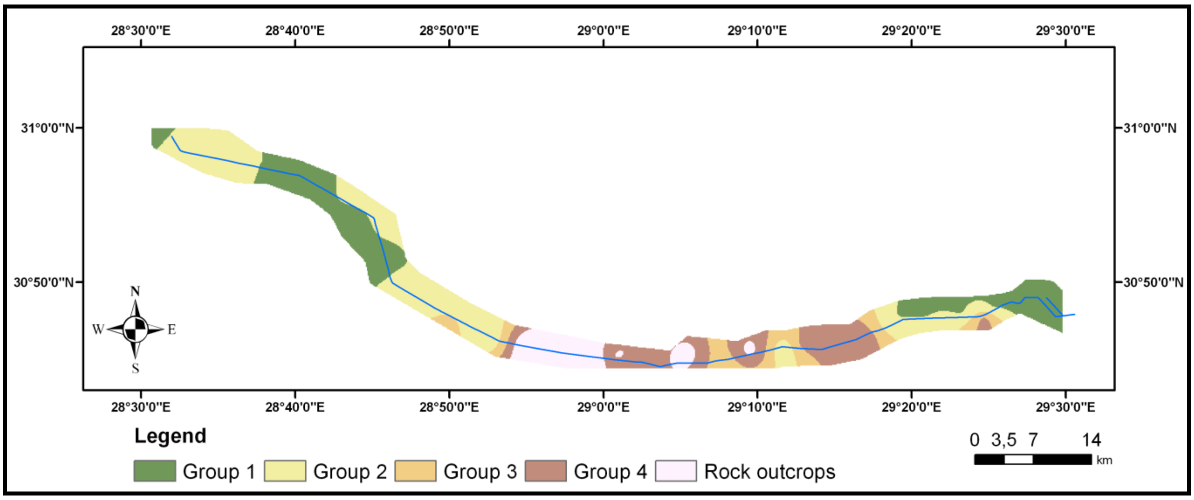


Figure 81: Distribution of cluster groups in the study area

For **group 2, s**oil salinity is less than within group 1 (ECe 1.1 to 15.3 dSm^{-1}) and most of these soils are non-saline to moderate saline. Soil reaction values are moderately alkaline of the most soil samples, extremely calcium carbonate content and low contents of organic matter. Al and Co contents range from 1.72 to 6.48 % and 12 to 33 ppm, for Al and Co content, respectively.

Soil properties in **group 3** are extermely calcareous, non-saline to strongly saline (1.4 to 19.3 dSm^{-1}), moderate alkaline to strongly alkaline (pH 7.8 to 9.3), low in content of organic matter and very low total nitrogen contents and high in Co contents 29 and 75 ppm.

With regard to the levels of soil properties of soil profiles located in **group 4** the obtained data indicates that the soil salinity ranges from non saline to highly saline, pH from slightly to strongly alkaline, and low contents of organic carbon and very low of nitrogen content.

The history of the region during the Quaternary has been a general regression of carbonate sedimentation northward. These sediments rest on an irregular platform cut into Tertiary rocks belonging mainly to the Miocene which are well exposed to the south of the coastal plain. The limestone ridges comprise both marine and aeolian sediments representing ancient shallow marine carbonates and coastal dunes. The thick accumulation of the most sand dunes carbonates it is amount of surface content of each ridges.

Based on total element contents Si, Al, Fe, Mg, K, Ca, Na, Ti, and P for soil profile adjacent El-Hammam canal, the obtained data could be classified into three groups:

Group 1 (profile no. 1, 2 and 43)

Group 2 (profile no. 3, 4, 5, 6, and 8)

Group 3 (profile no. 35, 36, 37, 38, 39, 40, 41, and 42).

By applying a cluster analysis for the soils representing El-Hammam canal extension using the same element contents, soils could be classified into three additional groups:

Group 4 (profile no. 17, 18, 19, 24, 25 and 26)

Group 5 (profile no. 16, 23, 27, 29, 30, 31 and 32)

Group 6 (profile no. 11, 13 and 15)

5.7. Uniformity of soil parent material and effects of soil formation

A wide variety of minerals has been employed but zirconium (Zr), titanium (Ti) and silicon (Si) containing minerals are most known by their high resistance to weathering (Anda et al., 2009). Thus, these elements are considered as potentially immobile constituents in the soils which exhibit enrichment with increasing weathering. It is recognised that Ti-bearing minerals are less resistant in soils than zircon, that indicates that zircon are be taken as an indix of the weathering conditions and consequently soil development. With respect to soil genesis, distribution of Zr, Si and Ti are taken as an indication of maturity and/ or the inheritance of soil materials from certain materials enriched in their initial zircon content (Sayed, 2006). Zr concentrations are mainly controlled by the abundance of zircons in the rock and their physical detachment from the host minerals upon weathering, while Ti mainly depends on the release from the structure of biotites, through chemical weathering (Taboada et al., 2006).

Zircon, rutile and biotite are the dominant sources of Zr and Ti in the soil matrix. Within the studied soils Zr content is positively correlated with Si content ($r = 0.125$), Ti content ($r = 0.735$), coarse sand ($r = 0.079$), fine sand ($r = 0.005$) and silt +clay (< 0.063 mm) fractions ($r = 0.226$). *Zircon is formed as residual grains in the sand and silt fractions of soils, because of its stability in pedogenic environments it is frequently related to the degree of soil development and soil age* (Vissarion and Nikolaos, 2005). In contrast, Ti contents have a negative correlation with Si ($r = -0.138$), medium ($r = -0.464$) and fine sand fractions ($r = -0.399$). This result indicates that Zr is enriched in the coarse particle fraction of the soils whereas the concentration of Ti is higher in the smaller fractions.

The Zr distribution in the weighted mean of the soil profiles is given in Figure 82. The lowest values are analysed in the west of El-Hammam canal extension and east of El-Hammam canal. Lowest values of Si (see Figure 43) and Zr contents occur in deep developed soils, while the largest concentrations are found in depressions with shallow soils.

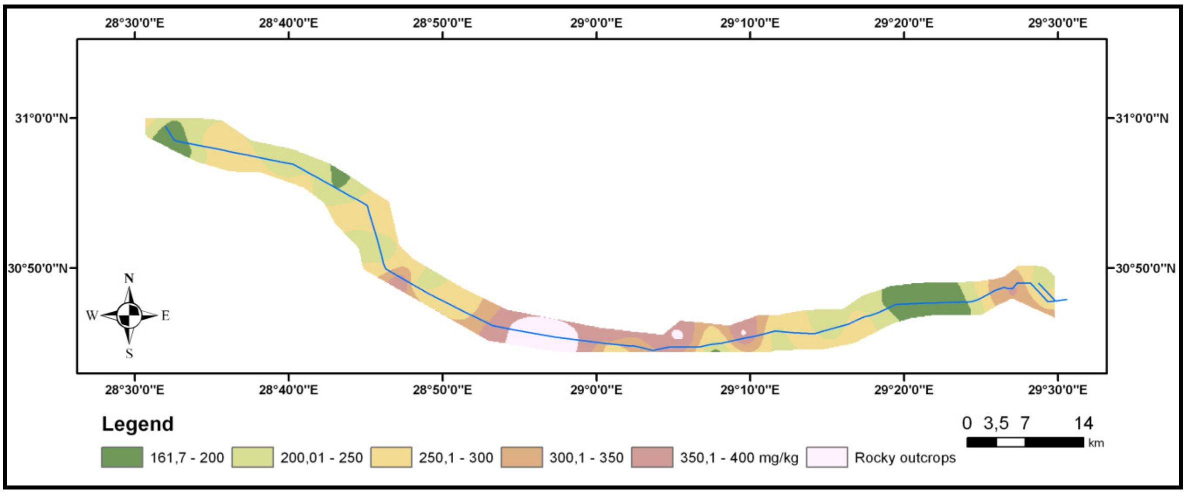


Figure 82: Distribution of Zr content in the study area

The lowest weighted mean values of **Titanium** contents are detected in El-Hammam canal soils, while the highest values are represented very shallow soil profiles of El-Hammam canal extension .TiO_2 weighted means values are ranged from 0.20 % and 0.48 % (Figure 83).

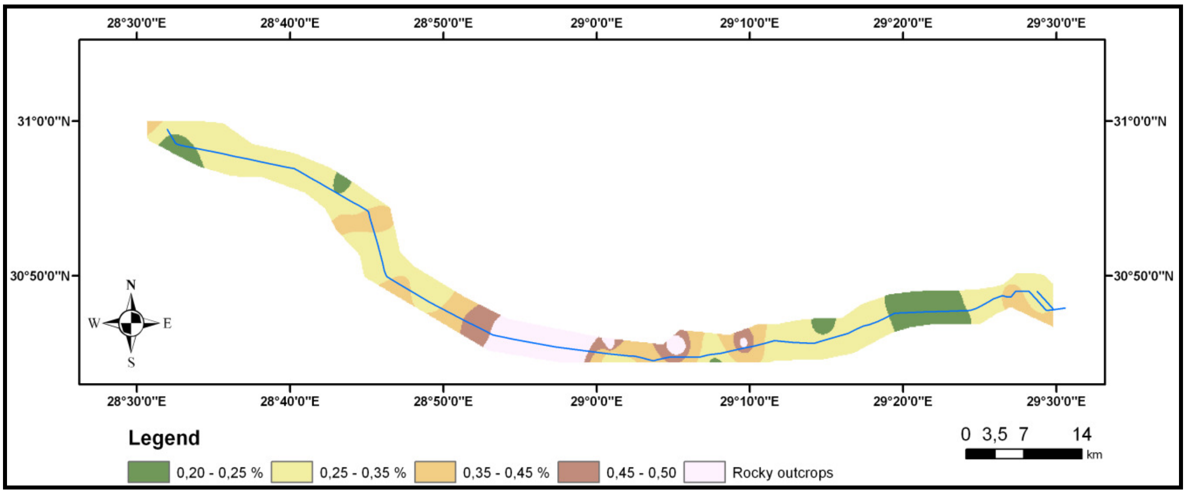


Figure 83: Distribution of TiO_2 content in the study area

Regarding the distribution of weighted mean contents of Zr, TiO_2 and SiO_2, the highest values are found in shallow and very shallow soil profiles. Depth distribution of Zirconium, titanium and silicon (Figure 84 and Figure 85) were taken as criteria for investigating of profile uniformity and weathering sequence for these sediments. These ratios indicate that the soils are mostly formed under inhomogeneous depositional regimes. The most common methods to evaluate parent material uniformity are the examination of sand/silt+clay and TiO_2/Zr or/TiO_2/SiO_2. Data presented in Figure 86 can be interpreted in a way that different degrees of weathering do occur within the soil profiles. However, as soil profiles are not homogenous with regard to the parent material, these results indicates that soils are weakly developed.

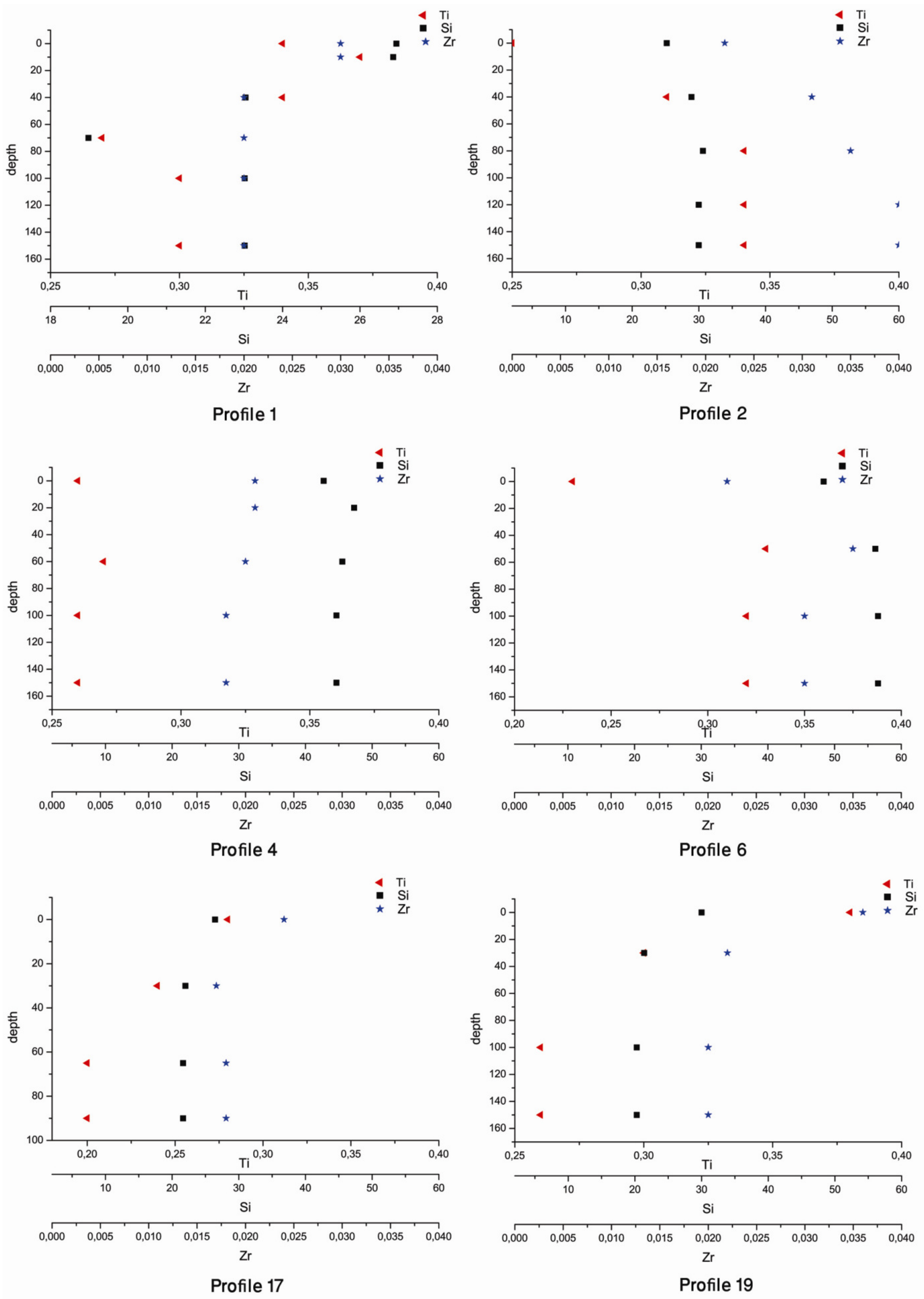


Figure 84: Depth distribution of Zr, Ti and Si for selected profiles

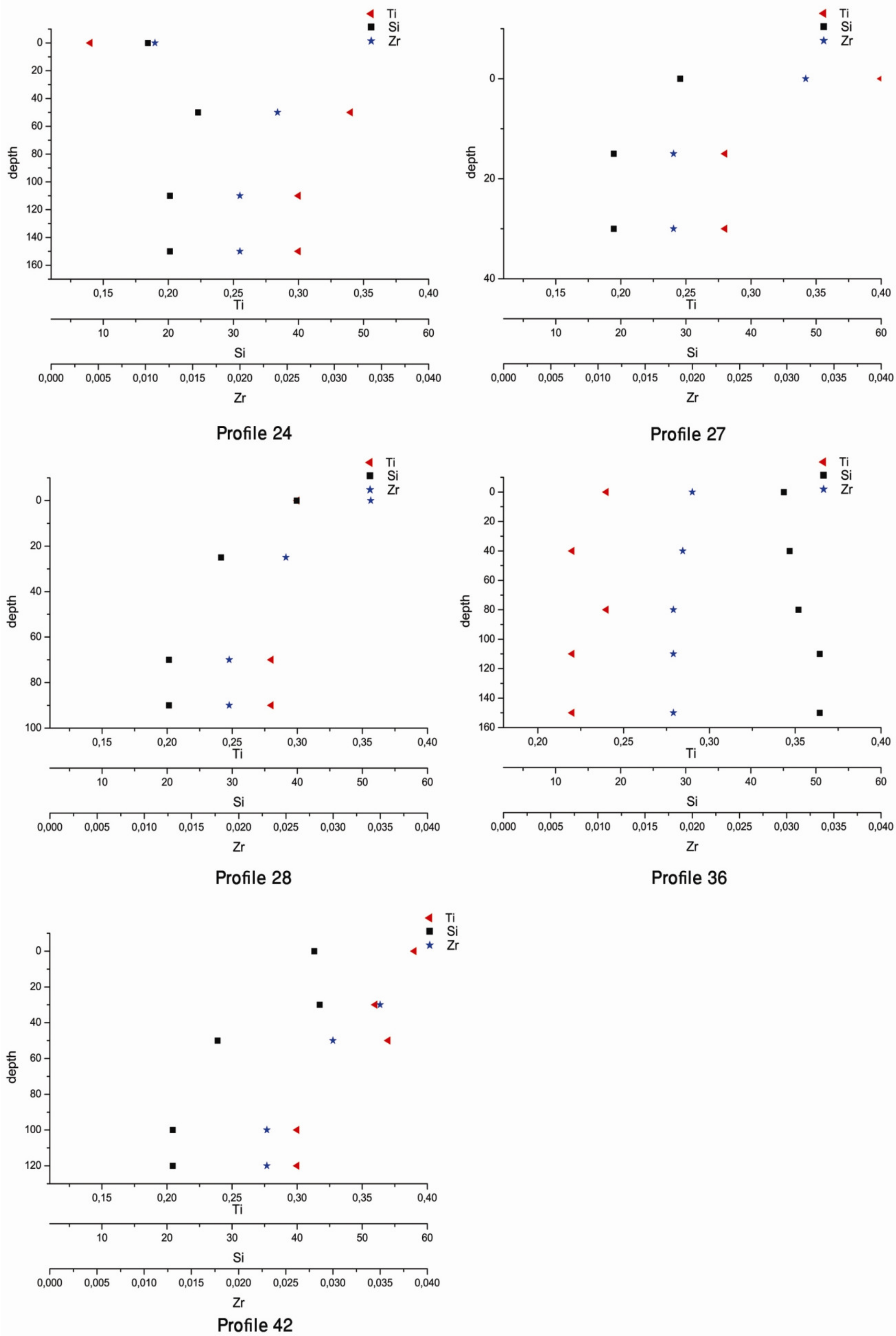


Figure 85: Depth distribution of the Zr, Ti and Si for selected profiles

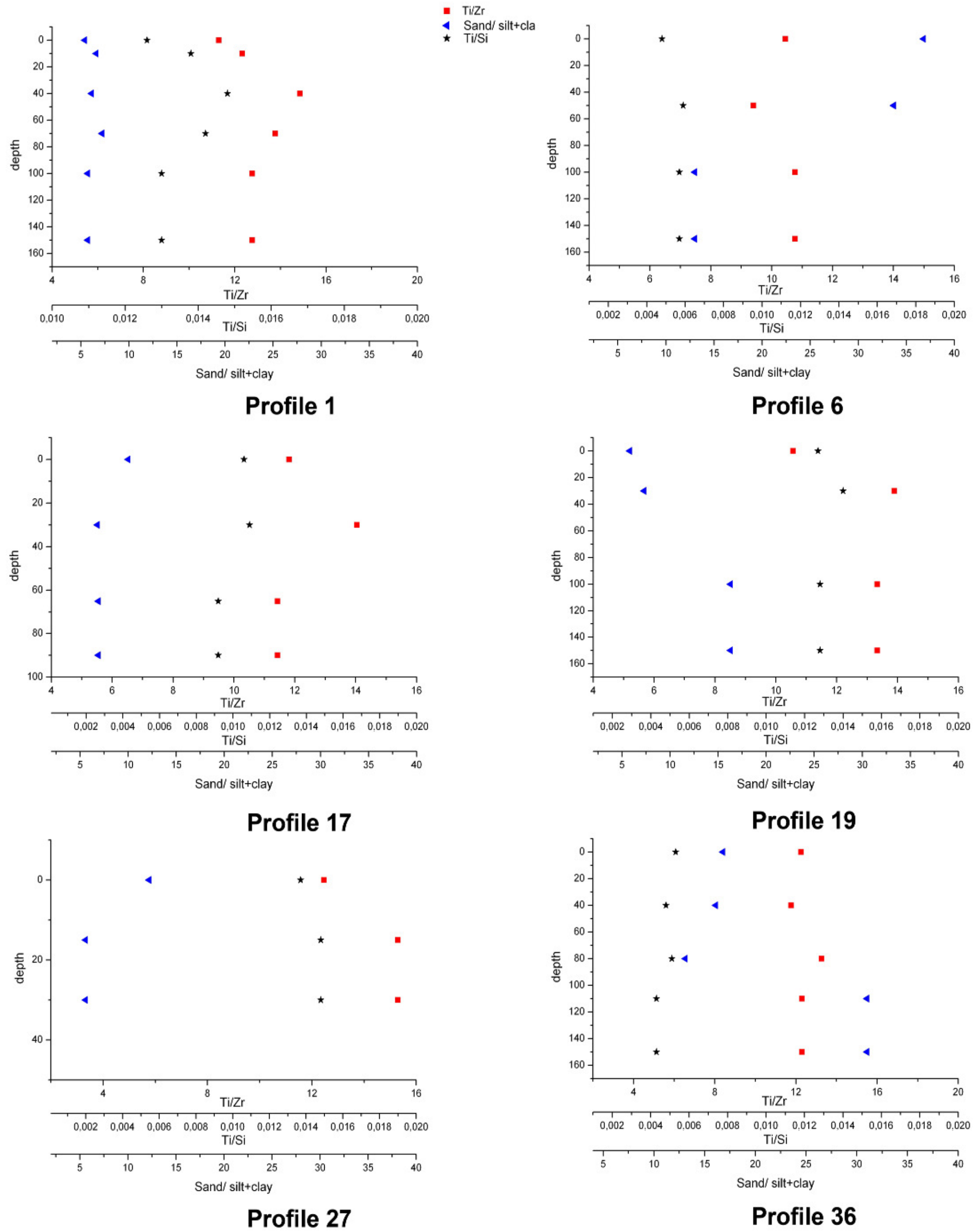


Figure 86: Depth distributions of sand/silt+clay, Ti/Zr and Ti/Si ratios for selected profiles

The weathering ratios of soil samples are irregular distributed with regard to depth and location of soil profiles. This is expected due to the formation of soils from different parent materials of heterogonous nature and/or multi-depositional regimes. Weathering ratios for different layers of most soil profiles indicates that the most active zone of weathering is surface layers.

Generally, the soils under study are pedologically young and are weakly developed along El-Hammam canal. However, based on data for Zr, Ti and Si the uniformity of the profiles was grouped (Figure 87) and further differentiated into subunits (Table 22). The obtained values indicate no consistent trend of the Ti/Zr and Ti /Si ratios in the studied soil profiles; this may be attributed to the fact that these soils had multi-origin or formed under multi-sedimentation regimes. Elements content, for the soils under study provide some indication of depositional variations or relative uniformity of the deposits at various sites. For example, the zirconium and titanium contents of soil profiles representing group A, were lower than elements contents of group C. This could suggest a role of physical weathering and transport by water or wind from coastal dunes and ridges.

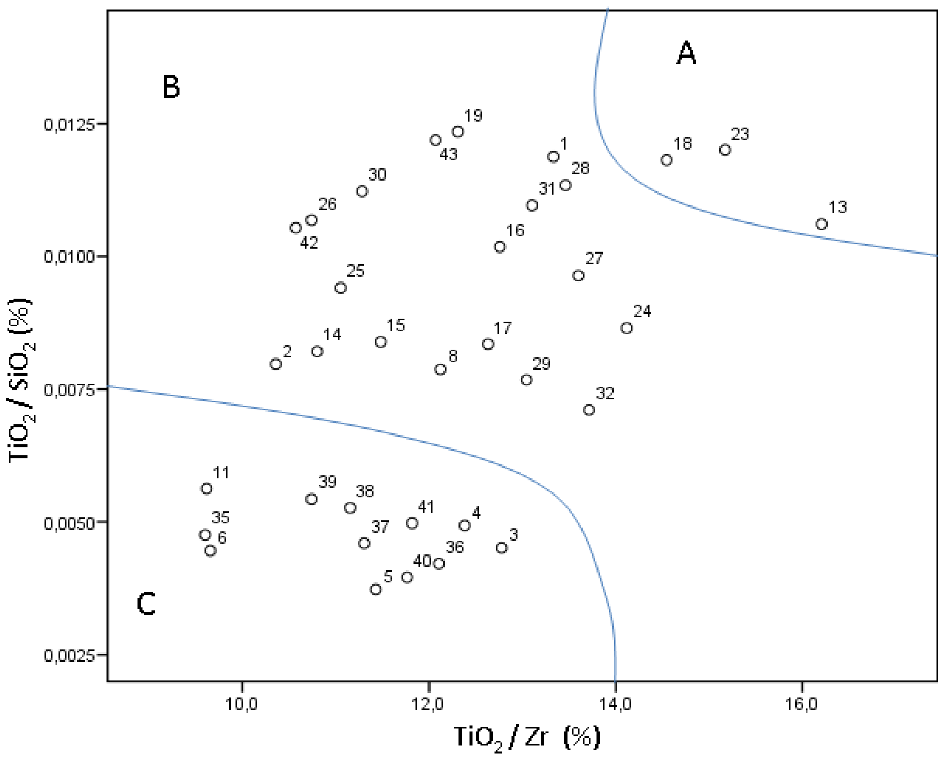


Figure 87: The main groups of soil uniformity

On the other hand, the relative elements values and ratios in the surface layers could be due to the continuous translocation of sand fraction with sediments of different nature. According to the data represented in Figure 88, soil profiles representing group C are located mostly along El-Hammam canal extension.

The highest contents are detected subsurface layers, which represented soil profiles near to the ridges and rock outcrops. From the data presented in Figure 89, it is clear that the soils are composed of heterogeneous materials. Contents of gravel and sand/silt +clay percentage of the investigated soils are relatively low in mostly group A and B soil profiles. Soil profiles which represented group C are located along El-Hammam canal extension except soil profile no. 8 in El-Hammam canal. The highest gravel content is detected in eastern side and increased to the west.

Table 22: Uniformity of soils based on TiO_2/Zr and TiO_2/SiO_2 ratios

Uniformity group	Uniformity unit	Uniformity sub-unit	Profile No.
A	A1		6, 11 and 35
	A2	A2-1	37, 38 and 39
		A2-2	3 and 4
		A2-3	5, 36, 40 and 41
B	B1	B1-1	26, 30 and 42
		B1-2	2, 14, 15 and 25
	B2	B2-1	19 and 43
		B2-2	1, 16, 28 and 31
	B3	B3-1	8, 17 and 29
		B3-2	24, 27 and 32
C	C1	C1-1	18 and 23
		C1-2	13

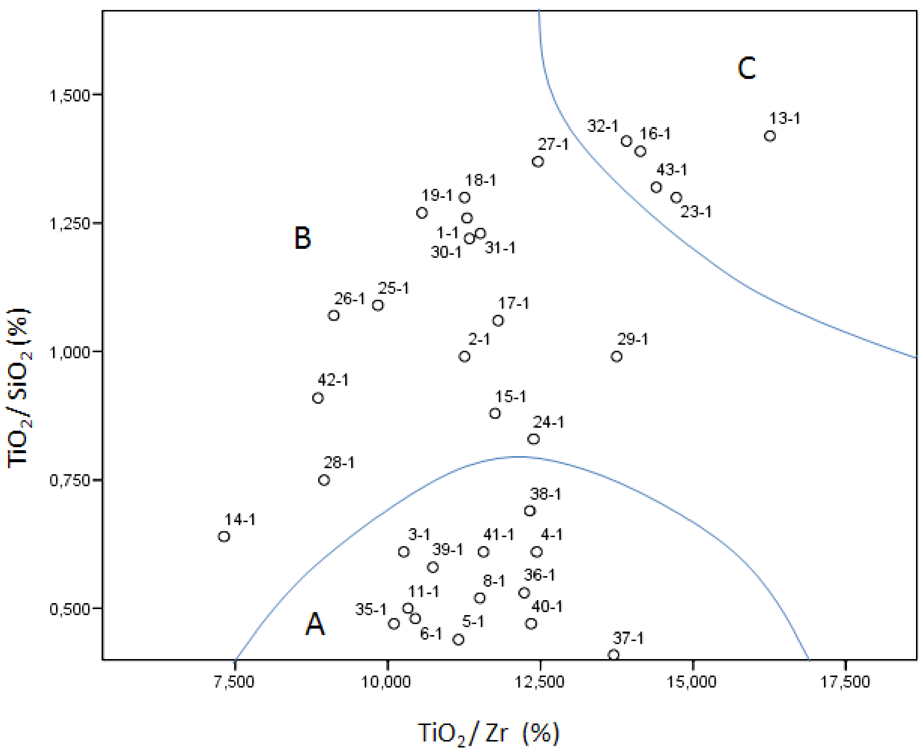


Figure 88: Distribution of soil uniformity indicators of topsoil samples

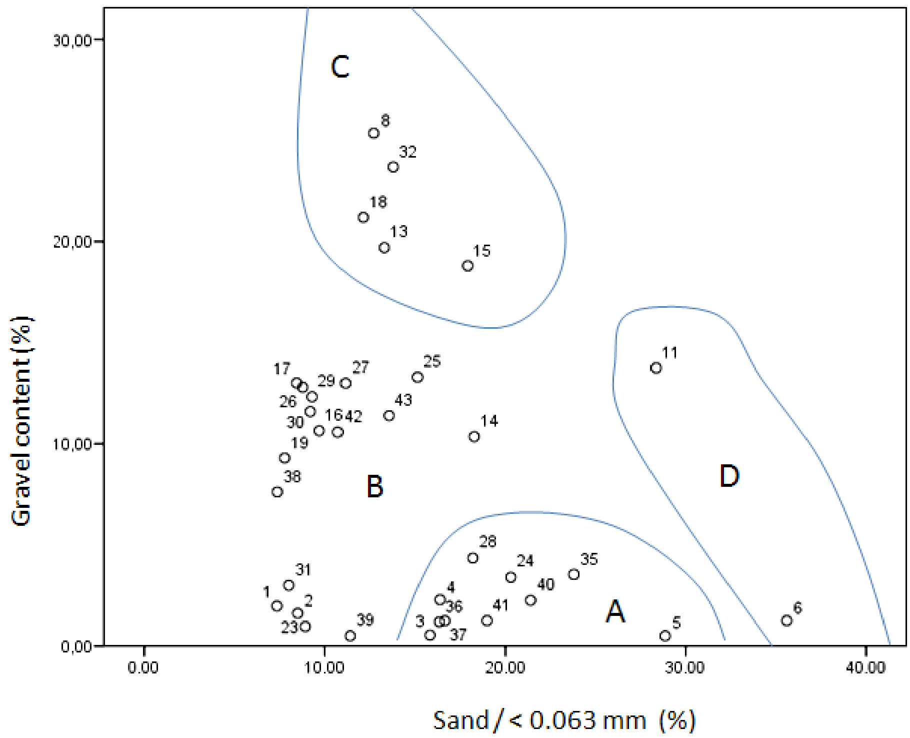


Figure 89 : Soil uniformity based on gravel contents and sand/ silt + clay percentages

The relatively high contents of heavy minerals in the deepest layers may be associated with the sedimentation regime rather than the effect of weathering processes. Highest concentrations of Fe_2O_3 may be related to be obtained from a goethite mineral. The strong association of elements such as Al, Fe, Ni, Mn and Zn in deepest horizons suggests a similar source. Vertical distribution of Al and Fe contents is strongly associated of soil profiles along El-Hammam canal and its extension (Figure 90). Low values of Al_2O_3/SiO_2 confirm the quartz enrichment in the sandstone. Heavy minerals occur mostly in lower proportions than in the soil profiles to the west (along El-Hammam canal extension).

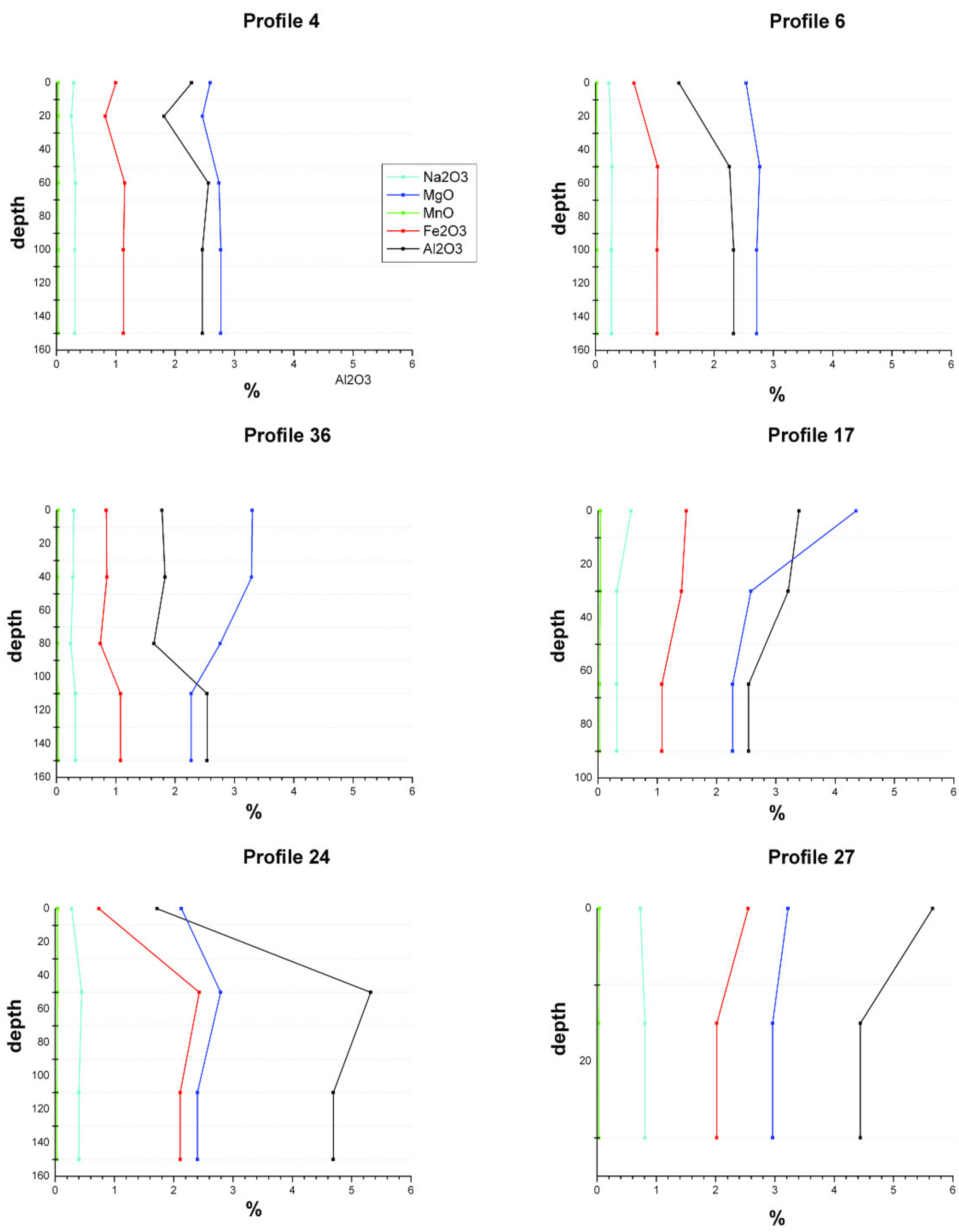


Figure 90: Depth distribution of major elements for selected soil profiles

Deep coarse-textured soils along El-Hammam canal occupy an areas that was formed from materials washed from the neighboring ridges and hills. Further, these areas constitute the main potential agricultural land.

The most significant factors affecting soil formation are climate, parent material and topography. Soil transportation by wind and water is the dominant factor. The dominant parent material is limestone. Sandstone and metamorphic rocks may also be encountered.

Wind-blown sand constitutes a major part of the soil in some areas. Water deposits usually fill the depressions and form the deep soils overlaying a thick layer of limestone (Mahmoud et al., 2009).

In general, the distribution patterns of soil minerals and elements that are identified as relatively high resistant to weathering and persist for a long time such as zircon, silicon and titanium among profile layers can indicate soil uniformity. The data reveal some variations among the horizons of the profiles. This assures that these soils are formed from materials of multi-origin and/or heterogeneity nature. According to the distribution of major and trace elements, considered mainly related to the source rock composition, is in accord with a provenance from the continental crust (limestone rocks, igneous rocks and quartz rich sediments). Soil profiles compared to the underneath layers are due to the difference in parent materials (source) and non-homogeneity, especially soil profiles represented along El-Hammam canal extension. Vertical distributions of the main soil properties and major elements of deepest layers are mostly homogenous; this indicates that the deepest layers of soil profiles could be formed under similar depositional regimes. Generally, the soils under study are pedologically young and are weakly developed.

5.8. Assessment of heavy metal pollution in the study soils:

Assessing the concentration of potentially harmful heavy metals in the soil is imperative in order to evaluate the potential risks to residents. Also, the presence of heavy metals in soils represents a significant environmental hazard, and one of the most difficult contamination problems to solve. Total heavy metal concentrations were determined in soil samples, the range of total concentrations of the most elements are presented in Table 23. With regards to the ranges of heavy metal concentrations, results shows that heavy metal contents are in a range of normal soil. Except for surface, subsurface and deepest layers of profiles no 31, 36, 38 and 41 of Co concentrations, whose ranges from 75 to 121 mg/kg. High contents of Co element content could be attributed to mafic minerals such as pyroxene, biotite and hornblende.

Heavy metal concentrations in sediments in the Western Harbour of Alexandria were determined by (Mostafa et al., 2004). Mostly of heavy metals concentrations in the sediment samples were above the thresholds that were believed to be safe for living organisms. Also, high sediment concentrations of heavy metals in the Western Harbour of Alexandria could result in accumulation in biological system and produce adverse health effects. Cobalt, chromium and manganese contents are higher than acceptable values in natural soils in highway side soils, Iran. High contents of these elements could be attributed to anthropogenic effects related to traffic sources (Saeedi et al., 2009).

Soil quality evaluation criteria used the National Soil Environmental Quality Standard (standard of agricultural land) according to (Liang et al., 2011). Based on heavy metals results for Pb, Cr, Cu, Ni and Zn, it is clear that the evaluation criteria levels are detected in normal levels and lower than national standard level.

Cobalt weighted means highest contents are recorded in soil profiles representing coarse-textured soils and along El-Hammam canal (Appendix, Table 46). On the other hand, the lowest value is presented in deep coarse-textured soil profiles that located end El-Hammam canal extension. High weighted mean contents of Cu are detected in deep and moderately coarse-textured soils along El-Hammam canal. Ni, Pb, Zn and Cr weighted means are recorded in shallow and very shallow soil profile, while the highest values are presented in deep coarse-textured soils. In general, heavy metals distribution along studied soils based on landscape, soil texture and soil reaction (pH).

Table 23: Concentration range (mg/kg) of heavy metals in soil samples with normal ranges in soils

Element	Study soil range	Normal soil range	Element	Study soil range	Normal soil range
Ba	**77-214**	**10-3000**	**Sc**	**1-16**	**0.5-55**
Co	**9-121**	**0.5-65**	**Th**	**1-14**	**1-35**
Cr	**15-45**	**5-1500**	**U**	**1-9**	**0.7-9**
Cu	**1-11**	**2-250**	**V**	**10-67**	**3-500**
Ni	**1-30**	**2-750**	**Y**	**9-19**	**10-250**
Pb	**1-17**	**2-300**	**Zn**	**4-48**	**1-900**

(Cabrera et al., 1999) and (Santos and Alleoni, 2012)

With regard to the depth distribution of the most heavy metals contents, it is clear that surface and subsurface layers differ in their contents. Figure 91 shows the depth distributions for selected soil profiles which represented the mapping units. Higher contains of heavy metals are recorded in deepest layers which indicates the inhomogeneous parent material and the differences in the natural background values.

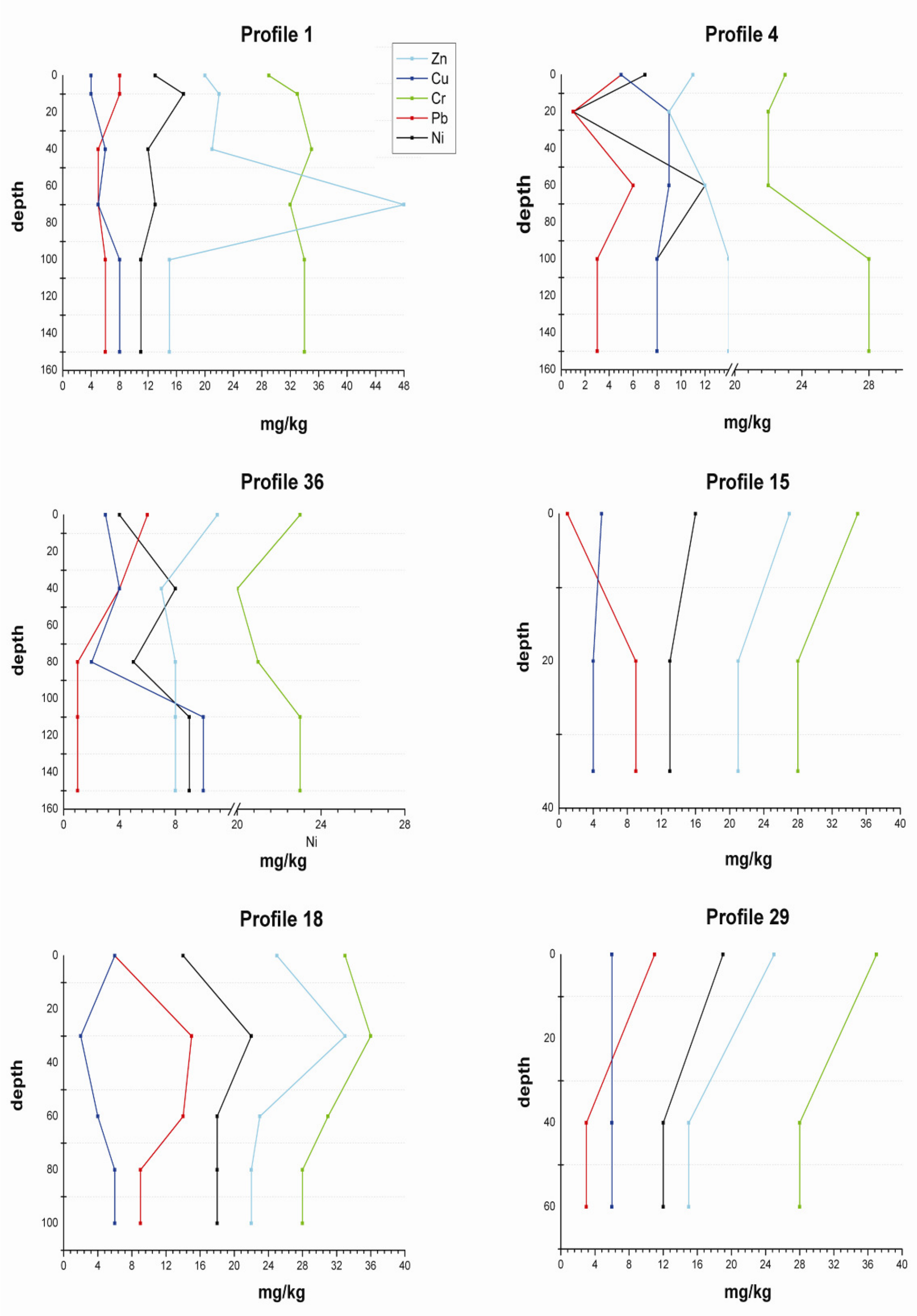


Figure 91: Depth distribution of the heavy metals in selected profiles

CHAPTER VI: SOIL CLASSIFICATION – EVALUATION AND SPATIAL DISTRIBUTION

The main objective of this chapter is the assessment of the soil characteristics (physical, and chemical) and their applicability for land evaluation by using soil classification systems of the selected areas in Egpyt for different agricultural use.

The basic components of land capability and suitability systems in this chapter are currently land capability and suitability classification, (USDA System, 2010) classes and its potential classification. The development of the land capability schemes during the 1930s in the USA marks the beginning of the second major development in the subject. However, the widespread adoption of land capability schemes only began after 1960s. The major aim of the classification was to express the risk of erosion and indicate sustainable land uses. Land suitability analysis is a prerequisite for agricultural production while land suitability evaluation is an examination process of the degree of land suitability for a specific utilization type and/or description method or estimation of potential land productivity (Emadi et al., 2010). The parametric and computer tools of land suitability evaluation method were applied to determine currently and potential land productivity. Land capability assessment**s are** based on a broader range of characteristics rather than soil properties. Further knowledge about slope, climate, flooding and erosion risk, etc. is necessary (Davidson, 1992). Different land capability classification systems, mostly adapted from the USA system (USDA land cabability _ American Method), are used in different parts of the world. To set up an information bank, the results obtained through the different land evaluation methods for different irrigation and all the data for soil characteristics were incorporated into the digital map of the soil series in the ArcGIS 9.2 software. Ultimately, land suitability maps for surface and drip irrigation systems. "*In many places, the land use can be entirely wrong. Land use changes from natural habitat to intensively tilled agricultural cultivation are one of the first reasons for soil degradation. Within a particular area, the positive correlation between present land use and potential land capability is very important. Normally, increasing agricultural land capability correlates with a decrease in the soil erosion process*" (De la Rosa et al., 2009).

The aim of land evaluation is to determined the suitability of land for alternative, currently and potential, land uses that are relevant to the specific area or region conditions. In general, land suitability evaluation was popularly been identified as current physical land suitability and potential land suitability.

6.1. Currently land capability and suitability classification

Current land capability refers to the capability for a defined use of land in its present condition, without major improvement. The north western coastal zone of Egypt is considered as a region with soils of high potentials. Evaluating their capability is an essential stage for future sustainable land use. Potential land capability refers to the capability of units for a defined use, after specified major improvements have been completed where necessary (FAO, 1976).

6.1.1. Land capability _ the American method (USDA System)

Land capability is a qualitative methodology to classify land resources based on soil, topography and climate parameters without taking into account the yield and social economic conditions. The classification is based on soil protection and it evaluates the most suitable kind of land use to achieve this target like rain-fed agriculture, extensive grazing, or forestry. Land is classified mainly on the basis of permanent limitations (FAO, 1977). The general rule is that if any one limitation is of sufficient severity to lower the land to given class it is allocated to that class, no matter how favorable all other characteristics might be. Thus, it is useless to have level land, well drained and free from flooding, if it only has 10 cm of soil that is too shallow to practice any crop production. (Dent and Young, 1981) Indicated that this type of classification emphasizes the negative features of land, which is taken into account in assigning different types of land to capability classes. Soil erosion hazard, and hence conservation requirements, normally gets more attention.

The term "land capability" is used in several land classification systems notably that of the Soil Conservation Service of the U.S. Department of Agriculture (Klingebiel, 1961). This classification system is a general approach, not related to a specific land utilization type. The land capability classification identifies the eight classes described in Chapter II. Data from Table 24 and Figure 92, land capability class IV was represented of the soil profiles have very distinct limitation. The main limitation is calcium carbonate content and moderately limitations are organic matter, alkalinity, drainage and texture. Land capability class V includes soils that have very severe limitations such as texture, soil depth, content of calcium carbonate and of organic matter.

Non-arable land located in area that have rocky out crops in surface andwere restricted by shollow soil depth, coarse texture, high calcium carbonate content and very low organic matter content. Land capability was applied to determined potentiality for agricultural development of the Delta of Wadi Hodein in the southern desert of Egypt .The results showed the region classified as capability classes III, IV and V. The limiting factors in this region are the water avaiablity, dry climate conditions and coarse texture (El-Taweel, 2006).

Land capability classification (the American method) was used to assesment soils at a site in Idoffa, Southwestern of Nigeria. The result showed that the most soils range from class II to VI. The main limitation factors were shallow soil depth, high gravel content and low fertility status (Oluwatosin, 2006). The USDA land capability classification (LCC) system is the best-known example of interpretative groupings of soils and the one most widely used. There are some problems such as there is no standard procedure to account for the separate effect of each soil factor. The American LCC system completely ignores the economic factors and the land is not evaluated for specific uses. The LCC system is useful for conservation farm planning and for grouping soil survey map units into general management groups (AGENCY, 2003)

Table 24:Land capability classes and their description

Capability Class	**Land use**	**Description** (Davidson, 1992)	**Profile No.**
Class IV	Suitable for cropland	Soils that have very severe limitations that restrict the choice of plants or require very careful management, or both.	1, 2, 43, 42, 38, 23, 18, 19, 25, 26, 17, 28, 29 and 31
Class V	Suitable for pasture, range, woodland and others.	Soils those have little or no hazards of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.	3, 4, 5, 6, 8, 11,14, 15,16, 24, 27, 35, 36, 37, 39, 40 and 41
Class VII		Soils that have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.	9, 10, 12, 13, 30, 32, 33 and 34

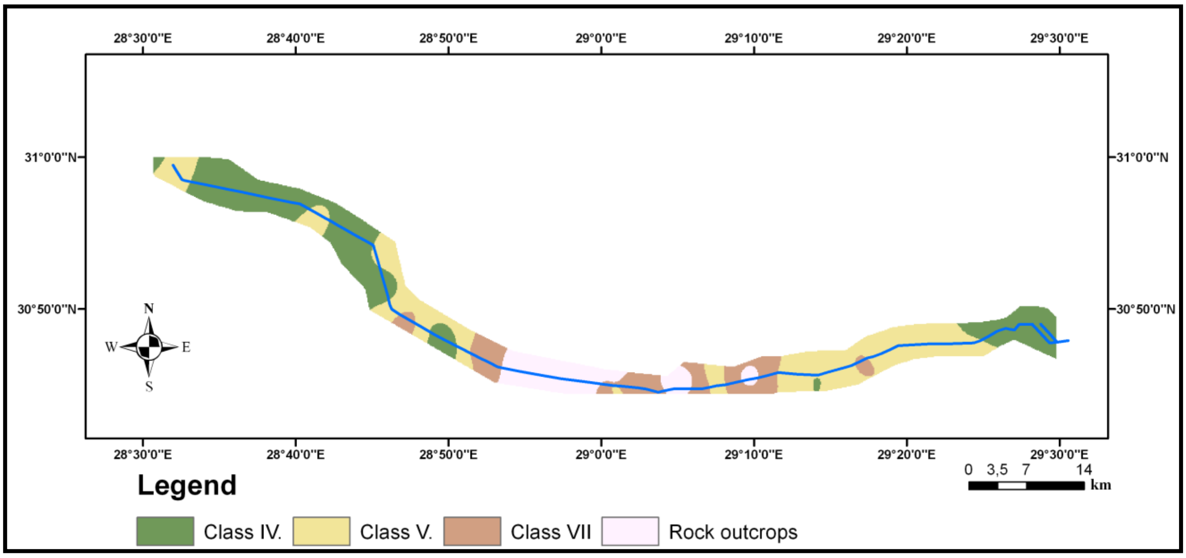


Figure 92: Land capability classes of the study area, (according to the American method, USDA)

6.1.2. Parametric system, land capability and land suitability for irrigation

The land evaluation was determined based on topography and soil characteristics of the region. In parametric approach, the land is evaluated according to numerical indexes. "*The parametric land evaluation consists in numerical rating of different limitation levels of land characteristics according to a numerical scale between the maximum (normalised as 100%) and the minimum value*" (Jafarzadeh et al., 2008).

6.1.2.1. Storie Index Method

6.1.2.1.1. Storie Index, according to Storie (1978)

The Storie Index is a semi-quantitative method of rating used mainly for irrigated agricultural based on crop productivity data collected from California soils in the 1920s and 1930s (O'GEEN, 2008). Soil factors, characteristics and soil grading are described in the Storie index (1978) and can be distinguished in Table 25. This index expresses numerically the relative degree of suitability, or value, of a soil for general intensive agriculture. The rating is based on soil characteristics only, other local factors, such as availability of water for irrigation, climate, and distance are not considered. Therefore, the use of the index is limited for land evalution.

Table 25: Soil factors, characteristics, soil grading and rating in Storie index, 1978

Factor	Soil characteristics	Soil grade	Rating %
A	Rating on physical properties	Grade 1 (Excellent)	80-100
B	Rating basis of surface texture	Grade 2 (good)	60-79
C	Rating of basis of slope	Grade 3 (fair)	40-59
X	Rating of contestations other than those in factor A,B and C Drainage , Alkaline, Nutrient level, Erosion and Microrelief	Grade 4 (poor)	20-39
		Grade 5 (very poor)	10-19
		Grade 6 (non-agricultural)	0-9

The factors A, B, C and X are evaluated because of a score ranging from 0 to 100 percentages, and the scores are then multiplied together to generate an index rating (Storie, 1978). Lower percentage ratings are given for conditions less favorable for crop production, while the most favorable or ideal condition has a rating 100 percent. Applying the Storie index (Storie, 1978), the productivity indices show that the soil types identified in all soil profiles which represent El-Hammam canal and Extension are inTable 26. The main results indicate that the productivity ratings and soil grade poor, very poor and non-agricultural (Figure 93).

Soil grading (4 = Poor): These soils are deep, coarse textured, have moderately affected with alkaline and poor nutrient level.

Table 26: Land productivity and soil grade of El-Hammam Canal and extension (according to Storie, 1978)

Productivity rating	Soil grad Capability classes	Profile No.
Grade 4 20-39	Poor (Soils that rate between 20 and 39 per cent and which have a narrow range in their agricultural possibilities)	1, 2, 37,38 and 43
Grade 5 10-19	Very poor (Soils that rate between 10 and 19 per cent are of very limited use except for pasture, because of adverse conditions such as shallowness, roughness, and alkaline content)	3, 4, 5, 6, 19, 23, 25, 26, 28, 29, 35, 36, 39, 40, 41 and 42
Grade 6 0--9	Nonagricultural (soils that rate less than 10 per cent include, for example, tidelands, river wash, soils of high alkali content and steep broken land)	8,11,13,14,15,16,17,18,24 ,27,30,31 and 32

Soil grading (5 = Very Poor): These soils are deep to moderately deep soils coarse textured, have moderately to strongly affected and moderately affected with alkaline and poor to very poor nutrient level. Soil profiles (6, 19, 25, 28 and 39) are very poor, but with the addition of natural soil conditioners to improve physical properties such as gypsum and organic matter, these lands grow up to Grade 4.

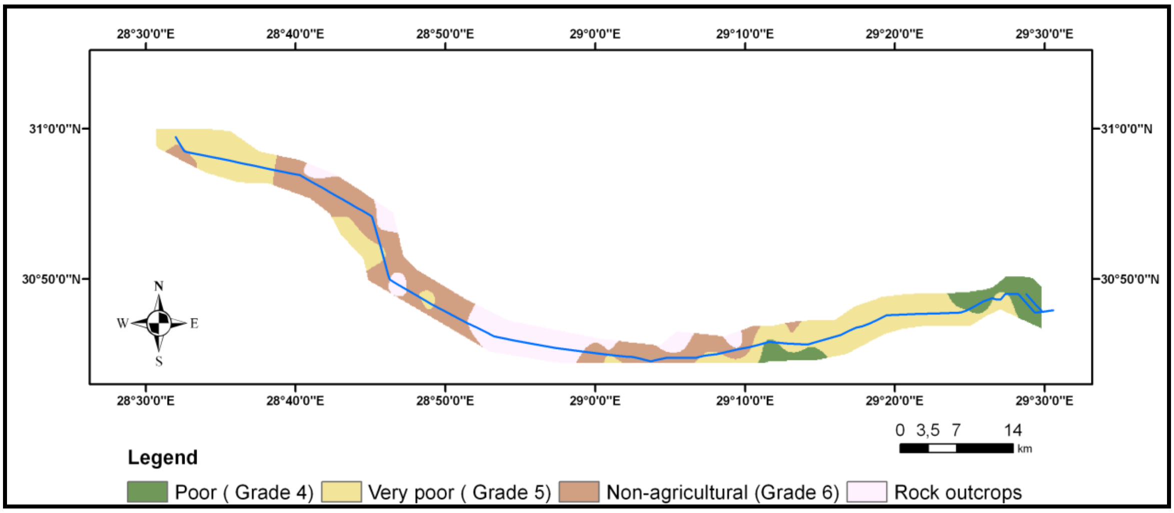


Figure 93: Land productivity of the study area, according to Storie, 1978

Soil grading (6 = Non-agricultural): These soils are deep to very shallow soils, coarse textured, have moderately to strongly affected and moderately affected with alkaline and poor to very poor nutrient level. In this unit some soil profiles are agricultural under rain-fed agriculture (14, 24 and 31), so in the future this area can have the possibility to be improved.

Generally, the main limitations in El-Hammam canal and its extension were soil surface texture, drainage, alkalinity, erosion and fertility. Soil salinity and drainage could possibly be corrected, while soil depth and soil texture limitations have to seen as persistent. Most of soil profiles represented land capability Grade 5, which is charctereized by very deep, coarse textured soils and low salinity (see Table 29). These soils are in the initial plan of agricultural development in the coming period after soil profiles represented Grade 4 (see Table 29); where one need to lower management.

The Storie index (Storie, 1978) was modified according to agricultural conditions of the project area (Dam et al., 2006) and was used to determine soil quality indices. All agriculture lands in the project area are described according to their environment and surroundings. All based on soil properties and productive capabilities including texture, structure, depth, drainage, parent material, stoniness, topography, climate and distribution of precipitation. An example is given by the Hydroelectric Power plant Project located east of Yusufeli Town, on the Coruh River in Northeast of Turkey.

The aim of the project was to determine soil quality and quantity by using an index that can be helpful for understanding of the characteristics of the soils in the project area. The Rating Index (Storie, 1978) is a formula whereby the productivity index of the land is developed by multiplying the several factors in the formula. The higher the product, the better suited the land type is for agricultural uses.

Rating Index = **A** x **B** x **C** x **X** x **Y** **Equation 7**

Index values were classified under six groups to evaluate agricultural productivity ratios of the specific soil characteristics, see Table 27. ″The percentage rating for each factor (A , B, C, X and Y) increases as the favorableness of the factor increases. Therefore, it follows that as the land productivity index approaches 100 percent, the agricultural quality of the land increases. Conversely, less desirable lands have low value indexes" (Dam et al., 2006).

According to Storie index modified and used to determine soil quality indices, parameters used for the rating index were detailed. These parameters of rating divided based on soil quality from low (0) to very high quality (100) in the entire determining factors. The soil types identified in all soil profiles which represent El-Hammam canal and Extension could be placed only into the productivity ratings and soil grads (E = very poor and F= non-agricultural). Factor Y (seeTable 27) account for rainfall and associated climatic feature, land in the higher rainfall zones are cloudy and therefore lower in productivity; irrigated lands are rated 100 because the moisture requirement is adequately met. The north-west coast of Egypt is one of the semi-arid areas where rainfall not exceeding 250 m/y. The Storie Index rating for a soil is obtained by multiplying the four factors thus; any factor may control the final rating. In many cases, soil properties such as depth, texture, slope and level of fertility are good but there is another factor such as salinity or alkaline has low index rating; the product of soil quality is very low or low. So the introduction of many soil properties and the application of a special form for each area separately under local conditions, maybe it well are to give an actual result of the soil quality.

Table 27: Soil factors, characteristics, overall rating and index percentages

Factor	**Soil characteristics**	**Overall rating**	**Index %**
A	Rating for the general character of the soil profile	A (Perfect)	80-100
B	Rating for the texture of the surface horizon	B (good)	60-79
C	Rating for slope of the land	C (moderate)	40-59
X	Rating for such factors as salinity , soil reaction , erosion Drainage , stone content ,gravel content , rock content , flooding , lime content ,organic matter content , water storage capacity Natural productivity (effective P_2O_5 and K_2O)	D (low)	20-39
		E (very low)	10-19
Y	Rainfall (considering the special micro-climatic; green house facilities , and tow crops per season)	F (non-agricultural)	0-9

For example, soil characteristics are soil depth, coarse texture, low to moderate fertility, but it has high salinity and moderately drainage. This land in the presence of a source of irrigation water, and coarse texture; soil salinity is not a factor hampering the productivity of the soil. The main limitation of the soil properties in the region under study are soil depth, calcium carbonate content and unsufficant drainage therefore, the establishment of a drainage system parallel to the irrigation canals is the first stage to increase the productivity of land in the soil adjacent of El-Hammam canal.

6.1.2.1.2. Storie Index (2008)

The NRCS has published the Storie Index ratings generated by revised Storie index method, which will reduce the subjectivity associated this form of land classification. The purpose of this publication is to document approach in converting Storie 1978 into the revised Storie index modeled in NASIS. The Storie index assesses the productivity of the soil from the following four characteristics: Factor A, B, C and X, with a score ranging from 0 to 100 % is determined for each factor (O'GEEN, 2008).

Storie Index rating=

$$\left[\left(Factor\,\boldsymbol{A}/\boldsymbol{100}\right)\times\left(Factor\,\boldsymbol{B}/\boldsymbol{100}\right)\times\left(Factor\,\boldsymbol{C}/100\right)\times\left(Factor\,\boldsymbol{X}/\boldsymbol{100}\right)\times\left(Factor\,\boldsymbol{Y}/\boldsymbol{100}\right)\right]\times 100 \qquad \textbf{Equation 8}$$

The most important modifications and differences between Storie Index, 1978 and Storie Index for use with digital soil information in the version of 2008.There are some amendments for the Story Index 1978 system, such as:

1- Improve the objectivity of scoring for factor A, profile groups were condensed from nine in Storie 1978 to four because the range in scores was similar in some group,
2- Dynamic Factor (Factor X) used EC and SAR values to document saline, sodic, and saline sodic conditions, instead of using alkali conditions as described in Storie 1978,
3- An assessment of nutrient status was not attempted in Storie model 2008 because fertility can be a very dynamic property in agricultural settings, depending on fertilization practices and other variables,
4- Flooding frequency and duration of saturation during the growing season were added to Factor X because of their importance in assessing land capability,
5- In Storie model 2008, mecrorelief was not used because it is often not populated in NASIS and land leveling has altered most agricultural land that once contained.

From the data presented in Table 28 and Appindeix Table 48, it is clear that land capability classes of the study area varies from “good” to “non-agricultural ” due to different limiting factors (Figure 94). Some of these limiting factors are not correctable such as; soil depth and soil texture, while salinity and SAR factors that can be correctable.

Table 28: Land capability classes of the study area, according to Storie, 2008)

Capability classes	Productivity rating	Profile No.
Good	60-90	1 and 23
Fair	40-59	2, 3, 4, 5, 6 , 24, 26, 35, 37, 38, 39, 40 and 42
Poor	20-39	8, 14,16, 17, 18, 19, 25, 31, 36 and 41
Very poor	10-19	11, 15, 28 and 43
Non-agricultural	0-9	13, 27, 29, 30 and 32

According to soil mapping units, mostly of soil profile represented land productivity good to poor grade are deep to moderately deep soils and coarse textured, have moderately limitation with texture. Very poor and non- agricultural grades represented by shallow, very shallow and rocky outcrops, except soil are represented by profile (43); these soils are deep, coarse textured soils and highly salinity.

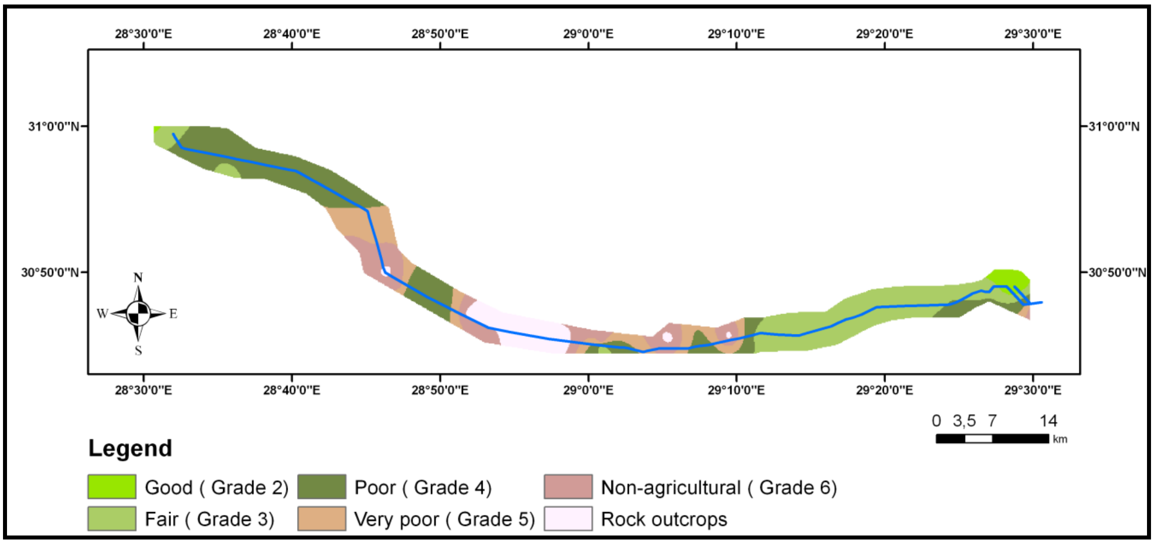


Figure 94: Land productivity of the study area, according to Storie, 2008

6.1.2.2. Land suitability for irrigation, Sys and Verheye, 1978 system.

The parametric approach Sys and Verhey (1978) **is** used to determind the suitability classes of each soil profile for mentioned irrigation systems. This system was to provide a method that permits a suitable evaluation for irrigation purposes based on wetness, topography, physico – chemical characteristics and conditions of salinity and alkalinity of the soil profiles. Applying Sys and Verheys (1978), the suitability index for irrigation (Ci) ranges is 3.3 to 46.5% and suitability classes between marginally suitable (S3) and permanently not suitable (N2), (see appendix Table 49).These classes are distinguished into the following subclasses , seeTable 29 and Figure 95:

S3: Marginally suitable and represented by soil profile (38), which represents a small portion of the area of El-Hammam canal, have coarse textured soil and moderate limitations with salinity and alkalinity.

The soils of this class could be distinguished into the following subclasses:

$S3_{n:}$ Marginally suitable and represented by soil profile (43), which represents a small portion of the area of the El-Hammam canal, have coarse to moderate coarse texture soil and sever limitations with salinity and alkalinity.

$S3_{S1:}$ Marginally suitable and represented by soil profiles (1, 2, 17, 19, 23, 26, and 42), that represents around 25.0 (10^3 ha) and its have coarse textured soil.

Table 29: Land suitability classes and subclasses for irrigation of the study area (according Sys and Verheye, 1978)

Suitability index (Ci)	Suitability Order	Suitability classes	Suitability subclasses	Profile No
25-50	S	S3	$S3_{S1}$	1, 2, 17, 19, 23, 26, 38 and 42
			S3 n	43
>25	N	N1	$N1_{S1}$	3, 4, 5, 6, 8, 35, 36, 37 , 39, 40, 41,18, 25, 14, 24, 28 and 29
			$N1_{S1,S2}$	31, 11,15 and 16
			$N1_{S1S2w}$	27
		N2	$N2_{S1S2w}$	13, 30, 32 and rocky 9 ,10, 12 ,33 and 34
		N2	$N2_{S1S2w}$	13, 30, 32 and rocky 9 ,10, 12 ,33 and 34

N1: Currently not suitable**,** it includes the remaining soils in the area of the study. These soils are characterized by deep to shallow depths, sandy textured throughout the effective root zone depth, well to poor drainage and low to high salinity and sodium hazard. The soils of this class could be distinguished into the following subclasses:

$N1_{S1}$: Currently not suitable, these soils are characterized by very severe limitations in soil texture.

$N1_{S1, S2}$: Currently not suitable and represented by soil profiles (31, 11, 15 and 16). These soils are characterized by very sever in soil texture and severity in soil depth.

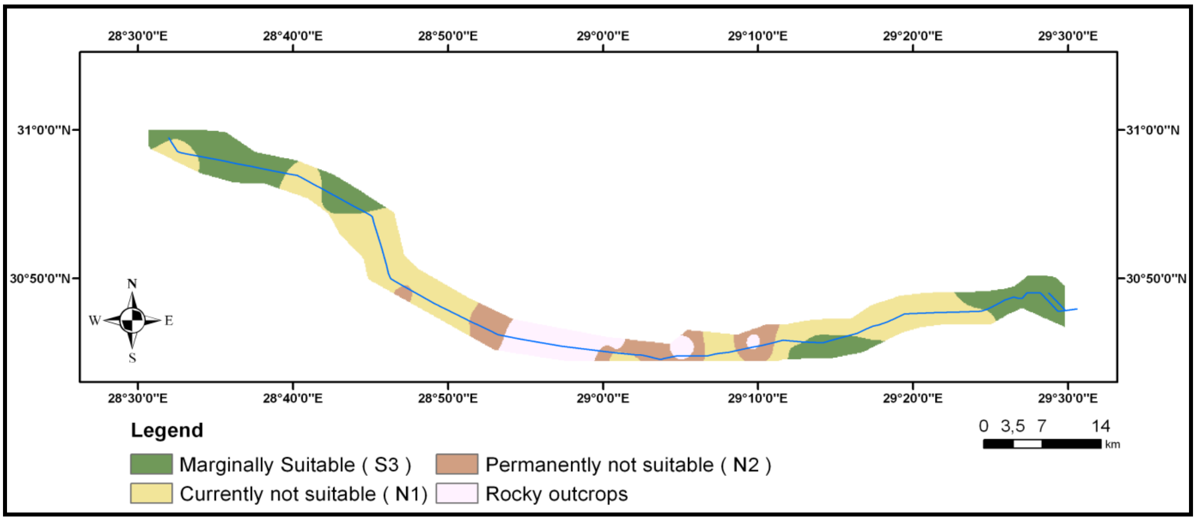


Figure 95: Land suitability classes for irrigation (Sys and Verheye, 1978) system

N1$_{S1,\ S2,\ n}$: Currently not suitable and represented by soil profile (27). These soils are characterized by severe to very severe limitations in salinity, soil depth and soil texture.

N2 $_{S1,\ S2,\ w}$: Permanently not suitable and represented by soil profiles (13, 30 and 32). These soils are characterized by severe to very severe limitations in drainage, soil depth and texture.

According to the previous data, the soil priority for agriculture could start with marginally suitable orders (S3) which are represented by the soil profiles 38, 43, 1, 2, 17, 19, 23, 26, and 42, respectively. Soil profiles (9, 10, 12, 13, 30, 32) probably use in the construction and drainage canals and places of Animal Husbandry.

6.1.2.3. Land suitability for different irrigation systems (Sys et al., 1991)

The main objective of this method is to compare different irrigation methods based on the parametric evaluation system. Parametric evaluation system for irrigation methods suggested by Sys et al. (1991), was primarily based on physical and chemical soil properties. In the proposed system, the factors which are affecting the soil suitability for irrigation purposes can be subdivided into four groups which are physical properties, chemical properties, drainage properties, environmental factors such as slope (Albaji and Boroomand-Nasab, 2010). To evaluate the land suitability for different irrigation methods, the parametric evaluation system described by Sys et al. (1991) was applied using the soil characteristics. These characteristics are used to calculate the capability index for irrigation (Ci). Suitability classes are defined by considering the value of the capability indices (Table 30). The results of the processing of the parametric evaluation system for gravity (surface) and drip (trickle) irrigations are given in Table 31.

Table 30: Suitability classes for the irrigation capability indices (Ci) classes

Soil class	Definition	Land index
S1	Highly suitable	> 80
S2	Moderately suitable	60-80
S3	Marginally suitable	45-59
N1	Currently not suitable	30-44
N2	Permanently not suitable	< 29

For the surface and drip (trickle) irrigation of the soil in the study area were classified as marginally (S3), currently not suitable (N1) and permanently not suitable (N2). The comparison of the two types of irrigation revealed that it would be of more benefit to irrigate by drip irrigation (trickle irrigation). The main of land suitability index for two-irrigation system are 31.3 and 32.4 for surface and drip irrigation, respectively. Whereas, the soils are marginally stable for drip irrigation bigger than soils are marginally suitable for surface irrigation (Figure 96 and Figure 97). The limiting factor to this kind of land use is mainly soil texture, soil depth, calcium carbonate content and salinity

Table 31: Suitability index distribution of the surface and drip irrigation, (According to Sys et al., 1991)

Suitability index (Ci)	Suitability classes	Surface irrigation	Drip irrigation system (trickle irrigation)
45-59	S3	1, 2, 17, 23, 26 and 31	1, 2, 17, 23, 26, 31 and 38
30-44	N1	3, 4, 5, 6, 16, 24, 35, 37, 38, 39, 40, 41 and 42	3, 4, 5, 6, 14, 16, 24, 36, 37, 39, 40, 41 and 42
<29	N2	8, 11, 13, 14, 15, 18, 19, 25, 27, 28, 29, 30, 32, 36 and 43	8, 11, 13, 15, 18, 19, 25, 27, 28, 29, 30, 32, 35 and 43

In the Ben Slimane Province, Morocco, the parametric system (Sys et al, 1991) applied to evaluate land suitability for both surfaces and drip irrigation (trickle irrigation). The results indicated to the largest part of the agricultural areas was classified as marginally suitable, the most limiting factors being physical parameters such as slope, soil calcium carbonate, sandy soil texture and soil depth (Briza et al., 2001).

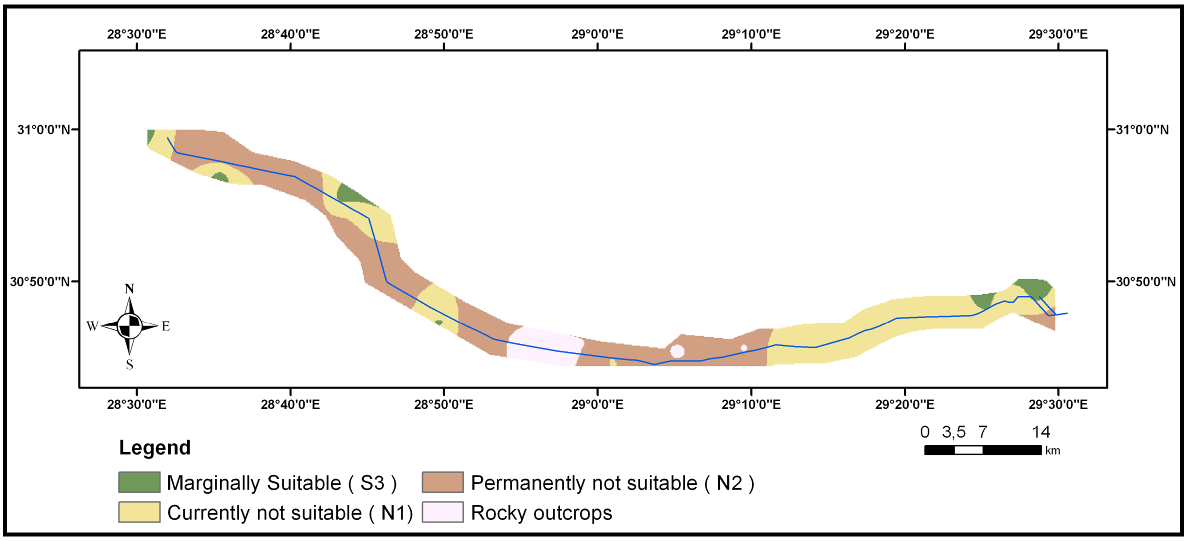


Figure 96: Land suitability classes for surface irrigation (Sys.C et al., 1991)

Land suitability evaluation for surface irrigation and drip irrigation (trickle irrigation), in the Tunisian Oued Rmel Catchment **uses** the suggested parametric evaluation. According to the results, the drip irrigation suitability gave more irrigable areas compared to the surface irrigation practice due to the topographic (slope), soil (depth and texture) and drainage limitations encountered within the surface irrigation suitability evaluation (Mbodj, 2004). In

Southern Ankara, Turkey, land suitability evaluation was applied by parametric for surface and drip irrigation. After analyzing and evaluating soil properties, by using geographic information system techniques, gravity and drip (trickle irrigation) suitability maps were generated. Results showed that 51.2% of the studied area was highly suitable for drop irrigation method, whereas, 13.1% was highly suitable for surface irrigation methods. On the other hand, it was found that some soils were not suitable for both irrigation systems. The main limitations factor were soil texture and soil depth for both irrigation system (Dengiz, 2006).

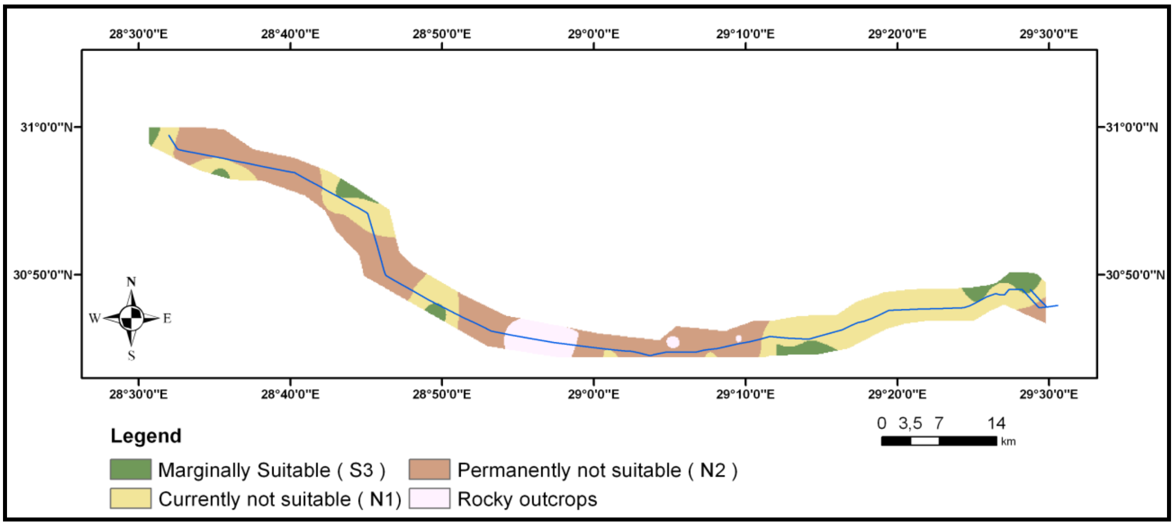


Figure 97: Land suitability classes for drip irrigation system

The different soils in Iran were studied to evaluate different of irrigation system and using parametric method (Sys et al, 1991). Shavoor plain, the plain west of Shush, Abbas plain, Boneh Basht plain, Dosalegh plain and the plain west of south Iran were studied by (Albaji and Boroomand-Nasab, 2010; Albaji et al., 2009; Albaji et al., 2010b; Albaji, 2009). Their results showed that drip irrigation proved more suitable than surface irrigation system in the most of studied areas. The major limiting factors for irrigation methods were soil texture, soil depth, calcium carbonate content and salinity. Drip and sprinkler irrigation systems are more suitable than the surface irrigation in the Miheh plain, Iran. The most limiting factors for drip and sprinkler irrigation methods were soil texture, slope and calcium carbonate content, whereas, slope and soil texture were limiting factor for surface irrigation method (Mehdi Jovzi et al., 2012).

Generally, the obtained results reveal that the soils are suitable for both surfaces irrigation and drip irrigation at various rating levels. The main recommendation: It is better to irrigate the soil using the drip irrigation system since it proves suitability to the irrigation purposes and ensures the sustainable use of the land for irrigation agriculture. The quality of water used for irrigating the soils must be evaluated appropriately. Further studies have to be carried out on water quality requirement for irrigation agriculture in this area. The main limitations factors were soil texture, calcium carbonate content and salinity. So, it is better to use surface irrigation especially in area belongs to highly EC in the surface layer and highly content of $CaCO_3$. In respect to the ECe value, it could expect helping in leaching salt out of the profile. Whereas, the soils with high salinity could irrigate by surface irrigation until leaching salt is completed then replaced by drip irrigation.

6.1.2.4. Land Suitability Classification for Different Crops, (according the system of Sys et al., 1993)

In this study, the approach was selected for land suitability evaluation of the study area, since it is valid for irrigation purposes in arid and semi arid regions. In the process of qualitative land suitability for crops, it is the physical-chemical soil characteristics (texture, structure, stones, profile depth, $CaCO_3$ status and gypsum status). Ratings, attributed to land qualities, were matched with each crop requirements these land qualities are drainage, soil texture, gravel percentage, soil depth, calcium carbonate content, salinity (EC), soil reaction (pH), sodicity (ESP) and fertility condition.

Soils adjacent El-Hammam Canal and its extension, crop requirement proposed by (Sys, 1993) was used to evaluate the soils of the study area for the most promising crops to be cultivated. The own results shows that these soils are represented by soil profiles (13, 30 and 32); with all certain crops under study except maize and onion are currently not suitable lands. Land suitability for the most important crops (fruits - vegetables - field crops and fodder crops) in the study area according to (Sys, 1993) is shown inTable 32. Results of applying this system indicate that crops already in the study area are the most suitability crops for arid and semi-arid soils. As shown from Figure 98, the suitability for the most crops varies from “marginal suitable” to “not suitable” due to different limiting factors.

Based on the obtained results, the following land suitability classes are proposed:

Highly suitable land (S1): In the area under study, soils of this class cover a very small area; these soils could be cultivated with wheat and guava.

Marginally suitable land (S3): In the area under study, soils of this class cover a small area; these soils could be cultivated with maize, wheat, barley, tomato groundnut and Guava. But with sorghum, fig and olive are covering more than 15 soil profiles, these data already accepted with requirements for Farmers in this area,

Currently not suitable land (N1): This includes land having very severe limitations that are not economically feasible to be corrected with existing knowledge. From the data showed, it is clear that soil represented a lot of soil profiles and all crops.

Permantly not suitable land (N2): Limitations of this land are so severe limitation as to preclude any possibilities of successful sustained use of the land. These soils have severe and very severe limitations, e.g., textural, soil depth, Calcium carbonate content, gravel content, salinity and fertility.

Table 32: Land suitability of El-Hammam Canal and extension for the most suitability certain crops, (Sys et al., 1993)

Crops	Highly suitable S1	Moderately Suitable S2	Marginally suitable S3	Currently not suitable N1	Permantly not suitable N2
Olive	None	None	1, 2, 3, 4, 5, 6, 23, 25, 26, 28, 35, 36, 37, 38, 40, 41 and 42	14, 17, 18, 19, 24, 29, 31, 39, 41 and 43	8, 11, 13, 15, 16, 27, 30 and 32
Fig	None	None	1, 2, 3, 4, 5, 6, 23, 25, 26, 28, 35, 36, 37, 38, 40, 41 and 42	8, 14, 17, 18, 19, 24, 39, 41 and 43	11, 13, 15, 16, 27, 29, 30, 31and 32
Guava	1	None	3, 36 and 37	1, 2, 4, 5, 6, 8, 11, 14, 15, 16, 17, 18, 19, 23, 24, 25, 26, 27, 28, 29, 31, 35, 38, 39, 40, 41, 42 and 43	13, 30 and 32
Tomato	None	None	25 , 36 and 37	1, 2, 4, 5, 6, 8, 14, 17, 18, 19, 23, 24, 26, 28, 29, 31, 35, 38, 39, 40, 41, 42 and 43	11, 13 , 15, 16, 27, 30 and 32
Wheat	1	None	2, 19, 23, 38, 31 and 42	11, 15, 16, 17, 26, 28, 29 and 43	3, 4, 5, 6, 8, 13, 14, 18, 24, 25, 27, 30 , 32, 35, 36, 37, 39, 40 and 41
Barely	None	None	1,2, 23, 26, 28, 29, 31, 38, 42 and 43	15, 16, 17 and 19	3, 4, 5, 6, 8, 11, 13, 14, 18, 24, 25, 27, 30 , 32, 35, 36, 37, 39, 40 and 41
Sorghum	None	1, 2, 23 and 38	3, 4, 5, 6, 15, 25, 26, 28, 29, 31, 35, 36, 37, 39, 40, 42 and 43	8, 11, 14, 16, 17, 18, 19, 24, 27 and 41	13, 30 and 32

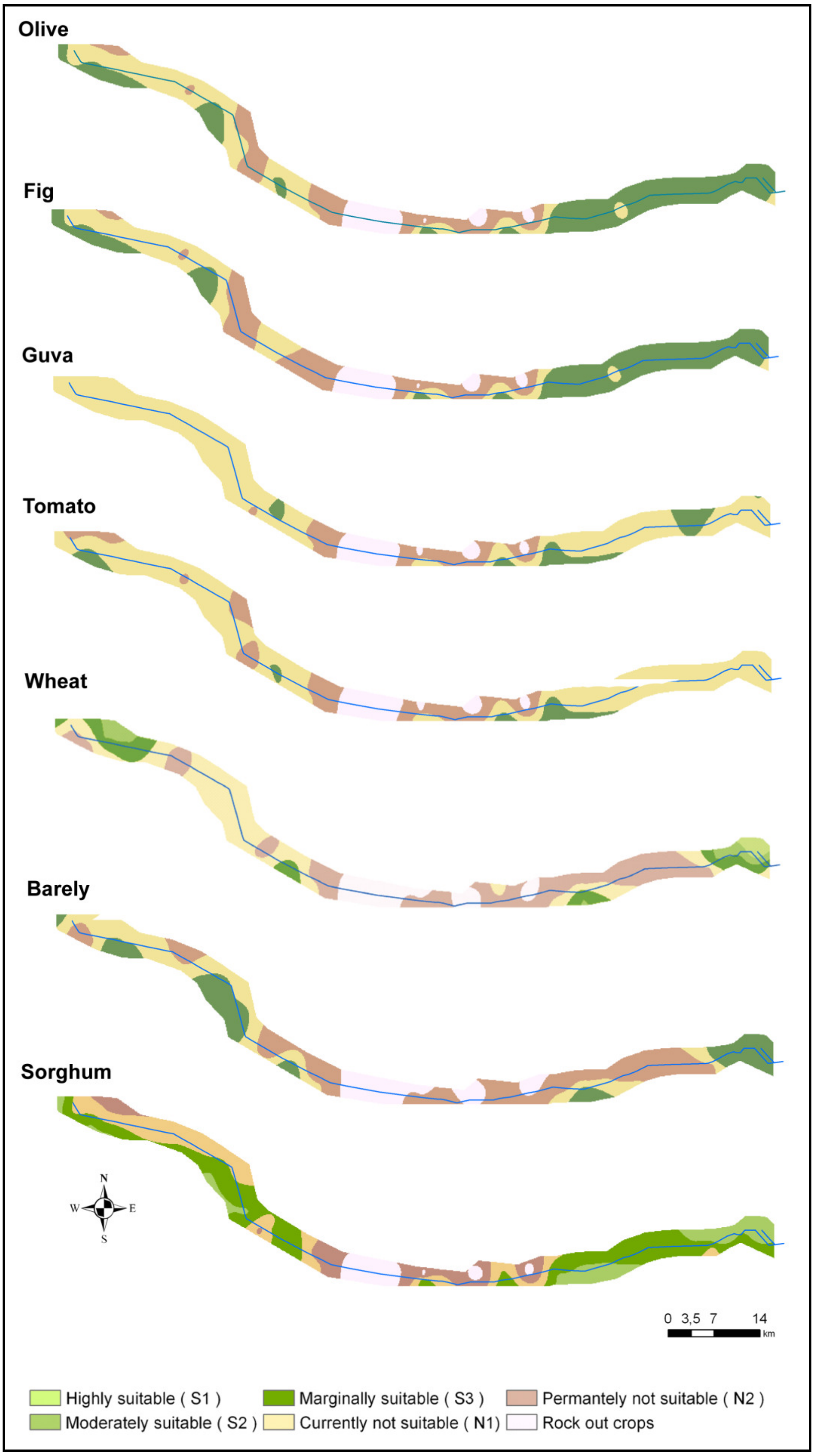


Figure 98: Land suitability for the most suitability certain crops, (Sys. Ir. C., 1993)

Calcium carbonate content, texture and soil depth are mostly the main limiting factors of the study area. Olive, fig, sorghum and barley crops are the most representing a large area of land productivity “marginal suitable”, and the soils have some limitation which are correctable, wheat crop is a strategic and important role in Egypt, so it can be added to these crops have to be the initial first in the next stage. Potentiality of land suitability for crops by applying the appropriate soil management practices, such as the improvement of the drainage, organic fertilization to improve permeability, CEC and nutrient availability and applying modern irrigation systems and reducing the irrigation periods to avoid the soil crust formation that is caused by the calcareous soil.

Land suitability and capability assessment in arid and semi-arid region, western part of the Nile delta in Egypt was used ALESarid-GIS (Abd El-Kawy et al., 2011). The area covers approximately 14.1 (10^3 ha) and consists mostly of uncultivated land. The results indicated land suitability classes are highly suitable (S1) to actually unsuitable (N2). The most suitable crops to grow in western of Nile delta are alfalfa, barely, wheat, sugar beet, onion, and pear. The dominant limiting parameters for crop suitability of the most crops were soil texture, exchangeable sodium percentage, soil salinity and water irrigation salinity

6.1.3. Tools for land evaluation systems

There is a high demand worldwide for information on the suitability of land for a wide range of land uses. Land capability and land uses in a rational and equitable way, using the techniques of land use planning, and computer program to determine land capability and land suitability for crops. Soils can be used for almost all agricultural purposes if sufficient inputs are supplied. The application of inputs can be such that they dominate the conditions in which crops are grown. However, each soil unit has its own potentialities and limitations. Land uses of each soil and requirements based on determined of main limitations (De la Rosa et al., 2004).

The Automated Land Evaluation System (ALES) is a computer program that allows land evaluators to build expert systems for evaluating land units according to the methods in the FAO Land Evaluation Framework. Decision makers can build their own expert system with ALES, taking into account local conditions and objectives. The Mediterranean Land Evaluation Information System, currently on Internet MicroLEIS.com, is an integrated system for land data transfer and agro-ecological land evaluation (De la Rosa and Van Diepen, 2002).

6.1.3.1. The ALES approach to land evaluation

A land capability model “ALES” is built to define the capability of the represented map units in the study area. In this model each soil characteristic of the study area is matched with its corresponding limiting values of the capability classes. The final land capability class depends on the highest limiting factor. Soil characteristics and limitations values for each capability class are showing in Table 10 (page 62) .For the purpose of the present study, ALES is used for physical suitability based on paramertars and limitations from (Mahmoud et al., 2009). After matching the land characteristics of the soil profiles, the obtained data indicates that the soil has severe limitation such as; texture, depth and calcium carbonate content. As shown from Table 33 and Figure 99**,** the capability of the study area varies from “marginal capability” to “not suitable” due to different limiting factors.

Table 33: Land capability classes and subclasses according to ALES program

Land Capability class	**Land Capability subclass**	**Profile No.**
Marginal (S3)	S3c ($CaCO_3$)	38, 20 and 21
	S3 c, t ($CaCO_3$, texture)	4, 5, 6, 37 and 39
Limited Capability (S4)	S4c ($CaCO_3$)	3, 35, 36, 40, 41, 42, 28, 29, 23 and 22
	S4t (texture)	8
	S4 t, s ,c (texture, soil depth and $CaCO_3$)	11, 15 and 27
	S4 s ,c (soil depth and $CaCO_3$)	16
Not suitable (S5)	S5c ($CaCO_3$)	1, 2, 43, 18, 19, 25, 14, 24, 26 and 17
	S5s (Soil depth)	13, 30 and 32
	Rocky	7, 9,10,12 and 33 and 34

The land capability is subjected to different limiting factors. Some can be mitigated or improved by applying the appropriate soil management practices, these soil management practices include:

- Improvement of the drainage.
- Deep plowing to improve soil permeability and moisture availability.
- Organic fertilization to improve permeability, CEC and nutrient availability.
- Applying modern irrigation systems and reducing the irrigation periods to avoid the soil crust formation that is caused by the calcareous soil.
- Irrigation water with salinity less than 130 ppm and add agricultural gypsum in soils.

Natural resources management and planning the sustainable land use in El-Hammam area, North-Western Coast of Egypt **was** studied by (Shendi et al., 2006).Capability model built in ALES software was used to define maps of the suitable areas for agricultural production and the results were exported to GIS. The results indicated that the area currently lacks high capability and moderate capability classes. There is about 12.9 (10^3 ha) which were classified marginally capable, about 5.7 (10^3 ha) of limited capability, and about 9.4 (10^3 ha) not suitable for agricultural use. By improving the soil properties, the soil can approach potential capability, and about 22.5 (10^3 ha) will become marginally capable, about 10 % and 9.7 % have limited capability and not suitable for agriculture use, respectively.

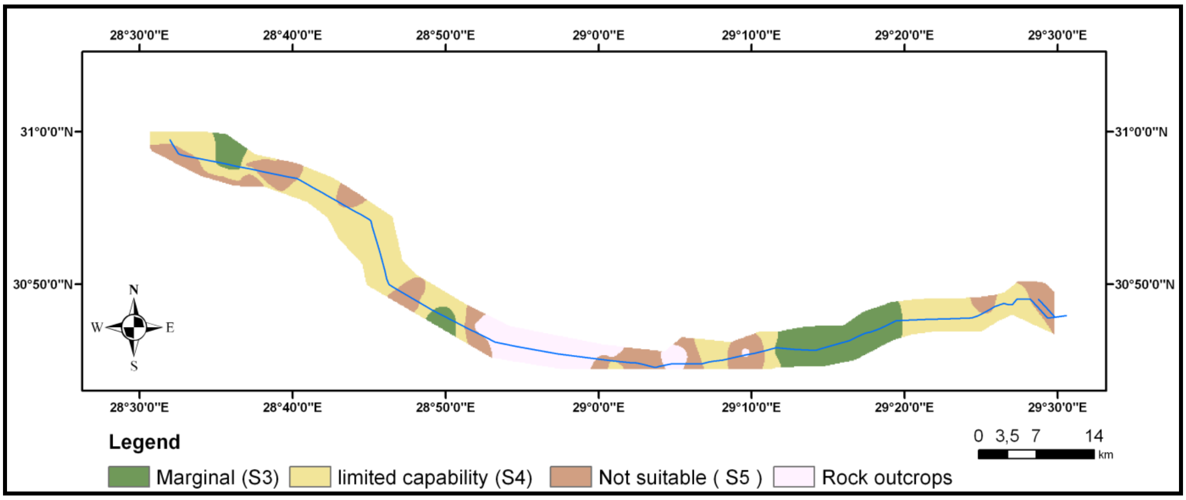


Figure 99: Land capability classes and subclasses in ALES program

The Agricultural Land Evaluation System (ALES) for arid and semi-arid regions, ALESarid-GIS, was developed and used to assess the agricultural land capability and suitability for crops in western part of the Nile Delta, El Nubariya city, Egypt. Land capability classification was classified in three capability classes (C3 – Fair, C4 – Poor, and C5 – Very Poor), (Abd El-Kawy et al., 2011).

In West Kenya the Automated Land Evaluation System (ALES) was used for selection of the best land for pyrethrum cultivation and determination of the production limiting factors. Highly suitable for growing pyrethrum were around 5.0 % from 42.0 %, found to be suitable of the studied area. Moderate and sever climatic limitations affected about 7.0 % and 11.0 % of the land, respectively, whereas soil erosion hazard and soil wetness limitations represented around 5.0 % and 3.0 %., respectively (Wandahwa and van Ranst, 1996).

6.1.3.2. Land capability model and suitability for crops (Micro LEIS)

6.1.3.2.1. Land capability model (CERVATANA)

The prediction of general land use capability is the result of a qualitative evaluation process or overall interpretation of the following biophysical factors: relief, soil, erosion risks and bioclimatic deficit, see Table 34. Land Capability evaluation orders and classes of land types are excellent (S1), good (S3), Moderate and marginal or null (N) and subclasses which depend on limitation factors: Slope = t, Soil = I, Erosion risks = r and Bioclimatic deficit = b. Applying to Land capability model (CERVATANA), concerning the slope, erosion, bioclimatic deficit and soil properties to soil profile represent are under study. Table 34 reveals that these soils could be pleased into the following orders and classes:

Good S2 : includes soil profiles represented most of El-Hammam Canal and a few soil profiles which represented El-Hammam Canal Extension. These soils are characterized by deep to moderate deep soils, coarse to moderate coarse texture, soils throughout the effective root zone depth, have very few to few gravels content, slightly to moderately saline and low to medium sodium hazard.The soils of this class and subclasses could be presented in Table 35.

Table 34: Agro-ecological evaluation method of land capability model (MicroLEIS-CERVANTANA model)

Land capability orders and classes			**Land capability subclasses**		**Limitation factors**
S	S1	Excellent	Slope	t	Slope
	S2	Good	Soil	I	Useful depth
	S3	Moderate			Texture class
N	N	Marginal or Nule			Stoniness and rockiness
					Drainage class
					Salinity
			Erosion risks	r	Soil erodibility
					Slope gradient
					Vegetation density
			Bioclimatic deficit	b	Aridity degree
					Frost risks

Table 35: Land Capability for soils of the study area (MicroLEIS- CERVATANA Model)

Land Capability Order	**Land Capability classes**	**Land Capability subclasses**	**Profile No**
S	S2 Good	S2I	1, 2, 4, 5, 6, 23, 24, 38, 39,41and 42
		S2Ib	3, 37 and 40
		S2Ir	8, 14, 17, 18 and 26
		S2Irb	35
	S3 Moderate	S3I	11, 15, 16, 19, 25 and 36
		S3r	31
N	N Marginal or Nule	NI	13, 27, 28, 29, 30, 32 and 43

Moderate S3: represented soil profiles adjacent to El-Hammam canal extension, see (Figure 100). Except soil profile 36**,** which represents some soils adjacent to the El-Hammam canal. These soils are characterized by deep, moderate and shallow deep soils, coarse to moderate coarse textured soils throughout the effective root zone depth, have very few to few gravels content. The soils of this class could be distinguished into the following sub classes:

S3I: represented by soil profiles (11, 15, 16, 19, 25 and 36). These soils have some limitations in soils factors: depth, soil texture, stoniness drainage and salinity.

S3 Ir: represented by soil profile (31). These soils have limitations in soil and erosion risks, depth, soil texture, stoniness drainage and salinity and vegetation density.

Marginal N: represented soil profiles adjacent to El-Hammam canal extension. Except soil, profile 43 which represents some soils in the front adjacent to the El-Hammam Canal. These soils are characterized by deep course to moderate coarse texture soils throughout the effective root zone depth, have very few to few gravels content, low erosion risks, level to undulating areas less than 7.0 % and rainfall less than 250.0 mm, strongly salinity and well drainage. The soil represented El-Hammam canal extensions are moderate to very shallow depth, coarse texture, poor or excessive drainage, strongly saline and moderate vegetation density.

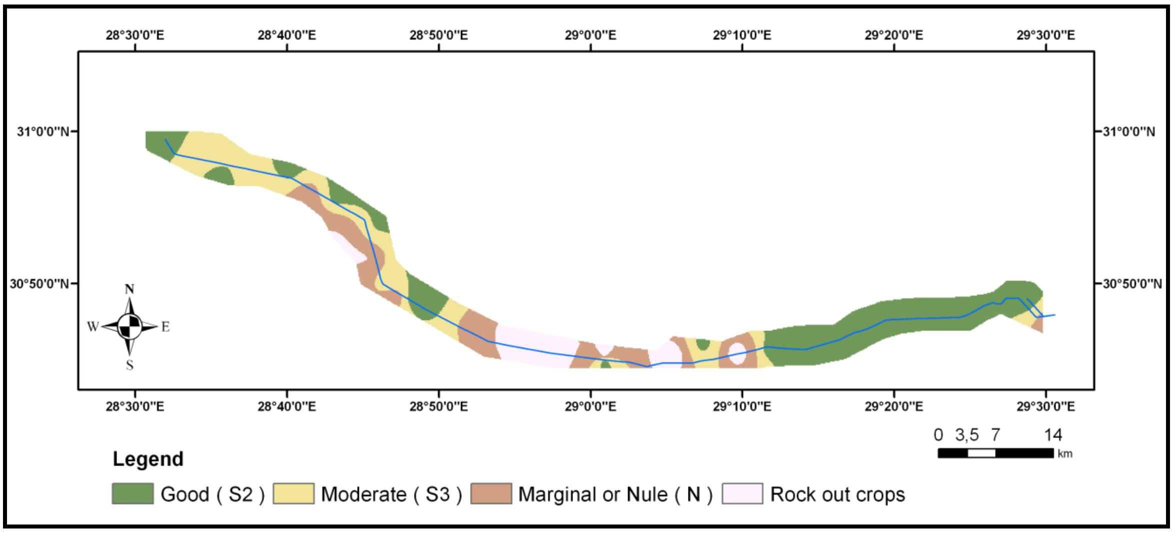


Figure 100: Land capability for soils of the study area (CERVATANA)

6.1.3.2.2. Land suitability model (ALMAGRA)

The MicroLEIS with an ALMAGRA model (Agricultural Soil Suitability) have been used to assess the suitability of different soils which adjacent El-Hammam canal and its extension. Land suitability classification model (ALMAGRA) is applicable to all arid and semi-arid condition throughout the Mediterranean Region. The soil suitability ALMAGRA model is based on analysis of edaphic factors which affect the productivity of twelve traditional crops.

The definitions of soil suitability classes, soil limitations and soil factors are presented in Table 36. Land suitability evaluation of the studied area was performed. Useful depth, texture, drainage, carbonate, salinity, sodium saturation and profile development were selected as limitation factors for crop's development. For perennial crops, the soil section considered is between 0 and 100 cm in-depth or between 0.0 cm and the limit of useful depth when the latter is between 0.0 and 100 cm. The main limitations factor for Suitability classes of El-Hammam Canal and Extension are calcium carbonate, soil texture, soil alkalinity, drainage, soil depth and some soils have very severe limitation in salinity.

Table 36: The definitions of soil suitability classes, soil limitations and soil factors

Soil suitability classes		**Limitations**		**Soil factors**	
Symbol	Definition	Symbol	Definition	Symbol	Definition
S1	Highly suitable	1	None	a	Sodium saturation
S2	Suitable	2	Slight	c	Carbonate
S3	Moderately suitable	3	Moderate	d	Drainage
S4	Marginally suitable	4	Sever	g	Profile development
S5	Not suitable	5	Very sever	p	Useful depth
				s	Salinity
				t	Texture

On the other hand, the soil maps for agricultural suitability designed in this research can be helpful in carrying out the management processes. The results of the suggested computer program "MicroLEIS" for agricultural soil suitability evaluation were obtained as data outputs presented in Table 37. The area under investigation has been divided into three relative suitability classes; suitable (S2 class), moderately suitable (S2 class) marginally suitable (S3 class) and not suitable (S5 class). The highly suitable (S1) was not determined for selected utilization types. The most suitability crops in the soils of the investigated area based on the MecroLIES model. They could be classified as olive, citrus, peach, alfalfa, wheat, melon and sunflower ranged between moderate suitable (S3) and not suitable (S5), while olive is ranged between suitable and not suitable (Figure 101).

Table 37: The suitability classification codes of 12 different crops generated by MicroLEIS of the study area. (MicroLEIS- ALMAGRA Model)

Soil	Land suitability for certain crops											
Profile	Wheat	Corn	Melon	Potatoes	Soje	Cotton	Sunflower	Sugarb	Alfalfa	Peach	Citrus	Olive
1	S3	S3	S3	S4	S3	S3	S3	S3	S3	S4	S4	S3
2	S3	S3	S3	S4	S3	S3	S3	S3	S3	S4	S4	S3
3	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
4	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
5	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
6	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
14	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S3
18	S5	S5	S5	S5	S5	S5	S5	S5	S5	S4	S4	S3
19	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5
23	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
24	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
25	S5	S5	S5	S5	S5	S4	S5	S4	S4	S5	S5	S5
26	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
35	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
36	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3
37	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
38	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S4
39	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
40	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
41	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
42	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S2
43	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5
8	S3	S4	S3	S3	S3	S3	S3	S3	S3	S3	S3	S3
17	S4	S4	S4	S4	S4	S4	S4	S4	S4	S3	S3	S3
28	S5	S5	S5	S5	S5	S4	S5	S4	S4	S5	S5	S5
29	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5
31	S3	S3	S3	S3	S3	S3	S3	S3	S3	S4	S4	S4
11	S3	S3	S3	S3	S3	S3	S3	S3	S3	S4	S4	S4
13	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5
15	S5	S5	S5	S5	S5	S5	S5	S5	S5	S4	S4	S4
16	S4	S4	S4	S4	S4	S4	S4	S4	S4	S5	S4	S4
27	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5
30	S4	S4	S4	S4	S4	S4	S4	S4	S4	S5	S5	S5
32	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5	S5

Limitations: 1=No; 2=Slight; 3=Moderate; 4=Severe; 5=Very severe. p=Useful depth t=Texture d=Drainage c=Carbonate s = Salinity a= Sodium sat g=Profile dev

Crops: T= Wheat; M= Corn; Me= Melon; P= Potatoes; S= Soje; A= Cotton; G= Sunflower; R= Sugarb; Af= Alfalfa; Mc= Peach; C= Citrus; O= Olive.

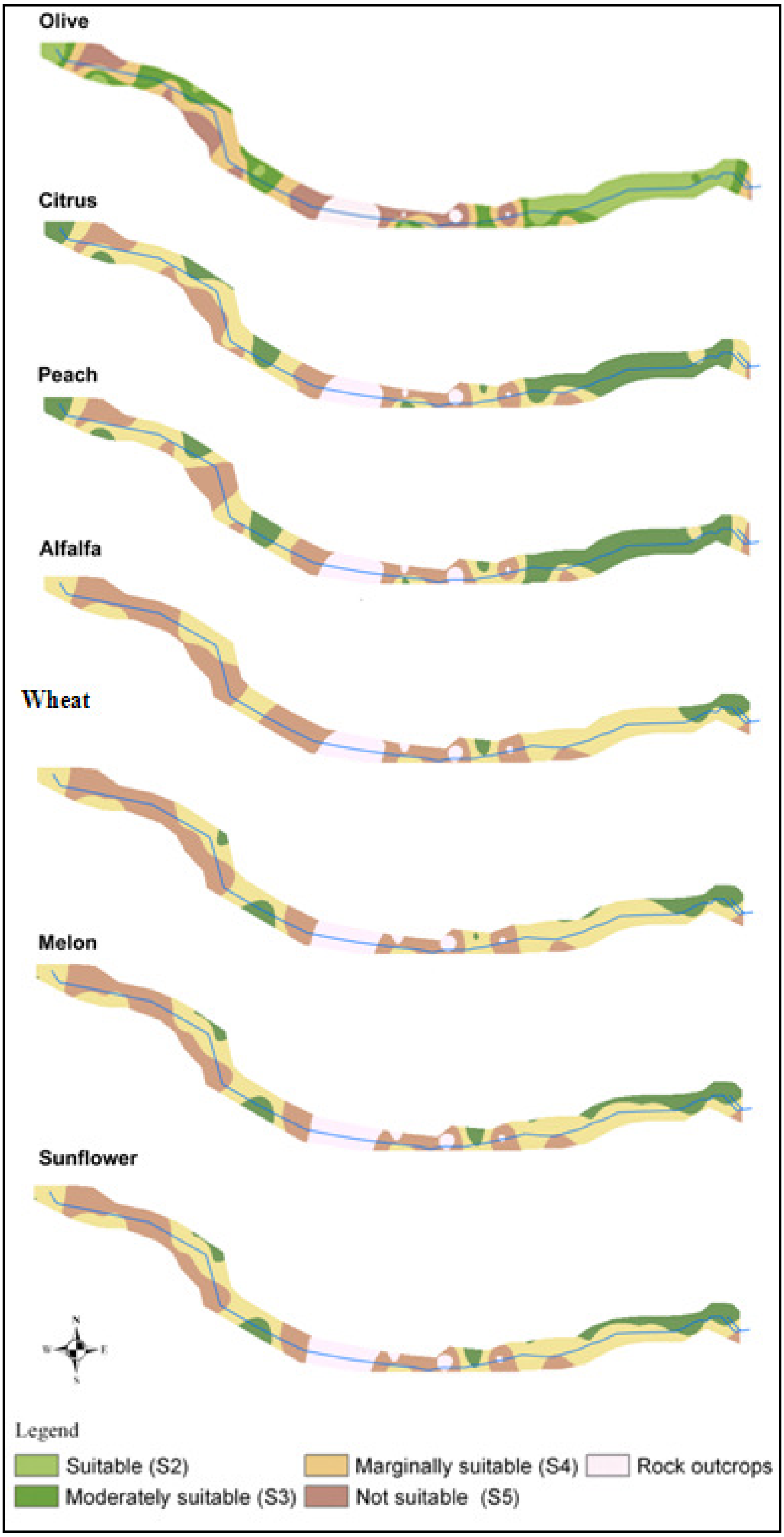


Figure 101: Land suitability for the most suitability certain crops (ALMAGRA MODEL)

Once the land unit data has been entered, ALMAGRA gives an on-screen evaluation based on the criterion of the maximum limitation and verification of the degree of a single variable is sufficient to classify the soil in the corresponding category. Suitability classes will be identified with attention to the land characteristics (Shahbazi and Jafarzadeh, 2010). According to the results of previous soil characteristics of the study area it is clear that the most limitation factors are soil texture, drainage, calcium carbonate content and salinity.

Results indicate that the area currently lacks high suitability for irrigation and capability in the most of the soil under study. By improving the soil properties such as salinity, drainage and applying modern irrigation system, the soil can attain potential capability (moderate) and suitable to marginally suitable for the major crops. The study area falls within the Mediterranean coast of Egypt and experiences long dry summers and very short rainy winters. Therefore, the Sys and Verheye (1978), land suitability for crops (Sys et al., 1993) and MicrolIES soil evaluation systems are most appropriate to the circumstances of the study area.

6.2. Potential land capability and suitability classification.

Land evaluation method was used to evaluate actual land suitability, which relates the suitability of land units for a specific use under present condition. Potential land suitability will be presented in the next stage, which relates to the suitability of the land units after investigation of the major improvements in the light of the economic possibilities available. Potential land capability and suitability refers to the capability of units for a defined use, after specified major improvements have been completed where necessary. In the study area the major improvements needed to overcome the current (present) limitations such as: salinity, derange calcium carbonate content and soil texture. Land suitability evaluation is an examination process of the degree of land suitability for a specific utilization type and a description method or estimation of potential land productivity. Land suitability is **a** very important step in the reclamation of the desert to determine the suitability of crops for different soils to produce the high yield to meet the requirement of the population. Potential of land suitability for surface and drip irrigation can use two methods of the evaluation in arid and semi-arid soils in the Mediterranean region. The first is the methodology produced by Sys and Verhye (1978) and the second is MicroLEIS (Integrated Package) de la Rosa et al (2000).

6.2.1. Potential land suitability for irrigation, Sys and Verhye (1978).

The results show that the land suitability class for drip irrigation is higher than surface irrigation as the mean **Capability Index (Ci)** for drip irrigation was higher than surface irrigation. Compared the suitability evaluation for the application of different irrigation systems, the conclusion of these investigations showed that the application of drip irrigation was more effective and efficient than the other irrigation methods and it improved the land suitability for irrigation purposes. In addition, because of the insufficiency of water in arid and semi-arid climate areas, this method can also be recommended for sustainable water use. The main limiting factor for drip and surface irrigation systems in this region are depth, soil texture, content of soil calcium carbonate and soil salinity and alkalinity while the other factors such as slope, drainage, content of gypsum have no influence on determining the suitability classes. In this study, an attempt has been made to analyze and to compare two irrigation systems by modification of the soil textureal rating index and land characteristics into account from land sutability for irrigation (Sys, 1978) system.

The results of land suitability evaluation for different irrigation approaches in soils adjacent El-Hammam canal and extension, the soil profiles include the highest class of suitability for drip irrigation, see Table 38. Moreover, the region under aridity and semi-aridity of the climate, only the drip irrigation is recommended for a sustainable use of this natural resource. Furthermore, typically because of applying the less amounts of water, it is necessary and more beneficial to use drip irrigation instead of surface irrigation method to improve the water use efficiency and to resolve water shortage problems throughout the coastal plain. Since the soil texture, drainage, calcium carbonate content, soil alkalinity and salinity are the major limiting factors for different irrigation systems, it is recommended to set up the drainage systems in order to improve the salinity limitations and to enhance the land production capability of the area. The most soils represented Typic Haplocalcids and Haypercalcic are moderately suitable and marginally suitable for drip irrigation**.** Potential land suitability for drip and surface irrigation systems are presented in Figure 102 and Figure 103.

Table 38: Potential Land suitability for irrigation (surface and drip irrigated) of the study area

Suitability index (Ci)	**Suitability Order *and classes***	**Profile No**	
		Surface irrigation	Drip irrigation (trickle irrigation)
50-75	S2	----	2, 3, 4, 5, 6, 17, 23, 26, 38, 39, 40 and 41
25-50	S3	1, 2, 17, 19, 23, 26 and 38	1, 14, 18, 24, 25, 29, 31, 35, 36, 37, 42 and 43
12.5-25	N1	3, 4, 5, 6, 16, 18, 24, 25, 28, 29, 30, 31, 35, 36, 37, 39, 40, 41, 42 and 43	8, 11, 15, 16 and 30
>12.5	N2	8, 11, 13, 15 and 27	13, 27 and 32

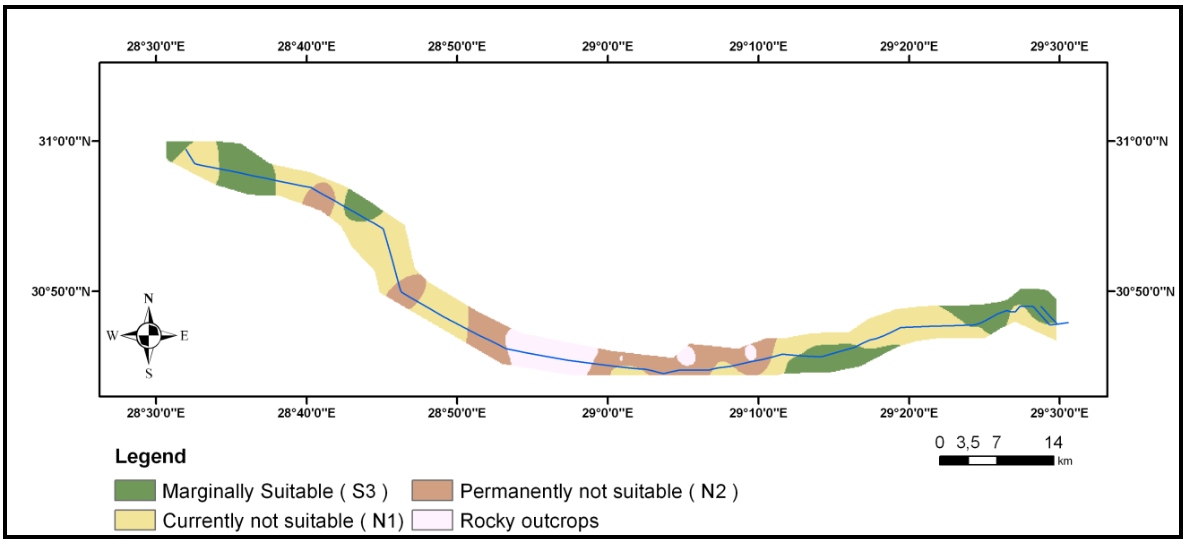


Figure 102: Potential Land suitability classes surface irrigation

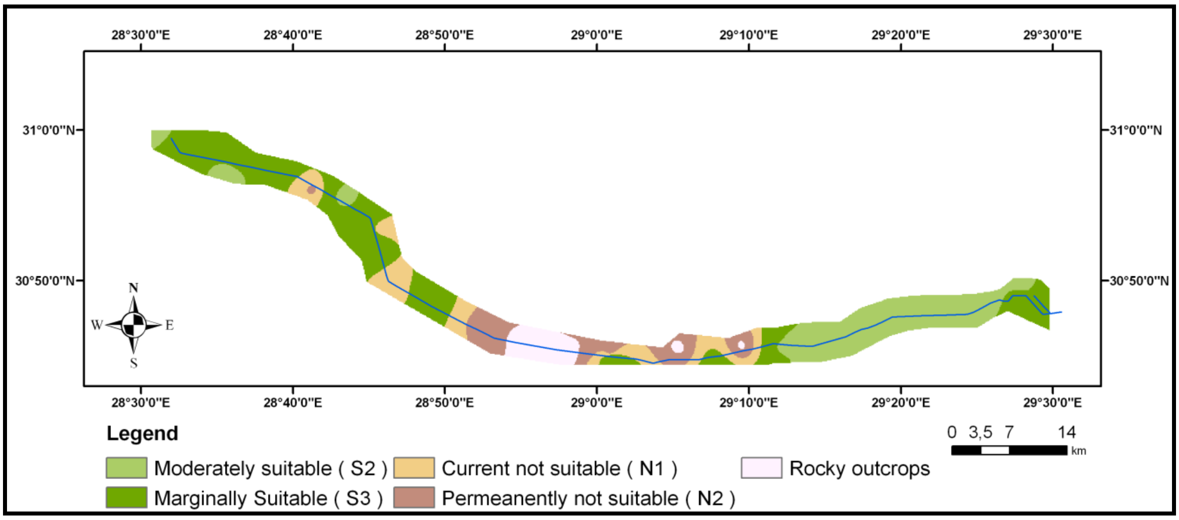


Figure 103: Potential Land suitability classes for drip irrigation

In General, the most important limiting factors for surface or gravity irrigation system in the study area were depth, soil texture and salinity and alkalinity, whereas, the major of limiting factors in drip or localized system are soil texture, and salinity and alkalinity.

6.2.2. Investigation of parametric method evaluation for different irrigation of the study area (Sys and Verhaye, 1978) and (Sys et al., 1991)

The most influential factors in transplant desert lands are scarcity of water, especially in arid and semi-arid regions. Western Desert in Egypt is one the most arid regions in the world, and **its** surface **is** composed of **a** bar rocky plateau, high-lying stony and sand**y** plains which consequently do not reach the Nile Valley (Hamied, 2009). Water transfer from the River Nile to the Western Desert are high-cost projects, which is important for the development of desert regions. Parametric methods to land suitability for agriculture under irrigation systems were examined different in many arid and semi-arid regions such as Egypt, Iran and Turkey, (Abdel-Hady et al., 2011), (Albaji et al., 2010a; Landi et al., 2008), (Kalkhajeh and Amerikhah, 2012) and (Dengiz, 2006). From the previous studies, it is clear that was the modification of the values of the ratings of the soil texture only in Sys and Verhye (1978) system to estimate the compensability of the soil for agriculture under the conditions of surface and drip irrigation. $CaCO_3$ content and sand fraction increased to reach the highest amount when approaching to the desert. Organic matter content is generally low and decreased with depth. Shallow and very shallow soils are varying in adjacent El-Hammam canal extension, as a result of erosion and scarcity of water for irrigation.

Soil texture, soil depth, calcium carbonate content and salinity were important soil characteristic determining irrigation methods. In contrast to these soil handicaps **r**esults for the application of different evaluation systems, land limitation factors of the study area and the land, which are in arid and semi-arid regions were soil texture, soil depth, calcium carbonate content and salinity. For almost the entire study area, soil depth, soil texture, $CaCO_3$ and salinity were considered limiting factors. Soil characteristics of the study area are coarse texture, very deep to very shallow depth, extremely calcium carbonate content and non-salinity to extremely salinity in small parts. In General, from previous studies it is clear that the main factors affecting the validity of the soil for agriculture under the conditions of surface irrigation and drip irrigation were soil texture, depth, content of calcium carbonate and salinity. Proposed of soil rating values of specific factors such as, soil texture, depth, content of calcium carbonate and salinity are given**,** and match the parametric method Sys and Verhye (1978). Values investigation of limitation factors for land suitability for surface and drip irrigation systems were shown in Chapter IV. The results are presented in Table 40 and Figure 104 , there is little difference in the value of the suitability index (Ci), however, do not show this difference in values of land suitability order and classes.

The main suitability index (Ci) for surface irrigation was 35.3 % , (marginally suitable) while for drip irrigation it was 34.7 %, (marginally suitable). The main limitations are soil texture, calcium carbonate content, soil depth, salinity and slope, respectively in surface irrigation system. While the most limiting factors were soil texture, soil depth and salinity for the drip irrigation. By analyzing the land suitability maps for surface and drip irrigation it is evident that a moderately suitable area can only be observed in some parts adjacent El-Hammam canal and its extension. The largest part of the cultivated area was evaluated as marginally suitable because of its very deep to moderate deep and low to moderate salinity. Other factors such as slope do not influence the suitability of the area. The results of potential land suitability indicated by applying surface and drip irrigation systems, suitability classes of soil profiles ranged between moderately suitable (S2) and permanently suitable (N2).

Table 39: Potential land suitability order and classes for surface and drip irrigation (Modification after Sys and Verhey, 1978 system)

Suitability index (Ci)	**Suitability Order *and* *classes***	**Surface irrigation and Drip irrigation**		
		Profile No.	Main Limitations	Area %
50-75	S2	17, 26 and 38	Texture and $CaCO_3$	6,8
25-50	S3	1, 2, 3, 4, 5, 6, 8, 14, 16, 18, 24, 25, 28, 31, 35, 36, 37, 39, 40, 41 and 42	Texture , soil depth and $CaCO_3$	50,01
12.5-25	N1	11, 15, 19, 27, 29, 30 and 43	Texture, slope, soil depth , $CaCO_3$ and salinity	21,53
>12.5	N2	13 and 32	Texture, slope, soil depth $CaCO_3$ and salinity	10,30

According to mapping units of the studied soils, the most soil profiles represented deep to moderately deep and coarse textured are marginally suitable (S3). The comparison of the different types of irrigation techniques revealed that the drip irrigations methods were more effective and efficient than the surface irrigation methods for improving productivity. Over much of the El-Hammam Canal area, the use of drip irrigation system has been applied for the most of soils irrigated by fruit such as, apple, guava and citrus, in addition to vegetables such as tomatoes. Wheat, barley and maize were irrigated by surface irrigation.

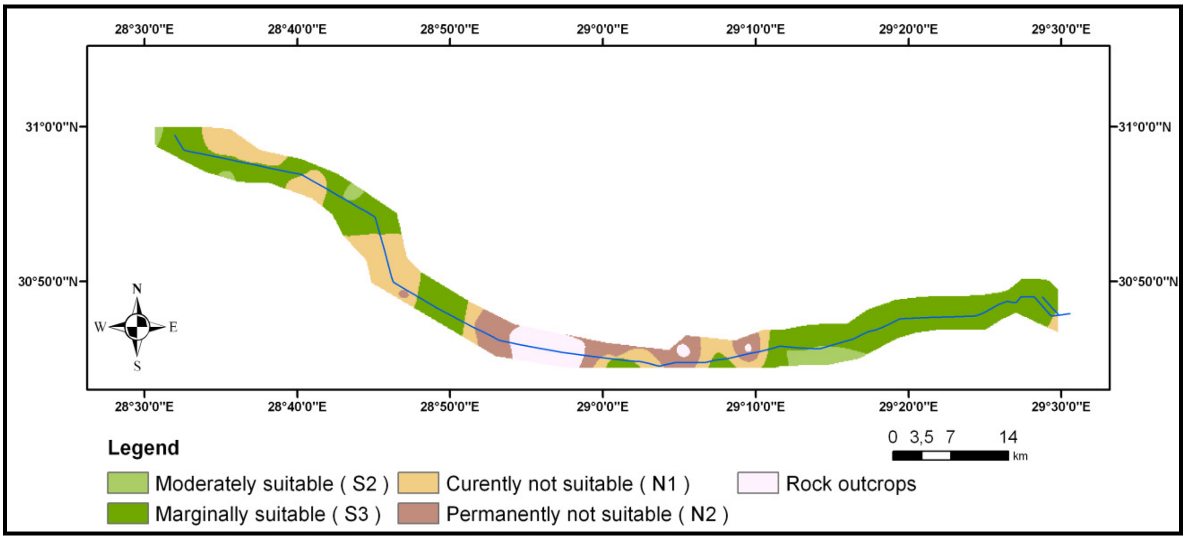


Figure 104: Potential land suitability classes for surface and drip irrigation

The major crops in El-Hammam canal extension are olive and fig irrigated by manual irrigation. Wheat, barley and sometimes sorghum depend on rain-fed agriculture in the soils adjacent of El-Hammam canal extension, due to water scarcity.

6.2.3. Potential land capability and suitability (MicroLEIS)

The current land suitability assessment is very important because it helps users to recognize the current limitations of the land area for particular land utilization. It provides opportunity to take the necessary steps for the further improvement and transferring a higher level of suitability in potential suitability evaluation. In the Mediterranean region, the main negative impacts of agriculture on soil quality are water erosion, subsoil compaction, diffuse contamination including salinization. In many of non-suitable for agricultural for different crops, it is necessary to change the irrigation system to surface irrigation with well drainage system. The main soil characteristics of the soils adjacent El-Hammam canal and its extension were deep to very shallow deep and coarse texture soils.

Currently land capability and land suitability for crops using CERVATANA and ALMAGRA MecroLIES models are not suitable soils including highly saline content. Once the land unit data have been entered, ALMAGRA gives an on-screen evaluation based on the criterion of the maximum limitation and verification of the degree of a single variable is sufficient to classify the soil in the corresponding category. The most limiting chemical factor being considered is soil salinity which can be removed by reclaiming these soils through leaching, especially as the good quality irrigation water is available and applied management programs, which can decreased the salinity. Suitability classes will be identified with attention to the land characteristics. From results, the most soil adjacent El-Hammam canal and its extension were coarse texture soils, so, after leeching of salt with well drainage system. Potential land capability for different soil profiles (13, 19, 25, 27, 28, 29 and 43) which have highly saline were marginally (S4) and not suitable (S5) could be change to moderately suitable and marginally suitable (Figure 105).

On the other hand, current land suitability for the most irrigated crops in the study area, which has highly saline, were not suitable (S5). Potential land suitability for the same soil profiles after leeching salt is marginally suitable (S4). The qualitative evaluation for the actual soil parameters is used to realize a precise and objective interpretation for Ahar Area, North-West of Iran. Land suitability for a wide range of crops, it can be concluded that the most effective soil parameter that influence the suitability classification in the studied area was soil texture. Furthermor, salinity has been distinguished as a limitation factor in some cases which can be removed from these soils through leaching, especially by using the high quality of irrigation water and applied management programs (Shahbazi et al., 2009).

Land suitability evaluation for crops in Soma area, Iran, using CERVATANA and ALMAGRA models studied by (Jafarzadeh et al., 2009). In Souma area 80.49% of the total area was good capable for agricultural uses and 19.51% must be reforested and not dedicated to agriculture. The arrangement of priority agricultural utilization or crop rotation was selected maize–wheat–alfalfa. Identification of agricultural land according to their limitations and ecological potentialities was the first major objective and the second major objective was to predict land suitability for a specific crop over a long period.

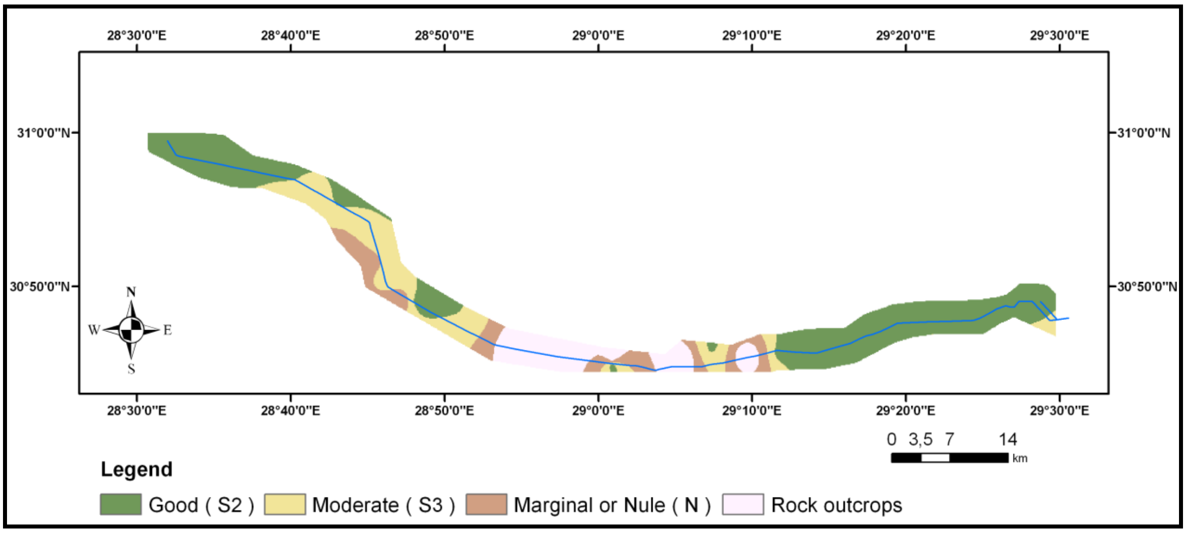


Figure 105: Potential land capability for irrigation (MicroLEIS)

MicroLEIS software has been used to evaluate the soil suitability of Sahal Baraka, Farafra Oasis, Egypt for specific crops. The main limitations factor were soil texture, drainage condition and sodium saturation. The largest part of the agricultural area was classified as low suitable to almost not suitable for studying crops due to physical and chemical soil parameters such as; soil texture, useful soil depth and drainage condition. The results of land suitability for olives, peach and sunflower revealed the following order of suitability: Olive > peach > sunflower, melon and corn. The most limiting chemical factors being considered is soil salinity which can be removed by reclaiming these soils through leaching, especially as the good quality irrigation water is available and applied management programs, which can be decreased the salinity (Wahba et al., 2007).

Also in newly reclaimed areas such as south-west of Bir Karawin in Farafra Oasis, Egypt. Soil classifications of the studied profiles were classified under subgroup of Typic Haplocalcids, Lithic-Haplcalcids, Typic Haplogypsids, Calcic Haplosalids and Gypsic Haplosalids. According to ALMAGRA model the obtained results reveal high suitability for wheat, potato and sunflower cultivations in the soil unit Typic Haplogypsids, while the rest of this group has low suitable with a dominant soil texture limitation of MicroLEIS micro-computer program. The main physical limitation factors for suitability of most crops were soil texture, useful soil depth and drainage condition. The most limiting chemical factors being considered is soil salinity which can be removed by reclaiming these soils through leaching, especially as the good quality irrigation water is available and applied management programs, which can be decreased the salinity (Darwish et al., 2006).

MicroLEIS program has been used to evaluate the soils located on the eastern side of Wadi El-Rayan, Egypt. The land capability classification used to evaluate some soils of Wadi El-Rayan demonstrated that most of the soils were not suitable for agricultural uses. The results of the current study indicated that the most limiting factors was salinity, followed by soil texture, soil depth, sodium saturation, lime content and gravel content. Salinity and alkalinity are correctable limitations but they are difficult to be accomplished because the water intrusion from Qarun and El-Rayan Lakes to the area (Aa et al., 2010).

6.3. Assessment of land priority using statistical analysis (SPSS)

In fact, one need**s** the farming procedures on which the land characteristics meet the crop requirements **to** lead to sustainable agricultural production. In this case, land suitability evaluation can provide data on the basis of which we are able to make decision about alternative cultivation in agricultural lands. The soil properties from the study area were matched with degree of limitations for land irrigation priority. Based on soil characteristics such as: particle size distributions, $CaCO_3$ contents, soil salinity and alkalinity, gravel contents, NPK, cation exchangeable capacity (CEC) and exchangeable sodium percentage (ESP), Organic matter contents and main trace elements content (Fe, Mn, Cu and Zn).

Previous results of soil properties indicate that most of these soils have extremely calcareous, coarse textured and low soil fertility parameters. Data represented in Figure 106 indicates that most soil profiles that represented El-Hammam canal are highly priority (groups 1 and 2). These soils are deep, coarse textured soils and irrigated soils. Applying statistical analysis concerning the phsyico-chemical land characteristics for irrigation using the soil ratings for land evaluation systems. The optimum requirements of a crop are always region specific. Climate and soil site parameters play significant role to maximize crop yields. The soil type and degree of limitations were evaluated using soil ratings. The soil properties from the study area were matched with soil site priority.

According to (Sys, 1978) using soil ratings of topography, calcium carbonate, salinity and alkalinity. Soil depth, texture and drainage soil ratings (Sys et al, 1991), also, slope, gravel content and SAR according to (Storie 2008) soil ratings. Results shows that the obtained good priority represented of soil profiles located around El-Hammam canal. Soil profiles have a highly priority are mostly deep coarse textured soils and represented by (4, 5, 6, 8, 18, 24, 35, 37, 39, 40 and 42) which represent ~ 30.0 % of studied area.

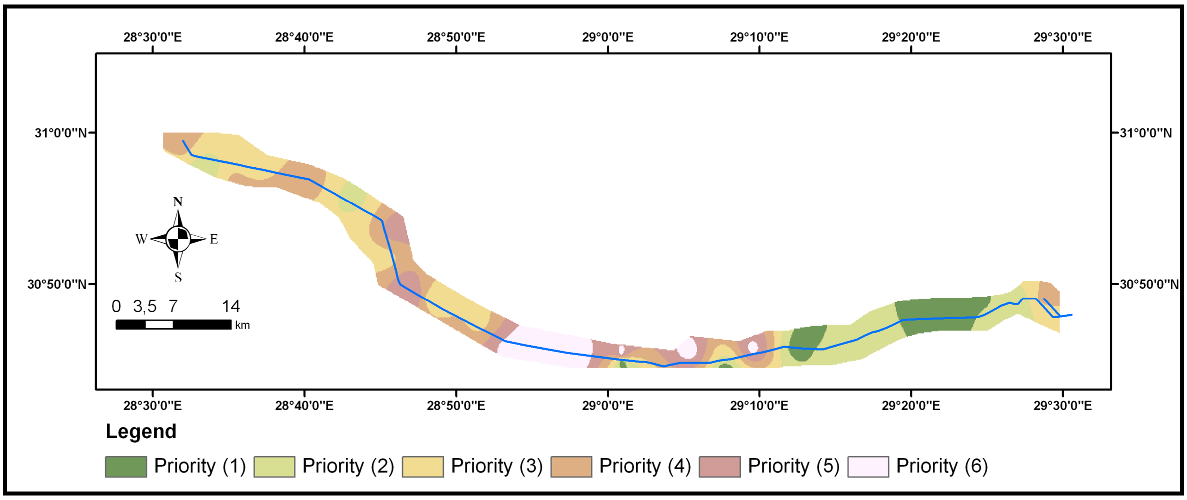


Figure 106: Soil priority for agriculture based on soil properties of the study area

Land suitability for the major crops of the Mediterranean region such as; olive, fig, peach, citrus, melon, potatoes, sunflower, alfalfa, wheat, barely and others, which were matched with degree of limitations according to (Sys et al ,1993) and MecroLIES (land suitability model). Applying statistical analysis, the priority indices outlined in Figure 107, shows that the soil types identified in all soil profiles could be placed into five groups. The main limitations of these soils are soil depth, drainage, calcium carbonate content and salinity.

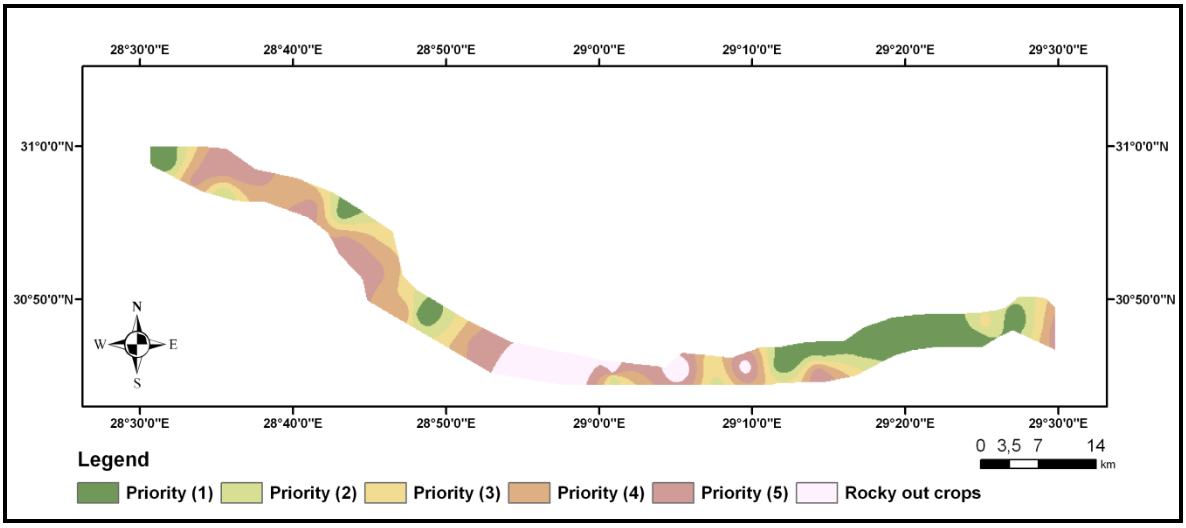


Figure 107: Soil priority of land suitability for the major crops

CHAPTER VII: DISCUSSION AND CONCLUSION

The main objective of the presented soil investigations is to optimize land use and to obtain a high and beneficial production. This aim requires information about soil performance under different forms of land use, land capability, suitability for crops and about the measures required to obtain the best output of the land. Applicability, comparison and discussion of different currently land capability and suitability of the evaluation systems are presented in this chapter.

Application results of the land evaluation methods related to land use planning are aimed more at policy development than at farm management. Land use planning policy should relate major land use to land capability and land suitability, for each particular site and socio-economic context.

Land capability and suitability methods were applied on the soils with the following objectives:

- Increase in field crops, fruit and vegetable consumption to support on nutritional security of the people.
- Emphasis on planting crops that more suitable in calcareous soils rather than in extension of the land national crops such as wheat as a strategic crop.
- Diversify fruit, field, forage and vegetable farming according to agro-ecological zones of Northwestern coastal plain, Egypt.
- Put emphasis on commercialization of fruit and vegetable cultivation.

7.1. Applicability of the evaluation systems to the study region

The arid to semi-arid region of Egypt is characterized by a scarcity of land and water resources, which threatens the livelihoods of the inhabitants. Rainwater harvesting is an important practice to improve water and land productivity and to cope with climate change in the drier marginal environments. The accurate determination of the location and types of rainwater harvesting interventions through a land suitability assessment is a key to successful implementation. However, adequate information about land resources is needed. Unfortunately, the arid areas suffer from a scarcity of detailed soil information and preparation of this data is often costly and time consuming. This research examines the utility of modern soil-landscape modeling techniques to provide soil and topographic information that improves land suitability assessment.

7.1.1. Comparison and discussion the currently land capability and suitability methods.

The most important and most currently used methods in land evaluation systems, for arid and semi-arid areas and **the** Mediterranean region**,** are belonging to one of the three major types of approaches e.g., categoric, parametric and special purpose systems. Land capability classification (LCC-USDA) is often associated with categoric systems group. Parametric systems are based on numerical correlations between land attributes and yields. Land evaluation systems are mostly interpretative classifications relevant to agricultural management and planning. The main land parameters considered for capability classification are climate, precipitation, salinity and sodicity, slope and erosion hazard, rootable depth, available moisture holding capacity and calcium carbonate content. Sys and Verheye (1978) method has been developed for analyzing resource suitability and other method used soil ratings for sutablity irrgation in arid and semi-arid region. This attempts to bring together several of the major methods and illustrate their use. This offers the possibility for evaluation and comparison.

The basic concept of the productivity index (Storie index, 1978) method is that agricultural-soil productivity, under optimal management conditions, depends on the intrinsic characteristics. This is a multiplicative parametric method to evaluate soil productivity. The concept of productivity is defined as the capacity to produce a certain quantity of harvest per hectare per year, expressed as a percentage of optimal productivity, which would provide a suitable soil in its first year of cultivation. The introduction of improvement practices leads to a potential productivity or potentiality. The quotient between the productivity and the potentiality is called the improvement coefficient .The improvement coefficient is the ratio between the productivity and the potentiality and represents a good index for evaluating the feasibility of these possible improvements. The parametric methods and quantitative method**s** are simple and easy to calculate. The evaluation systems reflect the degree of suitability of the different evaluation parameters, so that it proves easy to determine the possible improvements for each soil.

In **parametric methods**, however, a land index, which contains of the above physical properties (soil depth, texture and drainage) and chemical properties (lime content, salinity and alkalinity) is usually evaluated. The results of land productivity index for Storie Index (2008) are good to non-agricultural and land suitability for irrigation Sys and Verhey (1978) method soils are marginally to permentally not suitable. Part of the differences can be explained by results of multiplication of the land suitability ratings by each other used in calculating of the land index and limiting factors in parametric methods. Regarding the accuracy and several of the parametric method results in arid and semi-arid regions, the most important limiting factors in land suitability for irrigation and suitability for different crops were lime content, soil texture, drainage and salinity.

According to the carried out analysis with parametric method (Stortie Index (1976-2008) and Sys (1978) it infers that the Sys in relation to stories method was near the reality. Thus, it is better to use this method for determination of land class suitability especially with drip irrigation system. Storie Index (Storie 2008) after modifications and improvement is better than Store index, 1978.

MicroIIES model, Sys and Verhye, 1978 and Sys et al. 1993: The soils of the investigated area **are** based on the Micro LIES model could be classified as wheat, melon, sun flower, citrus, olive, and peach ranged between suitable (S2) and not suitable (S5) in general. The olive ranged between suitable (S2) and not suitable (S5) while the peach and citrus ranged between moderate (S3) and not suitable (S5). Land suitability index for the alfalfa, wheat, melon and sunflower ranged between moderate (S3) and not suitable (S5). On the other hand based on Sys et al 1993 wheat, barley, sorghum, tomato, guava, fig and olive ranged between marginally suitable (S3) and permanently not suitable (N2). Land suitability for crops of the most cultivated soils is marginally suitable (S3). Land suitability for irrigation according to Sys and Verheye (1978) for the soils of the investigated area ranged between marginally suitable (S3) and permanently not suitable (N2). The soil profile represented marginal land suitability and also the most cultivated soils. On the other hand, land capability of the investigated area **is** based on the MicroLIES model which ranges between good (S2) and marginal or nule (N). According to the previous lines, it is clear that the methods are different in their classes of suitability of the soils for the same crop which chose to cultivate in the reclaimed soils. That difference could be referred to that the Micro LIES model depend on the soil properties as soil profile depth, drainage, texture, $CaCO_3$ content, salts content, exchangeable sodium percentage and soil profile development, while the Sys method depend on the previous mentioned properties before and added the soil topography, coarse soil fragments, gypsum, cation exchange capacity and organic matter.

The land capability based on MicroLIES model is different from land suitability for irrigation. According to Sys and Verhey (1978) the difference could be referred to the MicroLIES model depend on the factors as slope, soil type, erosion risks and bioclimatic deficit, which include slope, soil depth, soil texture, stoniness and rockiness, drainage, salinity, soil erodibility, slope gradient, vegetation density and water erosion. The characteristics influenced the land suitability with regard to its irrigation capability according to Sys and Verheye (1978) which include topography, wetness, physical soil properties, salinity and alkalinity limitations.

The investigated soils are under shorter cultivation than the soils around El-Hammam canal, for this reason Sys model is more acceptable for application than the MicroLIES model for the major crops such as olive, fig, sorghum, barely and wheat. Whereas, the most soils adjacent to the El-Hammam canal extension are not cultivated, for this soil MicroLIES model is more acceptable than the method of Sys et al., 1993. Land suitability for crops according to MecroLIES and the Sys et al., (1993) were based on the highest limiting factors. The major suitable crops depending on MecroLIES method are olive, citrus and peach. These results are acceptable with the most irrigated crops in El-Hammam canal area. Furthermore, land capability based on MicroLIES model is more acceptable for application than the method of Sys and Verhye (1978).

Land suitability for different irrigation systems based on parametric evaluation approach (Sys et al. 1991**)** was applied in the Mediterranean and arid regions. The comparison with other studies for example in Iran, show the different irrigation systems and **use** parametric methods **in** the Shavoor plain, the plain west of Shush, Abbas plain, Boneh Basht plain and Dosalegh plain. Furthermore, in the Mediterranean area**s** such as Ben Slimane Province, Morocco, Tunisian, Southern Ankara and Turkey different parametric method Sys et al. (1991) were applied.The results showed that drip irrigation is more suitable than surface irrigation system in most of the studied areas. The major limiting factors for irrigation methods were soil texture, soil depth, calcium carbonate content and salinity. Drip and sprinkler irrigation systems are more suitable than the surface irrigation.

In this study, an attempt has made to analyze and compare two irrigation systems by taking into account various soil and land characteristics. Several parameters are used for the analysis of the field data in order to compare the suitability of different irrigation systems. The analyzed parameters included soil and land characteristics. The results obtained show that a drip irrigation system is more suitable than surface irrigation method. Moreover, because of the insufficiency of surface and ground water resources, and the aridity and semi-aridity of the climate in this area, sprinkle and drip irrigation methods are highly recommended for a sustainable use. Hence, the changing of current irrigation methods from gravity (surface) to pressurized (drip) in the study area are proposed.

The drip irrigation can obviously be a way to improve the practice on light soil textures. In the application of this type of irrigation, an agricultural management change would be necessary for the soils adjacent to the El-Hammam canal. Horticulture crops should be replaced by extensive crops such as wheat, barely und others, actually adopted and irrigated by rein-fed in El-Hammam canal extension. This is the same strategy adopted by farmers currently practicing in the area and actually irrigated by manual irrigation. On the other hand, because of insufficiency of water in arid and semi arid climate, maximizing water use efficiency is necessary to produce more crops per drop and help for solving the water shortage crisis in the agricultural sector.

7.1.2. Comparison of the different methods to evaluate the potential land capability and suitability

The physical land suitability and capability evaluation, applied and explained in this work, is based on internationally accepted methods for arid and semi-arid soils in the Mediterranean region. Some limitations of the present assessment methods will mentioned below.

Land suitability and capability index depends on the value of the highest specific limitation's factors. For example, some soil profiles which represented the soil adjacent to the El-Hammam canal in the study are very deep soils, coarse textured and well drained but have extremely saline. These soils in MecroLIES program, land suitability index are not suitable for all crops.

Texture classes rating for irrigation**,** suitability show**s** the lowest values presented when the soils have sandy texture.In fact, soils that have coarse texture in combination with high salinity are more suitable than those with a heavy texture.

Soil electric conductivity rating for crops evaluation according to MecroLIES is not suitable with more than 12.0 dSm^{-1}.

Most of the methods that are used consist of six parameters including slope, drainage properties, electrical conductivity of soil solution and alkalinity, calcium carbonate status, soil depth and texture. Each of six above mentioned parameters are scaled according to the related tables and capability index for irrigation (Ci).

Land suitability for different irrigation according to Sys and Verheye (1978): The main limiting factors for surface or gravity irrigation system in the study area were soil depth, soil texture, calcium carbonate and salinity. Whereas, the main limiting factors in drip irrigation or other local systems are soil texture and calcium carbonate. The results show that a drip irrigation system is more suitable than surface irrigation method of the study area.

Investigation of parametric method evaluation for different irrigation of the study area: In this investigation, method, land capability, index (Ci) and rating of parameters such as slope and wetness were applied from the Sys and Verheye (1978). The main limitations in the study area were soil texture, soil depth, calcium carbonate content and salinity. Soil rating for these parameters are used from Sys et al. (1991), indicates that a drip irrigation system is less suitable than surface irrigation. According to the soil and climate characteristics for the arid and semi-arid soils and insufficiency of water supply, it is recommended to use drip irrigation in the study area. This investigation method is fit to assess land suitability for different irrigation systems of the studied area. Results using land suitability proposed method is suitable and nearly similar results with the methods used to evaluate actual or currently land suitability for arid land (Sys and Verheye, 1978) and Mediterranean region (MecroLIES).

Land capability and land suitability model (CERVATANA and ALMAGRA) models were used to evaluate the potential land capability and land suitability for crops which representative soil profile of study area. Salinity is the main limitation factor and it is easily improved with less cost with coarse texture soils, water irrigation and drainage. Using the results of land capability of soil after leaching salt and the value of soil rating index of the salinity factor it is clear that the most soil profiles are good (S2) and moderate (S3). Land suitability for the major suitable crops ranged between suitable (S2) and marginal suitable (S4). Olive is the most suitable fruit crops in the soil adjacent El-Hammam canal and its extension and will be amended by crops like peach and citrus. Field crops, fodder, vegetables and oil crops such as wheat, alfalfa, melon and sunflowerare moderately suitable and marginally suitable. Soil profiles which are represented non-suitable (S5) include limitations factor non-correctable or high cost correctable.

From the previous results, the best-known methods for land assessment capability and suitability classification for soils under study are parametric methods and MicroLIES. Storie Index (2008) and the MecroLIES methods which take into consideration more parameters was the best method classified for the area under study. Parametric systems are based on numerical correlations between land attributes and yields. This method of soil rating, known as the Storie Index, is based on soil characteristics that govern the land's potential utilization and productive capacity. It is independent of other physical or economic factors that might determine the desirability of growing certain plants in a given location. Results of land productivity index affected by soil rating for factors and parameters were used to evaluate land capability classes.

On the other hand, Land capability and suitability according CERVATANA and ALMAGRA methods, land capability and suitability classes depending on the final value of the highest of limitations factor. Land evaluation methods, which include more parameters input, are given land capability and suitability index classifed detail. Furthermore, land capability and suitability classes, subclasses and units are tools to identify the most important determinants that hinder the production and least costly in reclamation plan depending on parameters input.

In the last three years, the agriculture around the El-Hammam canal expanded and includes more than 90% of the soils. Land along the El-Hammam canal extension still depends on manual irrigation and rain-fed agricultural. The north-western coastal plain of Egypt is located in an arid and semi-arid zone and is actually in the Mediterranean region. Storie index with digital soil information and CERVATANA model for land capability and productivity are suitable and acceptable to apply in the studied soils.

Land suitably for crops according to (Sys et al., 1993) and land suitability (ALMAGRA) model are more suitable methods and acceptable to apply in the study area. The most important crops that can be produced in the study area are olive, fig, citrus; peach, sorghum, alfalfa, wheat, barley; sunflower and tomato .Land evaluation methodologies results are assessed and compared in Table 40.

Table 40: Summary of results of the major are applied land evaluation methods in the study area

Land Evaluation System	Purpose & Land uses	Land capability and suitability classes				
USDA system, 2010?	Land capability & general land use	-	-	Class IV	Class V	Class VII
Storie index (1978)	Land use and land productivity	-	-	Grade 4 Poor	Grade 5 Very poor	Grade 6 Non-agricultural
Storie index, (2008)	Land use and land productivity	Grade 2 Good	Grade 3 Fair	Grade 4 Poor	Grade 5 Very poor	Grade 6 Non-agricultural
Sys and Verhye, 1978	Land suitability for irrigation	-	-	S3 Marginally suitable	N1 Currently not suitable	N2 Permanently not suitable
Sys et al ., 1991	Land suitability for drip and surface irrigation	-	-	S3 Marginally suitable	N1 Currently not suitable	N2 Permanently not suitable
Sys et al , 1993 Part III	Land suitability for crops	-	-	S3 Marginally suitable	N1 Currently not suitable	N2 Permanently not suitable
MicroLEIS	Land capability	-	S2 Good	S3 Moderate	N Marginal or Nule	
	Land suitability for crops	-	S2 Suitable	S3 Moderately	S4 Marginally	S5 Not suitable
ALES	Land capability			S3 Marginal	S4 Limited Capability	S5 Not suitable

7.1.3. Ecological and suitability requirements for most suitable crops

The Mediterranean coast in Egypt extends over about 900 km, the major part of coastal plain it is bordered by sand dunes of different nature. Application of the various evaluation programs for most land suitability crops suit the arid and semi arid region. The parameters of this programs included climate and soil properties. The main characteristic of the Mediterranean climate is that it has two well defined seasons in the year, with the rain period coinciding with low temperatures (winter) while the summers are hot and almost completely dry. The major soil temperature regime is thermic (mean annual soil temperature between 15° and 22°C).

Soil quality of the Mediterranean soils are influenced more by physical, rather than by chemical properties. Soil texture is an important factor, particularly because it affects the moisture retention of the profile thus, it may extend the length of the moisture available period for the crop. Deep soils are more suitable for crop production than shallow and very shallow profiles. Gravel and stones content are widespread and have a negative effect on crop production because it hinders root development and cultivation and reduces water retention. However, surface stoniness helps reduce surface evaporation, protects soil against water erosion and delays runoff. The surface stones, associated with the presence of numerous rock outcrops, makes that mechanized agricultural operations are often difficult. Surface crusting affects soils rich in silt and fine sand, hindering emergence of small seedlings, reducing soil infiltration and triggering runoff.

Soil chemical properties of Mediterranean soils are highly content of $CaCO_3$ and with pH ranged between 7.2 and 8.5. Their base saturation is generally high, except on very acid**ic** rocks. Most soils are also responsive to fertilization with P, are well supplied with K because of their high clay minerale content (illite), and contain adequate levels of Ca and Mg.

However, Fe, Cu, Mn, Zn and B deficiencies arise frequently in calcareous soils. In irrigated crop systems the salinization may become a major problem, mainly in areas where good quality water is scarce. Among the cultivated perennials there are few trees like olives and figs which are able to survive under Mediterranean rain fed conditions without damage. Soils of the broader El-Hammam canal region are irrigated by fresh water from the canal, while the soils directly around El-Hammam canal extension based on rainfed irrigation and rain water harvesting.

7.1.3.1. Olive

Olive is one of the oldest fruits known to man. It is extensively used for extraction of oil from its fruits. This oil is edible, possessing valuable therapeutic character. About 92% of its produce is used for oil extraction. In Egypt mostly of the soils located in the northwestern coastal plain are cultivated by olive. Annual mean temperatures of 15-20°C are desirable and during fruit production, a mean temperature of 18-22°C is optimal. Pollination is done by the wind. Amounts of precipitation of about 200 mm are sufficient for a low yield. Olives are cultivated on calcareous soils with a pH above 7.0. They survive long periods of very low soil moisture and are sensitive against water logging. Olives are salt tolerant plants. Intercropping between the olives is not recommended in dry years because it may cause a loss of yields.

The main limitation factors are soil depth and soil texture of the most investigated area, however, about (50% of evaluated soils) are moderate to marginally suitable for olive plantation.

7.1.3.2. Fig

Figs are more suitable and planted in a warm and dry climate. Cultivation of figs observed frequently in the study area, especially soils around El-Hammam canal extension. The growing period is 120 to 150 days. Cultivation is limited by mean winter temperatures of 0,5 to 2°C, resp. by minima of-7 to -12°C. Precipitation of about 200 mm is sufficient when figs obtain additional run-off water from surrounding area. During the development of fruits a steady water supply is necessary. Figs have a deep root systems and will grow on sandy and heavy calcareous soils, especially on alkaline soils. The plants are sensitive against soil salinity above 0,6% salt in the soil extract, especially sodium carbonate. The soil should be well drained and well aerated. Water logging should avoided in any case. Yield can expected from the 5th to 7th year after plantation onwards.

7.1.3.3. Wheat

Wheat is a strategic crop targeted in the general plan of Egypt to achieve food security through achieving self-sufficiency in it. Despite the fact that wheat is considered a temperate zone crop, it is also grown during the cool season in semi-arid areas in the subtropics and tropics. Wheat needs at least 240 mm of well distributed rainfall, although the crop is relatively drought tolerant. The growing period is between 210-220 days, depending on variety, temperature and day length. Soils best suited to wheat are medium to relatively heavy soils with good internal drainage. The crop is resistant to salinity, as an EC of 7 mmhos/cm results in a yield reduction of about only 10 %. In semiarid regions with irrigation, wheat grows in the winter period, preceding rice or cotton.

7.1.3.4. Barely

Barley cultivation is possible because of the very short period of vegetation (55 days in dry areas). Barley is also resistant to very high and very low temperatures and has a large salt tolerance. The fast ripening in a dry and warm weather enables a low yield, even with precipitation of 150-200 mm. Barley is sensitive against low pH-values, the optimum is pH 6 and at pH 8,4 barely growthis impossible. Barley is the most crops irrigated in investigated area which based on rain fed irrigation.

7.1.3.5. Alfalfa

Alfalfa (used for cellulose production) can be cultivated in temperate subtropical and tropical climates. It is a perennial grass that prefers deep soils with a loamy sandy texture. The soil reaction should be between pH 6, 2 and 7, 8. Drought resistance of alfalfa is medium, so that high available water content is important. The general level of nutrient requirements is high; especially for Ca and S. Alfalfa has a medium tolerance for soil salinity.

7.2. Perspective on agricultural development and further soil research

More than ninety percent of world's food production is dependent on our soil resources. Soil survey constitutes a valuable resource inventory linked with the survival of life on the earth. The technological advancements in the field of remote sensing and Geographical Information System are good tools for such surveys. Soil survey provides an accurate and scientific inventory of different soils, their types and quality, and extent of distribution so that one can make prediction about their sustainable management. It also provides adequate information in terms of landform, terraces, vegetation as well as characteristics of soils (texture, depth, structure, stoniness, drainage, acidity, salinity and others) which can be utilized for the planning and development.

The use of digital image processing for soil survey and mapping was initiated with the establishment of National Remote Sensing Agency and Regional Remote Sensing Service Centers in Egypt in Eighties.The initial works demonstrated the potential of digital image processing techniques for soil survey. A number of modeling studies were simultaneously carried out to derive a variety of information from soil maps, e.g. land evaluation, land productivity, soil erosion and hydrologic budget.

Soil resources are essential for land evaluation and decision making system. The north-western and eastern coastal plain of Egypt, received more attention as a promising region for different developmental activities, such as tourism, fishery, animal husbandry, agriculture and mining, and for its importance as a trading route between Egypt, Libya, Saudi Arabian, Jordon and Palestine. Shalatein, in the Eastern Desert of Egypt and Tushkay, in the western desert are an important area of population distribution and diversity of production food depending on the circumstances of warm climate in the region and for its importance as a trading route between Egypt and Sudan.

The major problem faced in conventional soil survey and soil cartography is the accurate delineation of boundary. Field observations based on conventional soil survey are expensive and time consuming, but necessary for gound truth validation. The remote sensing data in conjunction with ancillary data provide the best alternative, with a better delineation of soil mapping units. However, there is a need to have an automated method for accurate soil boundary delineation. Using the new mapping technologies of satellite remote sensing, laser-scanning technologies and advanced global navigation satellite system technologies offer both fast and accurate acquisition of topographic data. However, they also give new challenges for research and development as well as innovations for several application areas. A continuously developing range of field and remote data collection techniques ensures that map production flow lines must be able to handle spatial data varying in source, format, scale, quality, reliability and area of coverage.

Soil surveyors consider the topographic variation as a base for depicting the soil variability, using slope and aspects and land cover are being practiced for delineating the soil boundary. Multispectral satellite data are being used for mapping soil up to family association level (1:50,000). The methodology in most of the cases involves visual interpretation. Computer aided digital image processing technique has also been used for mapping soil.

The major challenge of Egypt is the need for better development and management of the natural resources. Irrigation projects that lead to a better use of the available fresh water are very important for the sustainable agricultural development. However, changes introduced in any national equilibrium result in a number of other changes and precautions ought to be considered to prevent land deterioration. The purpose of land reclamation and soil survey depends on identifying the characteristics as well as qualities and problems of the region selected, assess the area and the percentage of each type of soil mapping units.

While the land evaluation purpose is a map showing the ground units in accordance with the morphological characteristics, the results of natural and chemical analyzes of mapping units, as well as natural factors, economic and social. After the evaluation, the data combined to produce a map of grades of land use priorities for agriculture purposes. Suitability evaluation methods are needed for land reclamation because the choice of evaluation methods affects the accuracy and objectivity of the suitability evaluation results. Furthermore, it influences the decisionmaking related to land reclamation.

7.2.1. Site selection and other objectives

To meet the quickly increasing population requirement, it is important to use the vertical and horizontal expansion in the reclamation and cultivation of the desert soil. Nowadays in Egypt, location of land reclamation project, infrastructure and settlement of youth are the main reasons for the success in development projects.

Infrastructure is so important and frequently asked ahead of any significant decision to invest. Basic physical infrastructure such as roads, railways, ports and water treatment stations enable the economy to function and attract further new investments. With the need to build sustainable, knowledge-based economies, infrastructure has taken on a wider social context creating jobs and new potential for business growth. In Egypt, it is believed that infrastructure is a crucial component of a successful modern economy.

This research located in northwestern coastal zone of Egypt and has a good position such as, Alexandria, Borg El-Arab and El-Alamein airports. International and Wadi El- Natrun to El-

Alamein highway, and an additional some ways are crossing the area. Fresh irrigated and drinking water is taken from El-Hammam canal, while its extension does not have water.

Soil properties can provide information for land-use planning, project managements, and provide the methods by which surveyors can observe this information and assess some problems of the performance, or potential performance of the land. The need was to produce the results as quickly and efficiently as possible to aid agricultural planning. By using a GIS, a series of single factor (soil properties) and land evaluation maps are product for land capability and land suitability for crops. The aims of maps of soil survey showing the distribution of soil properties and land suitability maps for a range of crops.

The following expected results should be taken into account:

1- Production of a series of single factor maps for the following properties; soil order and suborder, drainage, slope, and land use, availability of irrigation water, erosion hazard, soil texture at different depths and distribution of the majour soil properties.
2- Soil erosion management for application to other areas.
3- Land suitability maps for general agriculture as well as for specific crops in arid and Mediterranean soils.
4- Maps showing alternative land uses and land priority based on land evaluation analysis.

7.2.2. Project design and implementation

Land use planning, soil survey, remote sensing, soil properties, land capability and land suitability for crops are important, so as to have a basis for the design of engineering works and to predict the response of the land to the projected management. Usually, a range of crops, management systems, and farm sizes will be considered.

7.2.2.1. Land use planning

Planning concepts for land use aim is establishing Government policies for future use and development of land for the community**.** Land-use planning objectives may include:

- Reclamation and settlement, or more intensive use, of areas that will support new communities and will yield a good return for the effort and cost of development;
- Conservation of the existing productive capacity of areas that cannot support viable developments. Avoidance of long-term environmental damage;
- Improvement of the productive capacity of soils that are already being farmed.

For strategic planning, one need**s** to know whether or not there is enough potentially suitable land to make development effective. For project feasibility studies, one needs to know the distribution of suitable and unsuitable soils and the kind and severity of soil problems. Also, one needs more details on projected production, probably under a range of alternative management systems. The initial cost of obtaining this production, the time scale involved in any land reclamation or improvement and the social and environmental impact of alternative systems of land use should be considered. The main stages of the reclamation soil project are field surveys, field and laboratory research work, design of irrigation and drainage system.

7.2.2.2. Soil survey

Soil survey is not a simple process of mapping discrete units of land. Each soil properties changes more or less gradually and changes in one characteristic and is not always in phase with changes in others. The first task of the surveyor is to define the specific purpose of the survey. Then it can be decided what characteristics of the landscape should be surveyed, what kind of soil mapping units will be used, and what scale will be suitable. Soil survey and classification process are included office work based on a proper field work and associated laboratory analysis.

7.2.2.3. Land evaluation requirements and land characteristics in arid and Mediterranean area

The choice of evaluation methods affects the accuracy and objectivity of suitability evaluation results for land reclamation areas and influences the decisionmaking related to land reclamation. The evaluation and land characteristics factors play an important role in the accuracy of suitability evaluation for land reclamation. A set of independent but complementary factors should be selected in the course of suitability evaluation. In the presented study, the following evaluation factors were chosen for most of the soil properties, climate and water status. After determining the evaluation factors, the evaluation grade standards of the main limiting factors should be established for evaluating the reclaimed land. The main reclamation directions should be farmland and desert based on the actual conditions in Egyptian soils.

Land evaluation systems (land capability, land suitability for crops) were applied in this study and matching with another locations of Egypt. MicroLIES, Sys and Storie models are used for the most soils. The MicroLIES model depends on soil profile depth, drainage, texture, $CaCO_3$ content, salts content and ESP %, while the Sys model adds to the previously mentioned properties soil topography, coarse fragment, gypsum, cation exchange capacity, and organic matter content. Storie index land evaluation system depends on soil profile depth, gravel, slope soil reaction (pH), Sodium adsorption ratio (SAR), salinity, and texture and erosion factors.

Land evalution (capability and suitability) are estimated or measured by means of land characteristics (LCs). Land characteristics, refer to an element of land that can be measured and estimated. According to (Elaalem, 2010b), (Nwer, 2005) and (Purzner, 2008), the following land qualities and land characteristics have a major effect on land suitability evaluation for cash crops in desert and Mediterranean area:

Rooting conditions: This land quality was assessed using the combination of two land characteristics:

Soil texture: Soil texture is considered one of the most important soil criteria affecting soil behavior and land management, and it influences a number of physical and chemical soil characteristics, such as total porosity, wilting moisture, aeration porosity and soil fertility

Root able depth: Root able depth is an essential requirement in land suitability classification. It is identified as a key for many soil characteristics, such as soil drainage, irrigation conditions and yields for all crops Each crop has an optimum soil depth and this depth differs from crop to crop.

Moisture availability: One land characteristic was employed to evaluate this land quality:

Available water holding capacity (AWHC): AWHC is considered an important soil criterion in land suitability classification and planning for irrigation. It is defined as the amount of water that can be stored in soils for plants to utilize during periods without rain or irrigation, and therefore this property of soil is used as an indication of soil wetness

Nutrient availability: To assess nutrient availability for the selected crops, only one land characteristics was used:

Soil reaction (Soil pH): Soil pH is the most important soil criterion in land suitability classification and it controls many chemical soil characteristics and some physical soil properties. Soil reaction controls the solubility of most soil minerals; for example, high soil pH leads to low micronutrient availability and decreases the availability of macronutrients such as calcium, magnesium and phosphorus. The majority of plants prefer to grow in pH between 5 and 7.5.

Nutrient retention: Two land characteristics were taken into consideration to evaluate this land quality:

Soil organic matter: This is a very important soil criterion and is considered to be the main source for many elements in soil. Soil organic matter supplies soils with nitrogen, phosphorus and sulphur, and helps to maintain the aggregates of soils and increase resistance to erosion. Increasing organic matter in soils will increase the amount of water for plant growth.

Cation exchange capacity (CEC): The cation exchange capacity (CEC) is used as one way of estimating soil fertility. Soils with a high value of CEC are considered fertile, and soils with a low value of CEC are considered infertile (London, 1984). The cation exchange capacity is used as a parameter for the buffering capacity for fertilizers. The natural fertility level and the buffering capacity do not strongly interact in their influence on the crop and are treated as separate components of the land quality.

NPK: Nitrogen helps plant foliage to grow strong. Phosphorous helps roots and flowers grow and develop. Potassium is important for overall plant health.

Trace elements Heavy metals: Background concentrations of trace elements in soils are important due to recent interest in contamination potential and toxic effect of these elements on humans and the environment. The original source of trace elements in soils is the underlying parent material. Trace elements are present in many minerals and ore deposits that make up different rocks and geologic units. In soil, trace element retention is dependent on several soil characteristics, as well as parent material. Soil characteristics include pH, cation exchange capacity (CEC), particle size distribution, organic matter content, and oxide content. Some heavy metals are essential in trace amounts namely Zn, Cu and Mn for plants and in addition Co and Ni for animals. A number of cases of health problems related to environmental Cd poisoning. Cadmium may not affect the growth of plants, but it can render a health hazard when consumed by humans and animals

Excess of salts: To assess this land quality, combinations of two land characteristics were used:

Soil salinity: Saline soils are those soils which have an electric conductivity (EC mmohs/cm) of more than 2; salinity refers to the total concentration of all salts in the soils. Soil salinity is a really serious problem for the majority of arid zone soils. A high quantity of salts in soils leads to a decrease in crop production. Plants differ in their resistance and responses to salts.

Soil alkalinity: Solonetzic soils are those soils that have an exchangeable sodium percentage (% ESP) of more than 15 and also have a high value of soil pH (mostly in the range of 8.5 to 10). Soils vary in their quantity of sodium, and plants have different responses to being grown in solonetzic soils; most plants cannot resist the high value of the ESP.

Soil toxicities: this land quality was evaluated by using:

Soil calcium carbonate: Soil $CaCO_3$ is also identified as an important soil criterion for agricultural crops in my area. This criterion affects soil moisture regime and availability of nutrients to plants.

Condition for germination: This was evaluated by taking into account the following land characteristics:

Stones at surface: Stones at the surface have different effects on agricultural functions such as crop cultivation, crop harvesting and seed germination. Increasing stones at the surface may limit the use of mechanization.

Oxygen availability: This land equality was assessed using:

Soil drainage: Soil drainage is an important soil criterion in land suitability classification, and is also considered one of the most important requirements that should be taken into account in designing agricultural lands under irrigation conditions. It refers to oxygen availability in the roots and in some cases could lead to reduced plant growth and yields.

Infiltration: This land quality has been evaluated using:
Infiltration rate: This refers to the entry of water into the soils. Infiltration rate is affected by main physical soil characteristics such as soil texture, porosity, structure and others.
Erosion hazard: Evaluation of erosion using:
Soil erosion: Erosion is also an important land characteristic in land suitability classification. The effect of erosion hazard is to decrease soil quality and agricultural productivity. Soil erosion degrades the soil fertility and also leads to a loss of vegetation cover

Potential for mechanization: Assessment soils based on the basis of slope steepness:
Slope steepness: This is considering an important factor in land suitability classification and irrigation assessment. It affects on the irrigation methods, irrigation efficiency, soil drainage, soil erosion, labour requirements and mechanization type. Finally, steps are interpretation of analytical results and management recommendations based on interpretive analytical results.

7.2.2.4. Reclamation Costs

Land reclamation is a cost and time consuming process. It needs serval years to recieve the optimum of production. Toshka, East Oweinat, North coastal plain and the Sinai Peninsula are coming under the spotlight again after the revolution; launched a new initiative aimed at reclaiming some one million feddans (1 feddan = 1.038 acres) over five years. Furthermore, the governments work on boosting productivity in Egypt's soils already under cultivation, a recommendation proposed by many other agriculture experts.

The preparation of reclamation cost estimates is a step-by-step process for calculating the amount of financial assurances necessary to perform site reclamation. The calculation of reclamation costs will be different between locations based on the tasks necessary to implement the approved reclamation plan. The Guidance and requirements for reclamation costs including estimate direct and indirect reclamation costs.

7.2.2.4.1. Direct reclamation cost

Direct reclamation cost estimate spreadsheets should be developed for the soils and irrigation network. Average of direct reclamation cost without geology, geophysics and soil analysis studies is ranges 6,500 to 7000 pound for 1 feddan (~17,000 pound /ha) for land reclamation and cultivation by orange and mandarin (Table 41). At the stage of planning, a decision must be made; either the project can support a limited extent of unfavourable soils, or the area affected by the soil problems and the cost of reclamation will be so great as to abort the project.

7.2.2.4.2. Indirect costs

Indirect costs must be added to the preliminary total direct cost estimate. Indirect costs are usually expressed as a percentage of the direct cost sub-total or total contract cost and typically include:

- Insurance 1% of total direct costs
- Workers Compensation 10% of total labor
- Contract Administration 15% of total direct costs
- Bond 1% of total direct costs
- Profit 10% of total direct costs

Reclamation soils steps can be summarized in the following stages and (Figure 108):

a. Processing of satellite data, GIS data preparation and soil map generation.
b. Field work, laboratory analysis and re-interpretation of satellite data.
c. Coding soil database attributes and testing the geographic soil database.
d. Land capability assessment and land suitability assessment for different crops.
e. Crop water requirements and planning the sustainable land use.
f. Soil erosion assessment, land use planning infra structure and urban settlement.
g. Water resources availability and economic return from water and financial return from land and water.

Table 41: Direct costs of reclamation soils and well drilling in Wadi El Natrun area (40.0 hectare), North Western Egypt

Well drilling cost	Cost Pound	Land reclamation and cultivation	Cost Pound
Drilling cost	80,000	Removal of stones, rocks, settlement and soil preparation	14,000
Electric cable	22,000	Irrigation network design	210,000
Pump 100 HP	60,000	Drilling soils, compost and organic fertilizer..etc	288,000
Pipes 180 meters	25,000	Seedlings (Orangenand mandarins)	172,500
Electric generator	90,000	Taxi workers	140,000
Taxi workers	4,000	Supervision of the implementation	15,000
Other costs	3,000	Other costs	23,500

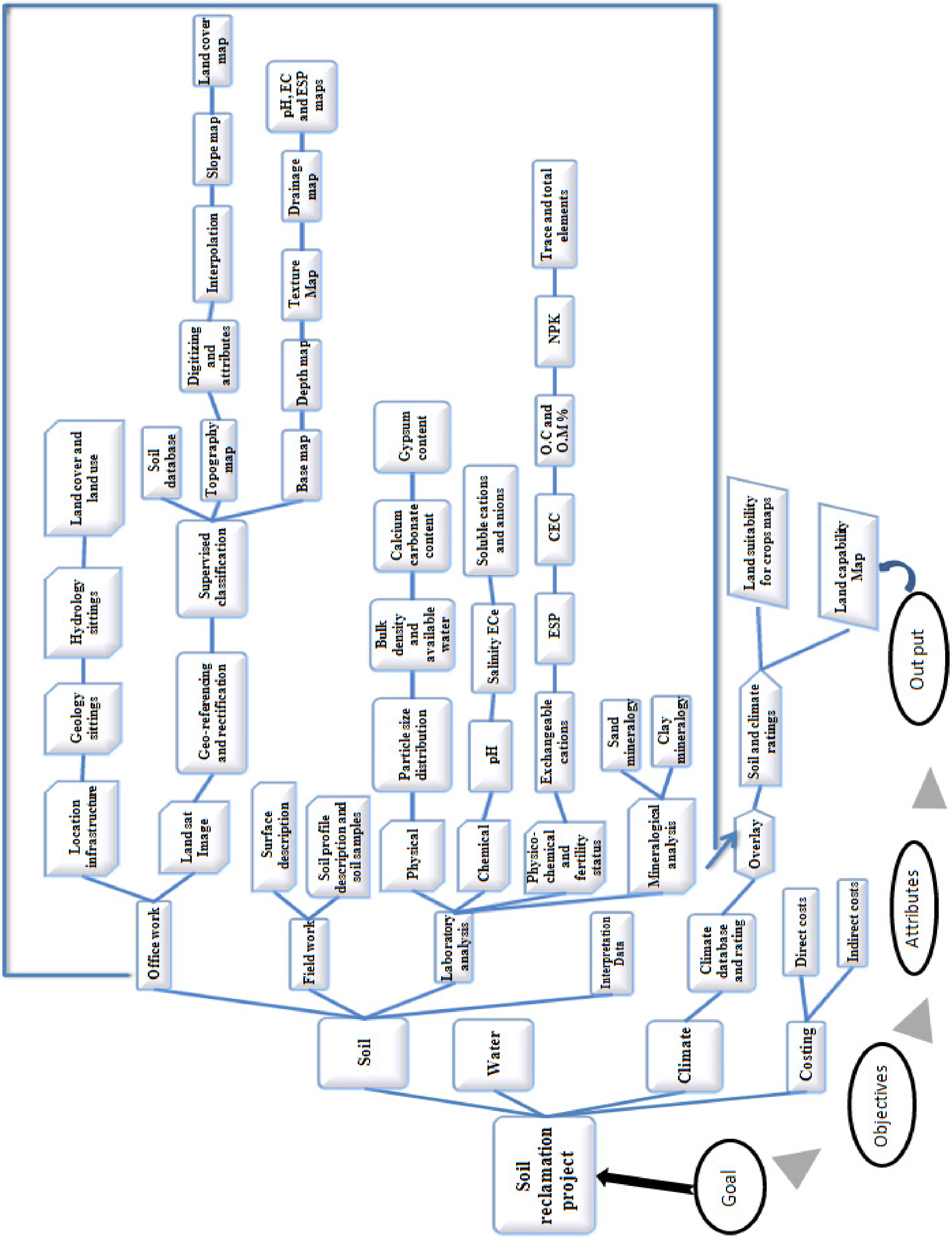


Figure 108: Flow chart of the methodology of the soil reclamation project

7.3. Conclusion and recommendations

The soils of the investigated area based on land capability- The American method "USDA" could be ranged between two ranges; is the soil suitable for crop land "that have very severe limitations that restrict the choice of plants or require very careful management, or both" (class IV). Is it suitable for pasture, range and woodland "that have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife" (class VII). The land evaluation was determined on parametric methods such as land capability and productivity (Storie index 1978 and 2008), land suitability for irrigation (Sys and Verhye,1978) and Land suitability for different irrigation systems (Sys et al.1991). Based on these methods, land capability and productivity according to Storie index (1978 and 2008) could be ranged between poor (grade 4) to non-agricultural (grade 6) and good (grade 2) to non-agricultural, respectively.

From previous results, the difference between land capability classes based on Storie index (1978 and 2008), is that the using limitations in Storie index (2008) was more commonly used than Storie index method (1978). Land suitability for irrigation according to Sys and Verhey (1978) method was to provide a method that permits a suitable evaluation for irrigation purposes based on wetness, topography, physico –chemical characteristics and conditions of salinity and alkalinity of the soil profiles. The results of land suitability for irrigation are marginally suitable (S3), currently not suitable (N1) and permanently not suitable (N2).

The most limiting factors for land suitability for crops (Sys and Verhye, 1978) are soil texture, soil depth and calcium carbonate content. Details are given for the analysis of the field data to make a comparison between the land evaluation methods and the suitability of different irrigation systems. The analyzed parameters included soil and land characteristics. The results obtained showed that the land suitability of drip and surface irrigations is marginally suitable (S3), currently not suitable (N1) and permanently not suitable (N2).

According to our discussions in the earlier chapters, the Drip and sprinkler irrigation system showed to be more suitable than the surface irrigation in the area under study. As a result, the drip irrigation in arid and sem-arid regions appeared to be the most appropriate irrigation, because of the shortage of water. The major limiting factor for the drip irrigation system was calcium carbonate content however, for surface irrigation system were soil texture and calcium carbonate.

Land capability classes according to ALES method are marginal (S3), limited capability (S4) and not suitable (S5). In this model each soil characteristic of the study area is matched with its corresponding limiting values of the capability classes. The final land capability class depends on the highest limiting factor. The major limiting factors for ALES manual method are soil depth, soil texture and calcium carbonate content. Land capability model

(CERVATANA) based on computer program and MicroLEIS web-Based Program, 2009 (http://www.evenor-tech.com/microleis), the result obtained are good (S2), moderate (S3) and Marginal or Nule (N) for soils profiles which represented the soils adjacent El-Hammam canal and its extension.

Results indicate that the area currently lacks high capability and land capability for most of the land use systems are ranged between moderate or/ marginally suitability classes and non-suitable .The results of land suitability for crops according to limiting factor method (Sys et al. part III, 1993) ranged between moderately suitable (S2) and permanently not suitable (N2). The most suitable crops for irrigation based on this method are sorghum > olive > fig > barely > wheat > tomato and guava. While land suitability for crops according to MicrolIES model (ALMAGRA) are suitable (S2), moderately suitable (S3), marginally suitable (S4) and not suitable (S5). Land suitability of El-Hammam canal and extension for the most suitability certain crops could be classified are olive > citrus > peach > wheat, alfalfa, melon and sunflower and ranged between suitable (S2) and not suitable (S5).

As shown from Table 42, the land capability of the study area according to Storie index (2008) varies from "good capability" to "Non-agriculture" due to different limiting factors. According to MicroLIES program, the capability varies from "good capability" to "marginal or noll suitable", wheareas, about (38.8 % of the evaluated soils) have good capability; about 28.3 % have moderate capability and about 21.9 % are marginal or not suitable. There are about (11 % of the evaluated soils) are rocky outcrops and could be available to be settlements for farmers and Bedouins.

Table 42:Current land capability and land suitability for crops of the study area

<table>
<tr><th colspan="2">Methods</th><th colspan="7">Land capability and land suitability for crops classes (10^3 ha)</th></tr>
<tr><td rowspan="4">Land capability</td><td rowspan="2">Storie index 2008</td><td colspan="2">Good</td><td>Fair</td><td>Poor</td><td>Very poor</td><td>Non-agricultural</td><td>Rock out-crops</td></tr>
<tr><td colspan="2">5.8</td><td>8.0</td><td>8.2</td><td>19.2</td><td>16.5</td><td rowspan="11">7.1</td></tr>
<tr><td rowspan="2">MicroLIES</td><td colspan="2">Good</td><td>Moderate</td><td>Marginal</td><td></td><td></td></tr>
<tr><td colspan="2">25.2</td><td>18.4</td><td>14.2</td><td></td><td></td></tr>
<tr><td rowspan="8">Land Suitability for crops</td><td>Crops</td><td>Highly suitable</td><td>Suitable</td><td>Moderately suitable</td><td>Marginally suitable</td><td colspan="2">Not suitable</td></tr>
<tr><td>Olive</td><td></td><td>17.4</td><td>19.1</td><td>23.2</td><td colspan="2">19.7</td></tr>
<tr><td>Fig</td><td></td><td></td><td>24.3</td><td>17.9</td><td colspan="2">15.5</td></tr>
<tr><td>Peach</td><td></td><td></td><td>21.6</td><td>18.8</td><td colspan="2">17.3</td></tr>
<tr><td>Citrus</td><td></td><td></td><td>20.3</td><td>21.3</td><td colspan="2">16.3</td></tr>
<tr><td>Wheat</td><td>1.5</td><td>4.5</td><td>8.7</td><td>21.5</td><td colspan="2">21.3</td></tr>
<tr><td>Barely</td><td></td><td></td><td>15.3</td><td>18.6</td><td colspan="2">23.8</td></tr>
<tr><td>Alfalfa</td><td></td><td></td><td>7.1</td><td>28.5</td><td colspan="2">21.8</td></tr>
</table>

The obtained results reveal that the evaluated crops could be determined and arranged according to their soil suitability classes as follows: olives > fig > peach > citrus > wheat, barely and alfalfa.This arrangement reflects the priority for agricultural utilization. Referring to the obtained evaluation results, there is soils about 16.5 (10^3 ha) express suitability for olive tree plantation. On the other hand, the most soils express moderately suitable for fig, peach, citrus, barely and alfalfa plantation, taking into consideration the soil texture, calcium carbonate content and drainage condition as limiting factors.

The main objective of this research was to compare different methods of land evaluation based on physical and chemical soil properties. The results obtained showed that the parametric method has better precision than limitation method. Modern methods such as; MecroLIES method is more suitable and easier than parametric methods. Land capability and suitability for crops (MecroLIES model) was applied on the soils of Mediterranean region. The North Western coastal plain in Egypt located in Mediterranean region, so we can say that this method is suitable for the study. However, we must take into account the following:

1-Emphasis in the coming period to consider amending soil salinity values depending on the values in Guideline of soil description 2006.

2-Soil rating index for coarse textured soil with high percentage of salinity and characterized by irrigation water resource is better than heavy coarse textured soil without source of irrigation water. Soil rating values of limitation factors in MicroLIES program are different than soil rating value of Sys et al 1993 , e.g.: highest rating value of soil salinity in MicroLIES is 12.0 dSm^{-1}, while Sys et 1993 soil salinity rating is 32 .0 dsm^{-1}

Land capability and land suitability for crops are subjected to different limiting factors in the soils adjacent El-Hammam canal and its extension. These factors are soil depth, soil texture, salinity and alkalinity and calcium carbonate content. Some can be mitigated or improved by applying the appropriate soil management practices, these soil management practices include:

1. Improvement of the drainage.
2. Deep plowing or sub-soiling to improve soil permeability and moisture availability.
3. Organic fertilization to improve permeability, CEC and nutrient availability.
4. Applying modern irrigation systems and the reduction of irrigation periods to avoid the soil crust formation caused by the calcareous soil.
5. Irrigation water with salinity less than 130 parts / million and Add gypsum agricultural in soils.

The main objective of land reclamation is to remove or improve one or more limitation factor affects the productivity of the soil where the soil is converted from non-productive state to another productive highly economical. Calcareous soils reclamation is an attempt to address the various problems which accompany such land to be converted into a suitable environment for the growth and economic productivity of plants. Soil properties and limitation factors are not preventing the economic exploitation when emphasis on planting crops that more suitable in calcareous soils. In general, reclamation of these lands does not mean an attempt to reduce the percentage of calcium carbonate in the soils. This land is located in the Mediterranean region, where the total area of calcareous soils in Egypt about 263(10^3 ha). These lands represent most of the agricultural expansion plans and development of the North Western Egypt.

Landmines and unexploded ordnance dating from World War II affect 2.500 sq. km of the Northwest Coast of Egypt are mainly in the El-Alamain-Qattara Area. It hindered and stopped significantly the agricultural region as well as industrial and tourist developmental programs of Matrouh Governorate. There is no resources database in a geo-reference and digital form for the landmine-affected and de-mined areas at the northwest coast of Egypt that ensure the implementation of sustainable integrated developmental programs. Therefore, Establishment of the United Nations Information Management System for Mine Action in Egypt is vital to enhance the capacity of the Government to set priorities and plan mine action in a coordinated manner.

The coastal plain of Egypt is characterized by a variety of soil types, in addition to supportive fresh surface water resources balanced with irrigation network urban settlements and infra structure. However, the study showed a variety of land suitability for the most local crops and capable soils. Urban expansion locations and management of soil productivity, in addition to fresh water and drainage are major issues to be followed for sustainability. Human occupation of the study area is lower than urban settlements and Nile delta, due to the lack of information of soils and planning infrastructure.

Physical and chemical properties of these calcareous soils are generally affected by the high content of calcium carbonate. Most of the defects in properties of these soils are due to the problems of salinity, alkalinity, and soil texture the hazards of these problems are extremely affected with increasing calcium carbonate contents, exchangeable sodium (Na) or poor aeration and hydraulic conductivity in the soils. So that cultivation of these soils to gain optimum yields depends mainly on the continuous improving of their physical and chemical properties.

Based on the previous conclusion, it is recommended to establish two settlements in the east nearly El-Alamein wadi El-Natrun highway road; this area has a good infrastructure (water irrigation, soil, drinking water and highway road, which is represented by limestone rocky outcrops on east and west the highway road. El-Dabaa and Sidi abd El-Rahamn area are available to be settlements for farmers and grazers. These people would use the available area for agriculture and grazing in the coastal plain northward of the highway. El-Dabaa Town is thus proposed to be an urban centre for the study area to provide professional services for the study area and housing services for the nuclear power station employees. On the other hand, Coastal beach tourist villages extend along of study area, study area to provide professional services for tourism.

The most of the methods which are used consist of six parameters including slope, drainage properties, electrical conductivity of soil solution and alkalinity, calcium carbonate status, depth and soil texture. Each of these parameters are scaled according to the related tables of soil ratings and capability index for irrigation. Soil ratings value for coarse textured soils are considered lowest value and soil salinity more than 12.0 dSm^{-1} are not suitable for most land evaluation systems. In this case; modification for salinity levels and soil texture ratings under ivistgation, because salinity is a correctable limitation and could be easily corrected in the field particularly in coarse-textured soils.

CHAPTER VIII: SUMMARY

Beside the region of the Nile Valley and Delta the North Western coast of Egypt is considered as one of the most important regions for land reclamation for agricultural expansion and for tourism development projects. Dealing with this region, the thesis has two general objectives. The first is to evaluate the land resources of a part of this region for future agricultural development. Based on this study and the reports about other Egyptian land reclamation projects the objective of the second part is to assess different methods to qualify soil properties for irrigated land use. Here the focus is on the type of soil information (e.g. remote sensing, mapping, laboratory analysis), there spatial density as well as on the methods to come to a holistic assessments of the land suitability for different types of agriculture.

The study area is lies between longitudes 29° 00’ and 28° 30’ E and latitudes 30° 30’ and 31° 00’ N adjacent to an irrigation channel (El-Hammam Canal) which is not under function in the western part. In total, the area has a size of about 650 km^2 and has only a minor agricultural land use property due to small amounts of annual rainfall. To fulfill the aim of the study, 43 soil profiles representing the study area were morphologically described and sampled. In the laboratory, the soil samples were analyzed on their relevant physical, chemical and physico-chemical properties. Land use productivity is controlled by soil physical and chemical characteristics and their spatial distributions. Spatial data of soil properties were presented as individual maps by GIS (E. g. depth, salinity, reaction, calcium carbonate contents and exchangeable sodium percentage).

The obtained results indicate that soils are coarse textured in general. Most of the soils have a sandy texture throughout the entire depth of the profile whereas some profiles exhibit a texture varying between coarse sand to sandy loam. Soil structure is different with depth, being single grains in the top surface layers of all soil profiles and massive to week subangular blocky in the subsoil layers. Soil reaction varies considerably between 7.4 and 9.4, indicating slightly alkaline to very strongly alkaline soil reaction. Soil salinity values ranged widely between 0.82 and 33.1 dSm^{-1}, with an average value of 6.2 dSm^{1} (slightly saline). Soil adjacent El-Hammam canal and their extensions are shown to be extremely calcareous, where $CaCO_3$ contents range between 27.1 % and 69.5 % with an average value of 46.4 %.

Cation exchange capacity is quite low and varies from 2.0 to 8.57 meq/100g with a dominance of Ca^{++} on the exchange complex. CEC values were higher in soil layers containing high fine material and /or high organic carbon. The presence of carbonate minerals associated with silicate minerals lead to a diminished cation exchange capacity. Exchangeable sodium percentage values are ranged between 0.69 and 39.85 %. Organic matter content is very low to low, it ranges from 0.12 to 1.69 % .The macronutrients (NPK) levels are low for N and P, while levels of K are somewhat sufficient in some soil profiles. Total content of iron (Fe_2O_3) generally ranges from 0.65 to 3.1 % and total content of manganese is ranged from

0.02 to 0.06 %. Total content of zinc ranges widely from 4.0 to 48.0 ppm, while total content of copper generally ranges from 2.0 to 11.0 ppm.

Soil classification was carried out following the most recent American system (keys to soil taxonomy, 2010) and the World reference base for soil resources (WRB, 2006). In the light of the relevant soil properties, two suborders could be distinguished under the order Aridisols, namely; Salids and Calcids and one suborder Psamments is related to the order Entisols. According to the World Reference Base for Soil Resources soil profiles were classified under the main group Calcisols.

Regards to distribution of weighted mean contents of Zr, TiO_2 and SiO_2, the highest value is formed in shallow and very shallow soil profiles. Depth-wise distribution of Zirconium (Zr), titanium (TiO_2) and silicon (SiO_2) were taken as criteria for investigating of profile uniformity and weathering sequence for these sediments. The most common methods to evaluate parent material uniformity are examination of sand/silt+clay and TiO_2/Zr or/TiO_2/SiO_2 ratios. The obtained data indicates that trend distributions of ratios are differential weathering within the soil profile and soil under study is pedologically young and is weakly developed.

To find the best priorities of agricultural land use within the studied area, the soils have been evaluated using the land capability and land suitability systems. These systems are based on the following parameters such as; slope, topography, depth, texture, calcium carbonate content, gypsum content, salinity and alkalinity, cation exchangeable capacity, exchangeable sodium percentage and sodium adsorption ratio.

Based on the actual soil properties, land capability and suitability for agricultural production were assessed using the six systems (American method -USDA, Storie index 1978 and 2008; Sys and Verhey 1978, Sys et al. 1993; ALES; MicroLEIS). Results indicate that the area currently lacks high capability and land capability for the most systems are ranged between moderate or/ marginally suitability classes and non-suitable.

Land capability of the study area according to Storie index (2008) varies from “good capability” to “non-agriculture” due to different limiting factors. The results show that, about 9.0 % of the evaluated soils have good capability; about 12.3 % have fair capability; 12.7 % are poor; 29.6 % very poor and about 22.5 % are not suitable for agricultural use. There are about (11 % of the evaluated soils) are rocky outcrops and could be available to be settlements for farmers and Bedouins. According to MicroLEIS program, the capability varies from “good capability” (38.8 % of the evaluated soils) to “marginal or null suitable” (21.9 %) with about 28.3 % of the area having a moderate capability.

The most limiting factors for current land suitability for major crops (wheat, sorghum, barley, alfalfa, maize, sunflower, tomato, melon, olive, fig, peach, guava and citrus) were soil depth, soil texture, drainage, calcium carbonate content, salinity and alkalinity. However, the potential suitability can be improved partly as main limitations coming from salinity and drainage could possibly be corrected, while soil depth and soil texture limitations have to seen as persistent.

The main objective of this research was to compare different methods of land evaluation based on physical and chemical soil properties. The results showed that methods integrating properties to one index have a higher precision than methods that qualify soils on limitations for single parameters. Modern software controlled methods such as MicroLEIS are more suitable and easier to apply than parametric methods. The application of the Storie index (2008) and CERVATANA (land capability model) to the studied area already under agriculture reveals good agreement between evaluation results and actual land-use. The classifications on land suitably for crops generated by Sys et al. (1993) and the ALMAGRA system have some disadvantages regarding the soil salinity and soil texture ratings, however, if the systems are improved they produce reasonable results.

Water must be supplied in sufficient quantity and desired quality, when the crop needs it. The drip irrigation can obviously be a way to improve the practice on light soil texture, aiming at maximizing water use efficiency, thus producing more crops per drop and helping to solve the water shortage crisis in the agricultural sector. Additionally to water supply an improvement of the soil productivity depends on the nutritional status of the soils. Here, the low organic carbon contents under natural conditions should be improved by fertilization and regular ploughing. However, the high contents of calcium carbonate needs a land use with adapted crops, which for the studied region are olive, fig and peach, tomatoes and sunflower.

The exercise proved that the analysis of soil characteristics and the application of tools for land capability and suitability evaluation are powerful tools for decision-making and can be used as a decision support system.

CHAPTER IX: Zusammenfassung

Der nordwestliche Küstenraum Ägyptens wird nach dem Niltal und – delta als eine der wichtigsten Regionen für die landwirtschaftliche Expansion und die touristische Entwicklung angesehen. In dieser Region verfolgt die Arbeit zwei Ziele: Erstens wird die natürliche Leistungsfähigkeit der Böden erfasst und hinsichtlich zukünftiger landwirtschaftlicher Entwicklungsprojekte bewertet. Aufbauend auf dieser Analyse und den Projektergebnissen weiterer ägyptischer landwirtschaftlicher Projekte werden zum zweiten die verschiedenen Verfahren zur Bewertung von Böden für die Trockengebiets-Bewässerungslandwirtschaft analysiert. Dabei liegt der Schwerpunkt auf der Art der benötigten Bodeninformation (z. B. Fernerkundungsdaten, Karten, Laboranalysen), deren räumliche Dichte wie auch der Methoden zur Integration der Daten hinsichtlich einer gesamtheitlichen Bewertung der Eignung für verschiedene landwirtschaftliche Nutzungstypen.

Das Arbeitsgebiet liegt zwischen 29° 00’ und 28° 30’ östlicher Länge und 30° 30’ und 31° 00’ nördlicher Breite beidseitig angrenzend an einen Bewässerungskanal (El-Hammam Kanal), der im westlichen Abschnitt noch nicht in Betrieb genommen wurde. Die Gesamtfläche beträgt etwa 650 km^2 und hat nur ein geringes landwirtschaftliches Nutzungspotential aufgrund der niedrigen Jahresniederschläge. In diesem Gebiet wurden 43 Bodenprofile an repräsentativen Positionen ausgewählt, morphologisch beschrieben und über die gesamte Profiltiefe beprobt. Im Labor wurden die Bodenproben im Hinblick auf ihre für die Bewertung wichtigen physikalischen, chemischen und physiko-chemischen Eigenschaften analysiert. Die räumliche Verteilung der Werte erfolgte auf Karten.

Die Ergebnisse der Bodenanalysen werden wie folgt zusammengefasst:

- Die Böden sind generell grob texturiert, meistens in allen Horizonten. Einige Profile weisen Mischungen von Grobsanden bis sandigen Lehmen auf. Die Sandfraktion hat einen Anteil von 86 % bis 98 % (Mittelwert 92 %), der Anteil der Kiesfraktion variiert von 0.2 % bis 38.5 %.
- Es handelt sich überwiegend um sehr kalkreiche Böden mit Carbonatgehalten von 27.1 % bis 69.5 % $CaCO_3$. Gips wurde in den Bodenproben nur vereinzelt gemessen und lag dann bei 0.01 % bis 2.29 %.
- Die Bodenreaktion ist sehr schwach bis stark alkalisch und weist pH-Werte von 7.4 bis 9.4 auf.
- Die Böden des Arbeitsgebietes sind schwach bis extrem salzhaltig; die Leitfähigkeit variiert zwischen 0.82 dSm^{-1} und 33.6 dSm^{-1}, wobei in der Bodenlösung Na^+ und Cl^- dominieren.

- Die Kationenaustauschkapazität ist niedrig und liegt bei 2.0 bis 8.6 m_{eq}/100 g, hier dominieren die Ca^{2+}-Ionen am Austauscher, die austauschbaren Anteile von Natrium liegen zwischen 0.69 % und 39.9 %.
- Der Gehalt an organischer Substanz im Boden ist sehr gering bis gering und liegt zwischen 0.12 % bis 1.69 %. Das Versorgungsniveau der Makronährstoffe ist für Stickstoff und Phosphor gering, für Kalium in einigen Bodenprofilen ausreichend.

Die Böden wurden nach den Systemen *Soil taxonomy* (2010) und *World Reference Base for Soil Ressources* (WRB, 2006) klassifiziert. Anhand der Bodeneigenschaften konnten die untersuchten Böden in zwei Unterordnungen der *Aridisols* gegliedert werden, die *Salids* und *Calcids* sowie die Unterordnung der *Psamments* die zu den *Entisols* gehört. Nach der WRB werden alle Böden des Arbeitsgebietes der Hauptgruppe der *Calcisols* untergeordnet.

Hinsichtlich der gewichteten Mittel der Zirkon (Zr), Titandioxid (TiO_2) und Siliziumdioxid (SiO_2) Gehalte, wurden die höchsten Werte in flachen und sehr flachen Böden gefunden. Die Tiefenverteilung der drei Elemente Zr, Ti und Si wurden herangezogen um die Gleichförmigkeit und die Verwitterungssequenz im Profil zu untersuchen, wobei Quotienten der Parameter Sand/Schluff+Ton, TiO_2/Zr oder TiO_2/SiO_2 eingesetzt wurden. Die vorliegenden Daten zeigen, dass in den Profilen unterschiedliche Verwitterungsstufen vorliegen und die untersuchten Böden pedogenetisch noch jung und schwach entwickelt sind. Betrachtet man die Schwermetallgehalte, so liegen diese im Bereich von normalen Böden.

Um die Böden hinsichtlich ihrer Eignung für die landwirtschaftliche Nutzung zu bewerten, wurden mehrere Verfahren zur Eignungs- und Potential-Bewertung herangezogen, die auf Parametern wie Neigung, Topographie, Entwicklungstiefe, Textur, Calciumcarbonatgehalt, Gipsgehalt, Salzgehalt und Alkalinität, Kationenaustauschkapazität, Anteil an austauschbarem Natrium und Natriumadsorptionsverhältnis basieren. Zum Einsatz kamen dabei sechs Systeme (USDA-Methode, Storie index von 1978 und 2008; Sys and Verhey 1978, Sys et al. 1993; ALES; MicroLEIS).

Die Daten der aktuellen Situation zeigen, dass es im Arbeitsgebiet an hoher Nutzungsmöglichkeit mangelt und sich die Landnutzungspotentiale im Bereich von mäßig und geringfügig und nicht geeignet bewegen. Das Nutzungspotential des Gebietes wird allerdings nach dem Storie index (2008) zwischen „good“ bis „non-agriculture“ aufgrund verschiedener begrenzender Faktoren eingestuft. Hinsichtlich ihres Potentials wurden dabei 9.0 % des bewerteten Gebietes als “good”, 12.3 % als “fairly good”, 12.7 % als “poor”, 29.6 % als „very poor“ und 22.5 % als „not suitable for agricultural use“ eingestuft, wobei rund 11 % der Fläche Felsdurchragungen haben, die nur für die Besiedlungen geeignet sind.

Nach der Bewertung mit dem MicroLEIS System variiert das Nutzungspotential zwischen “gut” (38.8 % der Fläche) bis “geringfügig bis nicht” (21.9 %) geeignet, wobei 28.3 % der Fläche als “mittel” eingestuft wurden. Die wichtigsten, die Nutzbarkeit limitierenden

Faktoren für die geprüften Kulturpflanzen (Weizen, Hirse, Gerste, Alfalfa, Mais, Sonnenblumen, Tomaten, Melonen, Oliven, Feigen, Pfirsich, Guava und Zitrusfrüchte) waren die Bodentiefe, die Bodenart, die Dränage, der Kalkgehalt, der Salzgehalt und die Alkalinität. Allerdings kann das Nutzungspotential teilweise verbessert werden, wenn die durch den Salzgehalt und die mangelnde Dränage hervorgerufenen Einschränkungen vermindert werden.

Ein wichtiges Ziel der Arbeit war der Vergleich der verschiedenen Verfahren zur Eignungs- und Potentialbewertung, die auf physikalischen und chemischen Bodeninformationen basieren. Die Ergebnisse haben gezeigt, dass Methoden, die die Merkmale mehrere Eigenschaften zu einem Index aggregieren Vorteile gegenüber den Methoden aufweisen, die jeweils nur mit Nutzungs-Ausschlusskriterien arbeiten. Dabei sind moderne, Software-unterstütze Methoden einfacher zu benutzen als Methoden, bei denen die Bewertung für jedes Merkmal einzeln durchgeführt werden muss. Die Anwendung des Storie index (2008) und von CERVATANA (ein Landpotentialmodel) auf den Teil der untersuchten Region, die bereits unter landwirtschaftlicher Nutzung ist, ergab gute Übereinstimmung mit den Bewertungen der Programme und der realen Nutzungssituation. Bei der Klassifizierung der Nutzungspotentiale für einzelne Früchte erstellt mit Sys et al. (1993) und dem ALMAGRA System wurden Unzulänglichkeiten bei der Einstufung der Salinität und der Bodenart festgestellt. Soweit diese Nachteile behoben wurden erbrachten die Verfahren vernünftige Ergebnisse.

Die landwirtschaftliche Nutzung ist an eine dem Pflanzenbedarf angepasste Wasserversorgung gebunden. Dabei hat die Tropfenbewässerung offensichtlich Vorteile auf sandigen Böden um die Wassernutzungseffizienz zu erhöhen, d.h. mehr Früchte pro Tropfen zu produzieren und damit der Krise der begrenzten Wasserversorgung im Agrarsektor zu begegnen. Neben der Wasserversorgung hängt die Produktivität von dem Nährstoffstatus der Böden ab. Um diesen zu verbessern sollte der natürlicherweise geringe Gehalt der Böden an organischer Substanz durch Düngung und regelmäßige Einarbeitung von Streu oder organischer Dünger verbessert werden. Allerdings stellen die hohen Gehalte an Kalk eine Nutzungsbegrenzung dar, die nur durch den Einsatz darauf angepaßter Früchte begegnet werden kann, wobei für das Untersuchungsgebiet Oliven, Feigen und Pfirsiche, Tomaten und Sonnenblumen in Frage kommen.

Die Untersuchung hat gezeigt, dass die Analyse der Bodeneigenschaften in Verbindung mit modernen Methoden der Landnutzungs- und –potentialbewertung ein wirksames Werkzeug für die Entscheidungsfindung darstellt.

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CHAPTER XII: APPENDICES

Appendix 1 Soil properties

Table 43: Weighted mean of major soil properties

Profile	$CaCO_3$	Gravel	pH	ECe	SOC	O.M	ESP	CEC
No	%	%	**in soil paste**	dSm^{-1}	%	%	%	**me/100g soil**
1	55,38	1,97	8,01	1,85	0,43	0,74	1,85	2,59
2	54,58	1,61	7,94	12,34	0,39	0,68	12,34	3,21
3	42,84	0,54	7,96	3,38	0,15	0,26	3,38	2,56
4	38,01	2,28	8,33	5,29	0,26	0,44	5,29	2,38
5	31,09	0,5	8,34	1,08	0,23	0,39	1,08	2,11
6	34,17	1,25	8,38	3,07	0,42	0,73	3,07	2,62
8	31,25	25,37	8,63	6,26	0,14	0,25	6,26	2,9
11	44,52	13,75	9,05	1,65	0,08	0,13	1,65	2,21
13	37,17	19,7	8,33	29,09	0,58	1,0	29,09	6,15
14	53,47	10,36	8,63	15,63	0,24	0,42	15,63	2,23
15	45,48	18,8	8,48	3,95	0,24	0,41	3,95	2,68
16	45,62	10,65	9,02	10,99	0,23	0,4	10,99	3,24
17	56,47	13,01	8,6	9,36	0,27	0,46	9,36	2,28
18	57,19	21,2	8,89	8,8	0,21	0,36	8,8	2,7
19	52,94	9,3	8,63	26,79	0,39	0,67	26,79	4,15
23	41,74	0,96	8,47	14,04	0,32	0,55	14,04	3,25
24	60,44	3,39	8,65	8,74	0,25	0,43	8,74	3,08
25	64,46	13,3	8,14	20,05	0,35	0,6	20,05	3,77
26	56,64	12,8	8,34	4,01	0,24	0,41	4,01	2,55
27	47,17	13,0	7,94	37,61	0,78	1,34	37,61	5,22
28	45,18	4,34	8,28	24,71	0,5	0,86	24,71	4,42
29	43,99	12,33	7,94	28,26	0,47	0,81	28,26	4,92
30	39,37	11,6	8,11	6,55	0,33	0,56	6,55	2,61
31	49,33	2,99	8,47	7,66	0,21	0,37	7,66	3,03
32	40,07	23,7	7,77	12,42	0,33	0,58	12,42	3,82
35	43,51	3,53	8,29	2,68	0,21	0,36	2,68	2,22
36	40,54	1,19	7,97	13,41	0,43	0,73	13,41	2,967
37	36,08	1,24	7,8	0,78	0,21	0,36	0,78	2,17
38	38,38	7,62	8,28	15,59	0,26	0,45	15,59	3,14
39	37,77	0,5	8,61	6,14	0,27	0,46	6,14	2,4
40	42,44	2,25	8,32	1,12	0,17	0,29	1,12	2,19
41	40,02	1,25	8,6	0,87	0,19	0,33	0,87	2,65
42	44,79	10,58	8,29	2,14	0,42	0,72	2,14	2,83
43	50,37	11,4	7,92	30,09	0,74	1,27	30,09	6,1

Appendix I Soil properties

Table 44: Analytical data represented the soil profiles of the study area

Profile No.	Depth cm	$CaCO_3$ %	$CaSO_4$ $2H_2O$ %	Gravel %	pH in soil paste	ECe. dSm^{-1}	O.C %	O.M. %	Total N %	Available P ppm	Available K ppm	Total C %	Exchangeable Cations Na^+ mg/l	Exchangeable Cations K^+ mg/l	Exchangeable Cations Ca^{++} mg/l	Exchangeable Cations Mg^{++} mg/l	ESP %	CEC me/100 g soil
1	0--10	54,86	n.d	1,20	8,09	3,18	0,49	0,84	0,055	0,88	267,15	7,49	16,48	19,68	435,40	33,60	3,26	2,63
	10--40	53,07	n.d	2,30	8,27	1,63	0,46	0,78	0,031	0,76	276,30	7,02	9,88	21,36	461,00	39,80	1,86	2,80
	40--70	56,86	0,02	2,60	8,33	1,57	0,20	0,35	0,014	0,35	290,03	7,53	9,16	23,88	517,60	30,00	1,58	2,80
	73-100	63,01	0,01	1,40	8,24	1,30			0,008			8,19	9,16	23,40	436,00	29,20	1,84	2,39
	100--150	57,6	n.d	1,60	8,18	0,88			0,008			7,64	12,76	15,68	430,20	31,80	2,60	2,40
2	0--40	57,79	0,01	0,98	7,91	9,09	0,26	0,45	0,038	0,46	244,28	7,68	39,00	64,08	443,80	44,60	6,59	2,77
	40--80	53,23	n.d	1,80	7,99	8,21	0,19	0,32	0,023	0,37	303,75	7,10	54,60	20,72	489,20	25,80	9,25	3,06
	80--120	50,84	n.d	2,50	7,90	5,24			0,023			6,53	215,50	22,76	428,80	51,40	29,99	4,37
	120--150	52,74	n.d	3,96	8,04	23,10			0,008			6,84	191,50	16,96	430,80	47,40	27,89	4,14
3	0--20	46,26	n.d	0,78	7,76	3,38	0,22	0,39	0,013	2,06	212,25	5,98	15,00	10,44	420,80	25,40	3,18	2,35
	20--60	42,13	n.d	0,50	8,21	3,10	0,16	0,27	0,015	0,38	294,60	5,41	22,68	11,80	462,80	51,20	4,14	2,93
	60--100	41,62	n.d	0,45	7,81	1,95			0,009			5,43	12,76	12,96	409,80	34,40	2,72	2,31
	100--150	40,5	n.d	0,33	8,33	1,56			0,005			5,47	11,36	9,44	413,20	35,80	2,42	2,32
4	0--20	42,49	n.d	3,20	8,30	2,24	0,12	0,20	0,012	0,30	216,83	5,32	17,04	14,36	403,60	27,20	3,69	2,29
	20--60	37,36	n.d	2,60	8,27	1,29	0,19	0,32	0,008	0,61	203,10	5,08	5,32	10,56	404,80	19,60	1,21	2,15
	60--100	38,23	n.d	1,50	8,40	3,42			0,011			5,04	51,80	19,16	406,80	32,20	10,16	2,65
	100--150	40,07	n.d	0,50	8,46	2,41			0,012			7,60	52,60	18,48	465,60	42,20	9,09	2,99
5	0--50	31,64	n.d	0,5	8,3	1,61	0,19	0,33	0,007	0,9	221,4	4,23	4,68	13,32	401,80	23,2	1,06	2,15
	50--100	30,53	n.d	0,5	8,37	1,03			0,007			4,13	4,72	13,88	394,20	16,2	1,1	2,08
	100-150	29,81	n.d	0,9	8,47	1,81			0,014			4,06	10	7,64	400,6	17,8	2,29	2,17
6	0--50	38,74	n.d	1,4	8,27	1,51	0,16	0,27	0,006	0,19	171,1	5,13	14,68	8,32	422,20	21,2	3,15	2,34
	50--100	29,59	n.d	1,1	8,48	5,60			0,016			4,06	17,32	9,32	533,60	20,4	2,98	2,91
	100-150	30,02	n.d	0,87	8,5	1,82			0,011			4,13	12	11,6	433,4	21,4	2,51	2,37
8	0--3	27,07	n.d	14,5	8,62	1,32	0,04	0,07	0,006	0,43	198,53	3,62	7,12	11,32	431,80	31,40	1,48	2,35
	3---65	31,45	n.d	25,90	8,63	1,54	0,22	0,39	0,012	0,12	363,23	4,37	38,64	34,08	472,20	50,20	6,49	2,93

Table 44: Cont.

Profile No.	Depth cm	$CaCO_3$ %	$CaSO_4$ $2H_2O$ %	Gravel %	pH in soil paste	ECe. dSm-1	O.C %	O.M. %	Total N %	Available P ppm	Available K ppm	Total C %	Exchangeable cations Na^+ mg/l	K^+ mg/l	Ca^{++} mg/l	Mg^{++} mg/l	ESP %	CEC me/100 g soil
11	0--20	44,98	n.d	8,60	9,44	0,92	0,12	0,20	0,008	0,75	212,25	5,94	3,64	12,08	421,40	19,40	0,80	2,22
	20--40	44,06	0,25	18,90	8,65	1,82	0,22	0,39	0,010	0,29	189,38	5,59	11,08	9,52	402,80	21,40	2,49	2,21
13	0--20	37,17	0,25	19,70	8,33	25,60	0,47	0,81	0,022	0,34	625,80	5,37	303,00	58,88	589,60	90,20	29,09	6,15
14	0--30	49,75	n.d	3,6	8,52	1,49	0,23	0,4	0,012	0,69	244,3	6,45	10,92	13,24	395,40	19	2,49	2,16
	30--90	54,69	0,05	12,4	8,67	7,34	0,15	0,26	0,018	0,3	303,8	7,22	160	26,12	430,60	56,8	23,76	3,88
	90--150	57,36	n.d	18,4	8,75	1,82			0,007			7,29	31,96	19,6	420,8	39,8	6,24	2,57
15	0--20	40,95	n.d	12,80	8,42	1,83	0,22	0,37	0,024	0,31	367,80	5,45	23,76	34,88	465,60	37,40	4,23	2,70
	20--35	51,53	n.d	26,80	8,57	1,45	0,35	0,60	0,028	0,31	294,60	6,74	19,32	23,00	464,00	34,80	3,57	2,64
16	0--20	44,9	n.d	12,90	8,82	1,97	0,30	0,52	0,023	0,79	427,28	5,98	55,40	47,28	502,60	33,00	8,68	3,17
	20--40	46,35	n.d	8,40	9,21	1,42	0,36	0,62	0,022	0,34	427,28	5,93	86,50	54,88	458,00	50,80	13,30	3,31
17	0--30	54,11	0,09	17	8,26	14,29	0,29	0,5	0,015	0,26	312,9	7,45	163,5	27,76	453,20	42,8	23,79	3,97
	30--65	59,83	n.d	12,8	8,75	1,93	0,16	0,27	0,003	0,28	267,2	7,77	10,64	28,52	403,80	30,4	2,25	2,24
	65--90	61,81	n.d	8,5	8,8	1,46			0,003			8,31	9,36	19,12	403,2	35,2	2	2,25
18	0--30	52,85	n.d	12,00	8,72	1,34	0,25	0,42	0,027	0,47	363,23	6,86	27,40	35,48	432,20	45,20	5,07	2,60
	30--60	56,16	n.d	14,00	8,99	1,94	0,25	0,42	0,017	0,17	349,50	7,32	62,00	42,12	418,20	37,60	11,07	2,83
	60--80	59,91	n.d	30,00	8,62	1,52			0,013		312,90	7,81	53,40	30,68	398,80	38,60	10,24	2,65
	80--100	62,55	n.d	37,00	9,27	1,76			0,005		290,03	4,25	51,00	30,68	410,00	43,00	9,54	2,70
19	0--30	48,25	n.d	3,00	8,75	3,60	0,2	0,35	0,022	0,54	386,1	6,52	40,72	25,64	419,80	52,6	7,56	2,7
	30--100	54,96	0,43	12,00	8,58	12,00			0,014	0,52	344,9	7,47	270,5	39,44	384,40	77,8	35,03	4,77
	100-150	54,84	1,32	38,00	8,4	22,70			0,012			7,78	434,5	33,24	666,8	61,8	36,32	7,65
23	0-- 40	42,44	n.d	1,10	8,21	3,04	0,13	0,22	0,017	0,42	450,15	5,69	66,00	37,08	442,40	58,20	10,93	3,07
	40--100	41,28	n.d	0,87	8,65	1,71	0,39	0,67	nd.	0,62	427,28	5,46	104,50	55,60	430,00	58,80	16,10	3,37
	100-150	44,41	n.d	0,50	8,95	1,39			0,012			5,61	111,50	53,08	427,40	21,20	18,18	3,27
24	0--50	69,52	n.d	1,98	8,68	1,22	0,22	0,37	0,01	1,35	239,7	8,83	15	15,48	469,60	18,2	2,89	2,56
	50--110	51,36	n.d	4,8	8,62	4,43			0,019			6,8	101	50,08	481,00	60,4	14,59	3,6
	110-150	57,76	n.d	18,2	8,58	3,61			0,017			7,34	96	44,48	415,2	42,4	16,05	3,15

Appendix I Soil properties

Table 44: Cont.

Profile No.	Depth cm	$CaCO_3$ %	$CaSO_4$ $2H_2O$ %	Gravel %	pH in soil paste	ECe. dSm-1	O.C %	O.M. %	Total N %	Available P ppm	Available K ppm	Total C %	Exchangeable cations Na^+ mg/l	K^+ mg/l	Ca^{++} mg/l	Mg^{++} mg/l	ESP %	CEC me/100 g soil
25	0--30	64,75	0,16	8,00	8,05	14,17	0,39	0,67	0,026	0,35	280,88	8,66	132,00	21,84	442,60	33,80	20,94	3,59
	30--80	65,31	0,04	11,00	8,21	8,50	0,30	0,52	0,011	0,26	230,55	8,81	127,50	16,12	513,00	30,40	18,56	3,88
	80--110	61,91	0,29	27,00	8,09	15,28			0,010			8,39	146,50	22,28	440,20	44,00	22,44	3,75
	110-150	62,05	0,73	38,50	7,91	15,32			0,006			8,13	162,50	20,12	692,20	46,00	17,65	5,17
26	0--30	49,59	n.d	4	8,35	1,70	0,32	0,56	0,025	0,46	340,4	6,51	11,2	30,24	440,00	32,4	2,18	2,44
	30--80	57,71	n.d	16	8,3	2,37	0,22	0,37	0,01	0,43	308,3	7,62	28,6	32,8	439,20	46,8	5,22	2,66
	80--100	64,54	n.d	18	8,44	2,63			0,009			8,36	18,8	26,64	420,6	38,8	3,72	2,44
27	0--15	41,05	0,26	8,00	7,97	25,10	0,42	0,72	0,033	0,54	486,75	6,02	269,50	63,72	270,40	72,60	39,85	4,17
	15--30	53,3	0,66	18,00	7,91	27,70	0,48	0,82	0,040	0,79	326,63	7,70	353,50	37,56	516,80	91,80	35,36	6,27
28	0--25	41,83	0,52	6,4	8,51	2,52	0,27	0,47	0,018	1,12	589,2	5,55	24,84	23,36	393,80	19,6	5,38	2,28
	25--70	42,96	0,24	3,8	8,23	19,02	0,37	0,63	0,033	0,42	418,1	6,13	293	52,72	467,80	90,2	32,42	5,45
	70--90	55,91	0,46	3	8,1	15,04			0,015			7,82	247,5	34,8	437,2	66	31,51	4,77
29	0--40	42,45	0,31	11,00	7,98	19,34	0,33	0,56	0,023	0,18	399,83	5,86	228,00	44,72	488,40	52,40	28,03	4,79
	40--60	47,07	0,21	15,00	7,86	16,96			0,012	0,29	271,73	6,61	246,00	21,32	526,40	62,60	28,73	5,19
30	0--20	39,37	0,47	11,6	8,11	8,10	0,35	0,59	0,027	0,42	708,2	5,36	34,4	25,84	426,20	39	6,55	2,61
31	0--15	45,48	n.d	0,89	8,46	1,06	0,2	0,35	0,018	0,48	445,6	6,01	121	65,08	465,00	56	17,11	3,69
	15--40	45,48	n.d	2,8	8,4	2,41	0,22	0,37	0,022	0,16	477,6	5,99	15,96	47,68	467,20	46,4	2,76	2,68
	40--60	57,02	n.d	4,8	8,55	2,34	0,26	0,45	0,012	0,84	294,6	7,56	41,64	52,04	463,2	66,6	6,68	2,98
32	0--10	40,07	0,02	23,7	7,77	5,64	0,22	0,37	0,029	0,21	367,8	5,48	93,5	55,76	516,4	87,4	12,42	3,82
35	0--30	27,98	n.d	4,3	8,28	0,94	0,19	0,32	0,001	0,28	152,8	3,5	5,16	5,64	402,80	24,8	1,18	2,16
	30--100	50,16	n.d	3,2	8,3	1,82	0,12	0,2	0,004	0,18	161,9	6,61	14,84	7,08	403,80	20,4	3,33	2,24
	100-150	41,59	n.d	1,9	8,35	2,45			0,004			5,32	23,72	10,48	422	19,4	4,99	2,41
36	0--40	39,87	0,05	1,90	7,89	10,33	0,20	0,34	0,004	0,32	198,53	5,26	66,60	12,84	432,40	25,20	12,40	2,89
	40--80	39,4	n.d	0,85	7,98	7,92	0,16	0,27	0,004	0,22	189,38	5,26	82,00	13,88	446,20	25,00	14,46	3,10
	80--110	44,17	0,11	0,43	8,12	4,67			0,006			5,13	71,40	15,32	425,60	22,60	13,35	2,89
	110-150	29,77	n.d	0,16	8,31	2,41			0,004			4,89	25,56	12,80	404,40	22,60	5,49	2,35

Table 44: Cont.

Profile No.	Depth cm	$CaCO_3$ %	$CaSO_4$ $2H_2O$ %	Gravel %	pH in soil paste	ECe. dSm-1	O.C %	O.M. %	Total N %	Available P ppm	Available K ppm	Total C %	Exchangeable cations Na^+ mg/l	K^+ mg/l	Ca^{++} mg/l	Mg^{++} mg/l	ESP %	CEC me/100 g soil
37	0--50	37,85	n.d	1,5	7,83	2,06	0,22	0,39	0,009	0,62	189,4	4,97	3,12	9,36	418,00	18,6	0,69	2,2
	50--100	34,32	n.d	0,98	7,76	1,98			0,016			4,6	3,76	9,96	407,80	15,4	0,86	2,14
	100-150	36,96	n.d	0,12	8,61	3,40			0,008			4,88	15,16	13,16	437	28	3,07	2,44
38	0--30	46,26	n.d	2,40	8,40	2,90	0,37	0,63	0,014	0,38	248,85	5,70	22,92	20,36	429,00	27,00	4,59	2,47
	30--90	42,13	0,04	10,50	8,31	6,87	0,23	0,40	0,017	0,30	285,45	4,92	137,00	24,48	426,40	36,40	21,95	3,56
	90--120	41,62	n.d	6,40	7,75	3,00			0,003			4,84	51,60	14,20	405,60	22,00	10,46	2,60
	120-150	40,5	n.d	3,80	8,75	1,86			0,005			4,58	6,64	17,68	420,60	20,80	1,43	2,25
39	0--50	35,05	n.d	0,4	8,4	4,00	0,23	0,4	0,023	0,44	203,1	4,69	24,08	13,92	401,00	23,2	5,21	2,33
	50--100	40,48	n.d	0,6	8,81	2,74			0,011			5,31	33,96	9,36	411,60	25,6	7,07	2,48
	100-150	36,62	n.d	0,5	9,02	1,95			0,008			4,87	7,64	9,92	414,8	26,8	1,66	2,26
40	0--50	41,86	n.d	3	8,38	2,06	0,09	0,15	0,006	0,23	166,5	5,34	4,84	6,36	369,20	27,2	1,19	2
	50--100	43,01	n.d	1,5	8,26	3,40			0,001			5,46	5,12	9	438,60	33,6	1,05	2,38
	100-150	43,6	n.d	2,8	8,54	1,98			nd.			5,67	5,8	10,12	448,8	28,8	1,18	2,42
41	0--50	39,61	n.d	1,5	8,64	1,10	0,17	0,3	0,01	0,25	194	4,99	5,16	8,84	455,20	25,8	1,04	2,43
	50--100	40,42	n.d	1	8,55	0,96			0,006			5,22	4,12	8,76	536,80	35,2	0,7	2,87
	100-150	38,62	n.d	0,5	8,62	1,50			0,007			5,01	4,6	11,36	462	28	0,91	2,47
41	0--50	39,61	n.d	1,5	8,64	1,10	0,17	0,3	0,01	0,25	194	4,99	5,16	8,84	455,20	25,8	1,04	2,43
	50--100	40,42	n.d	1	8,55	0,96			0,006			5,22	4,12	8,76	536,80	35,2	0,7	2,87
	100-150	38,62	n.d	0,5	8,62	1,50			0,007			5,01	4,6	11,36	462	28	0,91	2,47
42	0--30	39,63	n.d	5,50	8,10	0,82	0,39	0,67	0,028	2,58	290,03	5,43	6,20	24,24	453,60	20,00	1,23	2,41
	30--50	38,75	n.d	8,90	8,31	0,87	0,42	0,72	0,031	0,75	280,88	5,61	6,48	21,72	658,80	23,60	0,91	3,45
	50--100	50,3	n.d	14,30	8,40	1,17			0,027			6,74	18,92	36,00	503,20	36,00	3,18	2,84
	100-120	58,76	n.d	16,90	8,42	1,07			0,019			7,84	14,32	40,16	532,00	38,80	2,29	2,95
43	0--15	41,06	2,29	6,40	7,85	33,60	0,39	0,67	0,035	0,72	950,00	6,32	515,00	301,20	682,40	83,80	32,55	8,57
	15--30	50,51	0,87	8,12	7,89	21,80	0,30	0,51	0,012	0,27	513,23	7,15	359,00	71,28	535,20	66,40	34,79	6,31
	30--60	55,51	0,45	14,20	7,88	16,54	0,26	0,45	0,007		774,00	7,55	234,00	23,76	595,20	50,80	25,89	5,37
	60--110	49,95	0,33	12,40	7,98	18,10			0,028			7,14	283,00	34,64	545,80	62,40	30,57	5,63
	110-150	51,06	1,96	7,50	7,42	24,20			0,019			7,14	318,00	32,80	543,00	68,40	33,05	5,97

Appendix I Soil properties

Table 45: Description data represented the soil profiles of the study area

Profile	Land	Surface characteristics		Colour		Texture	Structure	Consistence			Soil properties				Boundary	
No.	use	Topography and slope	Vegetation and Surface cover	Dry	Moist			Dry or moist	Wet/ Stickiness	Wet/ Plasticity	$CaCO_3$ FAO	G.P FAO	ECe FAO	pH FAO	Dist. (cm)	Topo. (cm)
1	Cultivated	Flat	Wheat	10YR 7/4	10YR 6/4	SL	MA	SO	SST	SPL	EX.	V	VSL	M.Alk	C	S
	area	Neraly level	Plowed	10YR 7/4	10YR 6/4	LS	WEBLSA	SHA	SST	NPL	EX.	F	NS	M.Alk	C	W
			area	10YR 8/4	10YR 7/4	SiL	WEBLSA	HA	ST	SPL	EX.	F	NS	M.Alk	A	S
				10YR 8/6	10YR 7/6	LS	MA	HA	SST	NPL	EX.	V	NS	M.Alk	C	S
				10YR 8/4	10YR 7/4	SiL	MA	VHA	SST	SPL	EX.	V	NS	M.Alk		
2	Cultivated	Almost flat	Field Crops	10YR 8/4	10YR 7/4	LS	MA	SHA	SST	NPL	EX.	V	MO	M.Alk	C	S
	area	Nearly level	Plowed	10YR 7/4	10YR 6/4	SL	WEBLSA	HA	SST	SPL	EX.	V	MO	M.Alk	G	W
			area	10YR 8/4	10YR 7/4	LS	WEBLSA	HA	SST	SPL	EX.	F	SL	M.Alk	A	S
				10YR 7/4	10YR 6/4	VFS	MA	SHA	NST	NPL	EX.	F	ST	M.Alk		
3	Cultivated	Almost flat	Mango	10YR 7/4	10YR 6/4	FS	SG	LO	NST	NPL	EX.	V	VSL	Sl.Alk	C	S
	area	Nearly level	Drafty Sand	10YR 7/4	10YR 6/4	FS	MA	SO	NST	NPL	EX.	V	VSL	M.Alk	D	S
			Mango, peach	10YR 7/4	10YR 6/4	VFS	MA	SHA	NST	NPL	EX.	V	NS	Sl.Alk	D	S
			and citrus	10YR 7/4	10YR 6/4	FS	MA	SHA	NST	NPL	EX.	V	NS	M.Alk	C	S
4	Cultivated	Almost flat	Field crops	10YR 7/6	10YR 6/6	VFS	SG	LO	NST	NPL	EX.	F	VSL	M.Alk	G	W
	area	Nearly level	Drafty Sand	10YR 8/4	10YR 7/4	VFS	MA	SO	NST	NPL	EX.	F	NS	M.Alk	G	W
			Plowed area	10YR 7/4	10YR 6/4	VFS	MA	SHA	NST	NPL	EX.	V	VSL	M.Alk	C	S
					10YR 7/6	VFS		FR	NST	NPL	EX.	V	VSL	St.Alk	D	W
5	Cultivated	Almost flat	Field crops	10YR 7/6	10YR 6/6	VFS	SG	LO	NST	NPL	EX.	V	NS	M.Alk	D	W
	area	Nearly level	Drafty sand,	10YR 7/6	10YR 6/6	VFS	MA	SO	NST	NPL	EX.	V	NS	M.Alk		
			Plowed area.	10YR 7/6	10YR 6/6	VFS		VFR	NST	NPL	EX.	V	NS	St.Alk	D	W
6	Cultivated	Almost flat	Field crops	10YR 7/6	10YR 6/6	FS	SG	LO	NST	NPL	EX.	V	NS	M.Alk	D	W
	area	Nearly level	Drafty sand,	10YR 7/6	10YR 6/6	FS	MA	SO	NST	NPL	EX.	V	SL	St.Alk		
			Plowed area.	10YR 7/6	10YR 6/6	VFS		VFR	NST	NPL	EX.	V	NS	St.Alk		
8	Under	Flat	Boulders	10YR 7/6	10YR 6/6	VFS	SG	LO	NST	NPL	EX.	C	NS	St.Alk	A	S
	reclamation	Nearly level	and stones	10YR 7/6	10YR 6/6	GMS	MA	SHA	NST	NPL	EX.	M	NS	St.Alk	C	S

Appendix I Soil properties

Table 45: Cont.

Profile	Land	Surface characteristics		Colour		Texture	Structure	Consistence			Soil properties				Boundary	
No.	use	Topography and slope	Vegetation and Surface cover	Dry	Moist			Dry or moist	Wet/ Stickiness	Wet/ Plasticity	$CaCO_3$ FAO	G.P FAO	ECe FAO	pH FAO	Dist. (cm)	Topo. (cm)
11	Non land	Almost flat	Desert shrubs	10YR 7/6	10YR 6/6	VFS	SG	LO	NST	NPL	EX.	C	NS	VSt.Alk	D	W
	use	G.sloping	Boulders,stone	10YR 7/6	10YR 6/6	GVFS	MA	SO	NST	NPL	EX.	M	NS	St.Alk	A	S
13	Non land use	Flat Nearly level	Desert shrubs Plowed area	10YR 7/4	10YR 6/4	GMS	MA	SHA	NST	NPL	EX.	M	ST	M.Alk	G	S
14	Cultivated	Flat	Few scctered	10YR 7/4	10YR 6/4	VFS	MA	SO	NST	NPL	EX.	F	NS	St.Alk	C	W
	area	Nearly level	desert shrubs	10YR 8/3	10YR 7/3	CS	MA	HA	NST	NPL	EX.	C	SL	St.Alk	G	S
			Few gravel		10YR 7/4	GCS		FR	NST	NPL	EX.	M	NS	St.Alk		
15	Non land	Flat	Desert shrubs	10YR 7/4	10YR 6/4	CS	MA	SHA	NST	NPL	EX.	C	NS	M.Alk	C	S
	use	Nearly level	Boulders,stone	10YR 8/4	10YR 7/4	GSL	MA	SHA	SST	NPL	EX.	M	NS	St.Alk	A	S
16	under	Almost flat	Desert shrubs	10YR 7/4	10YR 6/4	LS	MA	SHA	SST	NPL	EX.	C	NS	St.Alk	G	S
	Cultivated	Nearly level	Plowed area	10YR 7/4	10YR 6/4	LS	WEBLSA	SHA	SST	NPL	EX.	C	NS	VSt.Alk	A	S
17	Cultivated	Almost flat	Wheat	10YR 8/4	10YR 7/4	GVFS	SG	SO	NST	NPL	EX.	M	MO	M.Alk	C	S
	area	Neraly level	Drifty sand	10YR, 8/6	10YR, 7/6	LS	MA	SHA	SST	NPL	EX.	C	NS	St.Alk	C	S
			plowed area		10YR, 8/6	LS		FR	NST	NPL	EX.	C	NS	St.Alk	G	S
18	Non land	Almost flat	Scattered	10YR,7/4	10YR,6/4	CS	SG	SO	NST	NPL	EX.	C	NS	St.Alk	C	S
	use	V.g.sloping	desert shrubs	10YR,7/4	10YR,6/4	CS	MA	SHA	NST	NPL	EX.	C	NS	St.Alk	D	S
			Drifty sand	10YR,7/4	10YR,6/4	GCS	MA	HA	NST	NPL	EX.	M	NS	St.Alk	D	S
				10YR,7/4	10YR,6/4	VGCS	MA	VHA	NST	NPL	EX.	M	NS	VSt.Alk	D	S
19	Cultivated	Almost flat	Crops	10YR,7/4	10YR,6/4	SiL	MA	SHA	SST	SPL	EX.	F	VSL	St.Alk	C	S
	area	G.sloping	Drafty sand and gravels	10YR,7/4	10YR,6/4	LS	WEBLSA	HA	SST	NPL	EX.	C	MO	St.Alk	A	S
					7.5YR, 8/6	VGUS	MA	FR	NST	NPL	EX.	M	ST	M.Alk		
23		Almost flat	Wheat, olive	10YR, 7/6	10YR, 6/6	SL	WEBLSA	SHA	SST	SPL	EX.	V	VSL	M.Alk	C	S
	Cultivated	G.sloping	Drifty sand	10YR 7/4	10YR 6/4	LS	WEBLSA	SHA	SST	NPL	EX.	V	NS	St.Alk	C	S
			plowed area	10YR, 8/4	10YR,7/4	LS	MA	SHA	SST	NPL	EX.	V	NS	St.Alk		
24	Cultivated	Almost flat	Crops	10YR, 8/6	10YR, 7/6	VFS	MA	SO	NST	NPL	EX.	V	NS	St.Alk	C	S
	area	G.sloping	Drafty sand ,	10YR,7/4	10YR,6/4	CS	MA	SHA	NST	NPL	EX.	F	SL	St.Alk	C	S
			Plowed area	10YR, 8/4	10YR, 7/4	GSL	WEBLSA	SHA	SST	SPL	EX.	C	VSL	St.Alk		

Table 45: Cont.

Profile No.	Land use	Surface characteristics: Topography and slope	Surface characteristics: Vegetation and Surface cover	Colour: Dry	Colour: Moist	Texture	Structure	Consistence: Dry or moist	Consistence: Wet/ Stickiness	Consistence: Wet/ Plasticity	Soil properties: $CaCO_3$ FAO	Soil properties: G.P FAO	Soil properties: ECe FAO	Soil properties: pH FAO	Boundary: Dist. (cm)	Boundary: Topo. (cm)
25	Cultivated	Flat	Few scctered	7.5YR, 8/6	7.5YR, 7/6	FS	MA	SO	NST	NPL	EX.	C	MO	M.Alk	A	S
	area	Nearly level	desert shrubs	10YR 8/4	10YR7/4	CS	MA	SHA	NST	NPL	EX.	C	MO	M.Alk	C	S
			Plowed area	10YR,7/6	10YR, 6/6	GMS	MA	HA	NST	NPL	EX.	M	MO	M.Alk	G	S
			and gravels	7.5YR, 8/7	7.5YR, 7/7	FS	MA	MO	NST	NPL	EX.	C	MO	M.Alk		
26	Plowed	Flat	Few scatterd	10YR, 8/6	10YR, 7/6	Ls	MA	SO	SST	NPL	EX.	F	NS	M.Alk	A	S
	area	Nearly level	low hummocks	7.5YR 8/4	7.5YR 7/4	GLS	MA	HA	SST	NPL	EX.	M	VSL	M.Alk	C	S
			Plowed area	7.5YR 8/4	7.5YR 7/4	GCS	MA	FR	NST	NPL	EX.	M	VSL	M.Alk		
27	under	Almost flat	Desert shrubs	10YR 7/4	10YR 6/4	CS	MA	SHA	NST	NPL	EX.	C	ST	M.Alk	A	S
	Cultivated	Nearly level	Plowed area	7.5YR 8/4	7.5YR 7/4	GLS	MA	HA	NST	NPL	EX.	M	ST	M.Alk	G	S
28	Cultivated	Almost flat	Desert shrubs	10YR, 8/6	10YR, 7/6	LS	MA	SO	SST	NPL	EX.	C	VSL	St.Alk	A	S
	area	G.sloping	Drafty sand	10YR 7/4	10YR 6/4	CS	MA	SHA	NST	NPL	EX.	F	ST	M.Alk	C	S
				10YR 8/4	10YR 7/4	LS	MA	SHA	NST	NPL	EX.	F	MO	M.Alk	G	S
29	Cultivated	Almost flat	Desert shrubs	10YR 7/4	10YR 6/4	LS	MA	SHA	SST	NPL	EX.	F	ST	M.Alk	C	S
	area	Neraly level	Boulders	7.5YR, 8/6	7.5YR, 7/6	GLS	WEBLSA	HA	SST	NPL	EX.	M	ST	M.Alk	A	S
30	Non land use	Flat Nearly level	Desert shrubs Plowed area	10YR7/4	10YR 6/4	LS	MA	SHA	SST	NPL	EX.	C	MO	M.Alk	A	S
31	Non	Almost flat	Desert shrubs	10YR 8/4	10YR 7/4	SiL	MA	SHA	SST	SPL	EX.	V	NS	St.Alk	G	S
	land use	G.sloping	Drafty sand	10YR 8/4	10YR 7/4	LS	WEBLSA	HA	SST	NPL	EX.	F	VSL	M.Alk	C	S
			and gravel	7.5YR, 8/6	7.5YR, 7/6	LS	MA	EXH	SST	SPL	EX.	F	VSL	St.Alk	G	S
32	Non land use	Flat Nearly level	Desert shrubs Boulders,stone	10YR 8/4	10YR 7/4	GFS	MA	SHA	NST	NPL	EX.	M	SL	Sl.Alk	A	S
35	Non	G.undulating	Few scattered	10YR 8/6	10YR 7/6	FS	MA	SO	NST	NPL	EX.	F	NS	M.Alk	G	S
	land use	G.slpoping	desert shrubs	10YR 8/4	10YR 7/4	MS	MA	SHA	NST	NPL	EX.	F	NS	M.Alk	D	W
			Drafty sand	10YR 8/4	10YR 7/4	MS	MA	SHA	NST	NPL	EX.	V	VSL	M.Alk		
36	Non	Almost flat	Few scattered	10YR 8/6	10YR 7/6	FS	SG	LO	NST	NPL	EX.	V	MO	M.Alk	D	W
	land use	G.sloping	desert shrubs	10YR 8/6	10YR 7/6	FS	MA	SO	NST	NPL	EX.	V	SL	M.Alk	D	S
			Drafty sand	10YR 8/6	10YR 7/6	VFS	MA	SHA	NST	NPL	EX.	V	SL	M.Alk	D	W
					10YR 7/6	VFS		FR	NST	NPL	EX.	V	VSL	M.Alk		

Appendix I Soil properties

Table 45: Cont.

Profile No.	Land use	Surface characteristics: Topography and slope	Surface characteristics: Vegetation and Surface cover	Colour: Dry	Colour: Moist	Texture	Structure	Consistence: Dry or moist	Consistence: Wet/ Stickiness	Consistence: Wet/ Plasticity	Soil properties: $CaCO_3$ FAO	Soil properties: G.P FAO	Soil properties: ECe FAO	Soil properties: pH FAO	Boundary: Dist. (cm)	Boundary: Topo. (cm)
37	Cultivated	Flat	Fruit crops	10YR 8/6	10YR 7/6	VFS	SG	LO	NST	NPL	EX.	V	VSL	Sl.Alk	G	W
	area	Neraly level	and drafty	10YR 8/6	10YR 7/6	VFS	SG	SO	NST	NPL	EX.	V	NS	Sl.Alk	G	S
			sand	10YR 7/4	10YR 6/3	VFS	MA	SHA	NST	NPL	EX.	V	VSL	St.Alk		
38	Cultivated	Almost flat	Whait	10YR 8/3	10YR 7/3	SL	WEBLSA	SHA	SST	SPL	EX.	F	VSL	M.Alk	C	S
	area	G.sloping	desert shrubs	7.5YR 8/6	7.5YR 7/6	SL	WEBLSA	HA	ST	SPL	EX.	C	SL	M.Alk	D	S
			Plowed area	7.5YR 8/6	7.5YR 7/6	SL	WEBLSA	HA	SST	SPL	EX.	C	VSL	M.Alk	A	S
				10YR 7/4	10YR 6/4	LS	WEBLSA	VHA	SST	SPL	EX.	F	NS	St.Alk		
39	Cultivated	Almost flat	Field crops	10YR 7/6	10YR 6/6	VFS	SG	LO	NST	NPL	EX.	V	SL	M.Alk	D	W
	area	Nearly level		10YR 7/6	10YR 6/6	VFS	MA	SO	NST	NPL	EX.	V	VSL	St.Alk	D	S
					10YR 7/6	VFS		FR	NST	NPL	EX.	V	NS	VSt.Alk		
40	Cultivated	Almost flat	Field crops	10YR 7/4	10YR 6/4	VFS	SG	SO	NST	NPL	EX.	F	VSL	M.Alk	D	W
	Area	Nearly level	Drafty sand,	10YR 7/4	10YR 6/4	VFS	MA	SO	NST	NPL	EX.	V	VSL	M.Alk	G	W
			Plowed area.	10YR 7/4	10YR 6/4	VFS	MA	SHA	NST	NPL	EX.	F	NS	St.Alk		
41	Cultivated	Almost flat	Wheat	10YR 7/6	10YR 6/6	VFS	MA	SO	NST	NPL	EX.	V	NS	St.Alk	D	S
	Area	Nearly level	Plowed area	10YR 8/6	10YR 7/6	VFS	MA	SHA	NST	NPL	EX.	V	NS	St.Alk	D	W
				10YR 7/6	10YR 6/6	VFS	MA	SHA	NST	NPL	EX.	V	NS	St.Alk		
42	Cultivated	Almost flat	Wheat	10YR 8/6	10YR 7/6	VFS	SG	LO	NST	NPL	EX.	C	NS	M.Alk	G	S
	area	G.sloping	Plowed area	10YR 8/6	10YR 7/6	LS	MA	SO	NST	SPL	EX.	C	NS	M.Alk	C	S
				10YR 7/4	10YR 6/4	MS	MA	SHA	NST	NPL	EX.	C	NS	M.Alk	C	S
				10YR 7/4	10YR 6/4	GMS	MA	HA	NST	NPL	EX.	M	NS	M.Alk		
43	Cultivated	Flat	Field crops	10YR 7/6	10YR 6/6	LS	MA	SO	SST	NPL	EX.	C	ST	Sl.Alk	C	W
	area	Neraly level	Cultivated area	10YR 7/4	10YR 6/4	LS	MA	SHA	SST	NPL	EX.	C	ST	M.Alk	A	S
				7.5YR 8/4	7.5 YR 7/4	SL	WEBLSA	HA	SST	SPL	EX.	C	ST	M.Alk	C	S
				7.5YR 8/6	7.5YR 7/6	MS	WEBLSA	HA	NST	NPL	EX.	C	ST	M.Alk	G	W
				7.5YR 8/6	7.5YR 7/6	LS	WEBLSA	VHA	SST	NPL	EX.	C	ST	Sl.Alk		

Appendix I Soil properties

Table 46: The weighted mean of total elements of the studied soil profiles

Profile	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	K_2O	TiO_2	P_2O_5	Cr	Co	Cu	Ni	Pb	Sr	Zn	Zr
No	%									mg/kg							
1	26,94	3,53	1,68	0,03	2,63	30,35	0,71	0,32	0,06	31,94	29,92	4,75	13,51	6,05	704,70	27,86	241,72
2	36,37	2,65	1,23	0,03	2,75	29,65	0,61	0,29	0,05	27,40	26,20	3,60	10,20	2,60	977,00	14,00	281,20
3	50,96	2,05	0,97	0,03	3,00	21,38	0,46	0,23	0,04	22,80	18,20	6,80	10,00	4,40	900,00	11,40	176,00
4	52,69	2,20	0,99	0,03	2,60	20,07	0,50	0,26	0,04	22,20	17,60	8,20	6,20	3,80	868,60	10,60	205,40
5	64,30	1,52	0,66	0,02	2,64	14,92	0,41	0,24	0,03	20,50	62,00	7,50	6,00	7,00	530,00	8,00	210,50
6	62,77	1,84	0,85	0,03	2,66	17,15	0,45	0,28	0,04	23,00	32,00	6,50	5,50	1,00	584,00	10,00	285,50
8	50,80	3,67	1,74	0,03	3,16	15,29	0,74	0,40	0,05	35,49	63,71	9,77	15,72	7,18	298,90	18,58	326,65
11	44,41	1,67	0,83	0,03	5,82	18,38	0,40	0,25	0,05	21,50	43,00	2,00	6,50	2,50	224,00	8,50	259,50
13	44,30	6,51	3,10	0,05	4,80	19,68	1,09	0,47	0,10	47,00	19,00	0,00	23,00	13,00	338,00	40,00	289,00
14	32,88	2,98	1,43	0,03	3,55	27,76	0,59	0,27	0,05	28,90	39,50	4,70	11,20	5,00	583,10	15,80	250,40
15	36,94	3,89	1,79	0,04	2,94	23,47	0,73	0,31	0,06	32,00	17,86	4,57	14,71	3,86	785,00	24,43	265,43
16	36,34	5,27	2,40	0,05	2,91	24,21	1,02	0,37	0,08	40,00	25,00	4,50	16,50	7,50	1027,00	30,50	287,50
17	28,74	3,08	1,35	0,04	3,08	32,13	0,67	0,24	0,04	27,17	23,00	3,22	9,39	1,67	1305,00	16,22	194,11
18	27,08	4,62	2,08	0,04	2,78	31,17	0,89	0,32	0,06	32,50	27,00	4,40	18,00	10,90	930,00	26,40	221,40
19	25,91	4,15	1,92	0,04	2,73	30,14	0,87	0,32	0,07	33,90	24,70	6,30	18,30	7,00	1138,70	22,50	259,20
23	36,65	6,13	2,82	0,05	3,20	22,27	1,26	0,44	0,08	45,20	26,20	5,40	25,80	12,20	778,00	35,60	287,80
24	27,74	3,52	1,59	0,04	2,46	33,45	0,73	0,24	0,07	28,50	18,50	6,50	9,50	12,00	1552,00	21,00	174,00
25	22,32	2,51	1,12	0,03	2,10	37,01	0,54	0,21	0,04	23,20	16,90	3,70	8,30	6,10	1382,90	14,60	193,30
26	27,14	3,50	1,55	0,03	2,48	31,06	0,76	0,29	0,06	30,70	18,10	4,80	8,80	5,30	1223,10	19,60	273,90
27	35,27	5,05	2,29	0,04	3,09	28,27	0,95	0,34	0,09	37,50	21,50	5,00	20,00	5,50	850,50	28,50	252,00
28	30,86	4,70	2,11	0,04	2,93	25,56	0,95	0,35	0,07	37,06	26,33	4,72	14,78	7,89	873,90	26,56	258,17
29	39,07	3,79	1,80	0,03	2,64	24,89	0,73	0,30	0,05	34,00	40,33	6,00	16,67	8,33	719,30	21,67	226,67
30	39,19	5,60	2,59	0,04	4,06	20,21	0,98	0,44	0,08	40,00	36,00	3,00	22,00	4,00	515,00	32,00	388,00
31	34,66	4,71	2,30	0,04	3,69	25,83	0,82	0,38	0,08	40,25	58,25	4,50	22,42	6,92	568,60	25,75	294,58
32	67,51	6,32	2,97	0,05	5,37	19,38	1,02	0,48	0,09	46,00	31,00	0,00	22,00	7,00	305,00	41,00	345,00
35	50,43	1,44	0,70	0,03	2,87	21,74	0,34	0,24	0,03	20,90	37,10	8,00	3,20	10,10	713,80	6,10	254,80
36	54,55	1,84	0,87	0,02	3,28	19,72	0,42	0,23	0,03	21,40	66,80	3,20	5,80	4,00	547,00	8,80	189,40
37	56,52	1,76	0,80	0,03	2,46	17,87	0,43	0,26	0,04	21,50	53,00	6,50	8,50	1,50	740,00	9,50	234,00
38	55,06	2,56	1,16	0,03	3,29	19,67	0,61	0,29	0,03	22,40	51,90	4,80	8,80	6,90	312,30	12,60	258,30
39	53,39	2,22	0,97	0,03	2,52	19,42	0,52	0,29	0,04	25,00	38,00	6,50	6,50	7,00	837,50	12,00	269,00
40	50,50	1,62	0,74	0,03	2,74	21,30	0,38	0,20	0,04	17,00	23,50	5,00	4,00	4,50	984,00	8,00	167,50
41	52,21	2,14	0,97	0,03	2,65	20,36	0,50	0,26	0,04	23,00	32,50	4,50	4,00	6,00	950,00	14,50	217,50
42	35,11	3,45	1,62	0,03	2,50	24,28	0,74	0,37	0,07	32,10	40,80	3,50	12,30	4,50	776,60	18,70	351,60
43	28,71	3,62	1,79	0,03	3,08	29,66	0,81	0,35	0,06	35,10	27,65	4,90	17,50	8,70	786,20	21,10	290,35

Appendix I Soil properties

Table 47: The main equation of total elements

Element Equations	Max	Min	Mean	Unit
Al_2O_3/MgO	2,15	0,27	1,10	%
K_2O/Al_2O_3	0,3	0,16	0,22	%
K_2O/Na_2O	3,31	1,84	0,54	%
TiO_3/Al_2O_3	0,18	0,06	0,10	%
Al_2O_3/ TiO_3	15,86	5,64	10,46	%
SiO_2/Al_2O_3	42,32	4,89	16,87	%
Al_2O_3/ SiO_2	0,20	0,02	0,09	%
MgO/CaO	0,32	0,05	0,13	%
Cr/Ni	10,0	1,31	2,85	mg/kg
V/Cr	1,70	0,50	1,01	mg/kg
Ni/CO	1,30	0,07	0,40	mg/kg
Sr/Ba	29,91	1,64	6,72	mg/kg
Ba/Sr	0,61	0,03	0,21	mg/kg
Rb/Sr	0,10	0,01	0,03	mg/kg
Zr-Cr	406	95	218	mg/kg
V-Ni	43	1,0	18	mg/kg
La/Sc	21,0	0,39	2,70	mg/kg
Th/Sc	6,0	0,13	0,98	mg/kg
Th/Cr	0,58	0,03	0,23	mg/kg
Th/Co	0,92	0,03	0,25	mg/kg
U/Th	4,0	0,10	0,48	mg/kg
Zr/Sc	322,0	9,42	44,4	mg/kg
CIA	23,36	4,22	11,06	%
CIW	24,27	4,26	11,36 %	%
ICV	24,46	4,58	10,94 %	%
CIA without CaO	82,29	59,36	74,12 %	%
Silica-sesquioxide ratio	29,64	3,36	11,59	%
CIW without CaO	94,92	69,16	88,33 %	%
ICV without CaO	4,69	1,28	2,05 %	%

Appendix II Soil classification and evaluation

Table 48:Land productivity and master productivity rating of El -Hammam Canal and extention, (According to Storie, 2008)

Profile	Depth	Gravel	Slope	pH	SAR	ECe	Erosion	Texture	Index	Capability
No.	cm	%	%		%	dSm^{-1}			rating	classes
1	93.3	98.2	97.7	100.0	98.2	93.7	100.0	95.0	78.2	good
2	93.3	98.5	97.7	100.0	84.9	69.7	100.0	80.0	42.5	fair
3	93.3	99.5	97.7	100.0	96.1	89.4	100.0	60.0	46.8	fair
4	93.3	97.9	97.7	100.0	93.7	90.9	100.0	60.0	45.5	fair
5	93.3	99.5	97.7	100.0	99.2	94.8	100.0	60.0	51.2	fair
6	93.3	98.8	97.7	100.0	96.6	86.1	100.0	60.0	45.0	fair
8	54.8	77.7	97.7	100.0	92.5	94.0	100.0	60.0	21.7	poor
11	36.3	87.5	95.4	100.0	98.5	94.6	100.0	60.0	17.0	Very poor
13	19.2	82.4	97.7	100.0	67.3	12.6	100.0	60.0	0.8	Non-agricultural
14	93.3	90.5	97.7	100.0	81.1	80.6	100.0	60.0	32.4	poor
15	32.2	83.2	97.7	100.0	95.4	93.5	100.0	60.0	14.0	Very poor
16	36.3	90.3	97.7	100.0	86.5	93.3	100.0	80.0	20.7	poor
17	70.0	88.2	97.7	100.0	88.5	77.3	100.0	80.0	33.0	poor
18	75.2	81.1	96.5	100.0	89.2	93.5	100.0	60.0	29.5	poor
19	93.3	91.5	95.4	100.0	69.5	64.3	100.0	80.0	29.1	poor
23	93.3	99.1	95.4	100.0	83.0	91.2	100.0	95.0	63.4	good
24	93.3	96.9	95.4	100.0	89.3	88.9	100.0	60.0	41.1	fair
25	93.3	87.9	96.5	100.0	76.3	57.0	100.0	60.0	20.7	poor
26	75.2	88.4	97.7	100.0	95.3	91.3	100.0	80.0	45.2	fair
27	28.0	88.2	97.7	100.0	60.0	10.3	100.0	60.0	0.9	Non-agricultural
28	70.0	96.0	97.7	100.0	71.5	50.3	100.0	60.0	14.2	Very poor
29	51.4	88.8	97.7	100.0	68.1	33.8	100.0	80.0	8.2	Non-agricultural
30	19.2	89.4	97.7	100.0	92.0	69.2	100.0	80.0	8.6	Non-agricultural
31	51.4	97.2	95.4	100.0	90.6	92.1	100.0	80.0	31.8	poor
32	9.9	79.0	97.7	100.0	84.8	78.3	100.0	60.0	3.0	Non-agricultural
35	93.3	96.7	97.7	100.0	97.1	93.9	100.0	60.0	48.2	fair
36	93.3	98.9	95.4	100.0	83.7	68.8	100.0	60.0	30.4	poor
37	93.3	98.8	97.7	100.0	99.6	92.1	100.0	60.0	49.6	fair
38	93.3	93.0	97.7	100.0	81.2	79.6	100.0	95.0	52.0	fair
39	93.3	99.5	97.7	100.0	92.6	86.9	100.0	60.0	43.8	fair
40	93.3	97.9	97.7	100.0	99.2	89.3	100.0	60.0	47.4	fair
41	93.3	98.8	97.7	100.0	60.4	95.9	100.0	60.0	31.3	poor
42	93.3	90.3	95.4	100.0	97.8	96.0	100.0	60.0	45.3	fair
43	93.3	89.6	97.7	100.0	66.4	27.7	100.0	80.0	12.0	Very poor

Appendix II Soil classification and evaluation

Table 49: Land characteristics ratings and productivity class, sub classes. (According to Sys and Verheye, 1978)

Profile	Land characteristics							Ci	Suitability classes	Suitability subclasses
	It	W	S				n			
			S1*	S2*	S3*	S4*				
No.	R	R	R	R	R	R	R			
1	100	80	55	100	80	90	100	31.7	S3	S3 S1
2	100	95	55	100	80	90	98	36.9	S3	S3 S1
3	100	100	30	100	90	90	100	24.3	N1	N1 S1
4	100	100	30	100	90	90	100	24.3	N1	N1 S1
5	100	100	30	100	90	90	100	24.3	N1	N1 S1
6	100	100	30	100	90	90	100	24.3	N1	N1 S1
8	100	80	25	75	90	90	100	12.2	N1	N1 S1
11	90	65	30	55	90	90	100	7.8	N1	N1 S1,S2
13	100	60	25	55	90	90	75	5.0	N2	N2 S1,S2,w
14	100	100	30	100	80	90	85	18.4	N1	N1 S1
15	100	65	50	55	90	90	100	14.5	N1	N1 S1,S2
16	100	65	55	55	90	90	96	15.3	N1	N1 S1,S2
17	100	100	55	100	80	90	90	35.6	S3	S3 S1
18	95	90	25	90	80	90	100	13.9	N1	N1 S1
19	90	100	75	100	80	90	80	38.9	S3	S3 S1
23	90	100	55	100	90	90	96	38.5	S3	S3 S1
24	100	100	30	100	80	90	96	20.7	N1	N1 S1
25	100	100	30	100	80	90	80	17.3	N1	N1 S1
26	100	100	55	100	80	90	100	39.6	S3	S3 S1
27	100	65	30	55	90	90	58	5.0	N1	N1 S1,S2,n
28	90	100	30	100	90	90	80	17.5	N1	N1 S1
29	100	80	55	90	90	90	75	24.1	N1	N1S1
30	100	60	55	55	90	90	90	13.2	N2	N2 S1,S2,w
31	90	80	55	55	90	90	100	17.6	N1	N1 S1,S2
32	100	60	55	30	90	90	90	3.3	N2	N2 S1,S2,w
35	90	100	30	100	90	90	100	21.9	N1	N1 S1
36	90	100	30	100	90	90	85	18.6	N1	N1 S1
37	100	100	30	90	90	90	100	21.9	N1	N1 S1
38	90	100	75	100	90	90	85	46.5	S3	S3 S1
39	100	100	30	100	90	90	100	24.3	N1	N1 S1
40	100	100	30	100	90	90	100	24.3	N1	N1 S1
41	100	100	30	100	90	90	100	24.3	N1	N1 S1
42	90	100	55	100	90	90	100	40.1	S3	S3 S1
43	100	95	75	100	80	100	58	33.1	S3	S3n

It=Topography W= Wetness S1*=Texture S2*=Soil depth S3*= $CaCO_3$ status S4*=Gypsum status n= Salinity and alkalinity limitations, R=Rating.

S3= marginally suitable, N1= currently not suitable, N2= permantly not suitable

Appendix II Soil classification and evaluation

Table 50: Land suitability of El-Hammam Canal and extension for certain crops. (Sys et al., 1993)

Profile	Land suitability for certain crops												
No.	Ma.	Wh.	Ba.	So.	Po.	To.	On.	Gr.	Fi.	Ol.	Gu.	Man.	Ci.
1	N1	S1	S3	S2	N1	N1	N1	S3	S3	S3	S1	N1	N1
2	N1	S3	S3	S2	N1	N1	N1	S3	S3	S3	N1	N1	N1
3	N1	N2	N2	S3	N1	N1	N1	S3	S3	S3	S3	N1	N1
4	N1	N2	N2	S3	N1	N1	N1	N1	S3	S3	N1	N1	N1
5	S3	N2	N2	S3	N1	N1	N1	N1	S3	S3	N1	N1	N1
6	S3	N2	N2	S3	N1	N1	N1	N1	S3	S3	N1	N1	N1
8	N1	N2	N2	N1	N1	N1	N1	N1	N1	N2	N1	N1	N1
11	N1	N1	N2	N1	N1	N2	N1	N1	N2	N2	N1	N2	N1
13	N1	N2	N2	N2	N2	N2	N1	N2	N2	N2	N2	N2	N2
14	N1	N2	N2	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1
15	N1	N1	N1	S3	N1	N2	N1	N1	N2	N2	N1	N2	N1
16	N1	N1	N1	N1	N1	N2	N1	N1	N2	N2	N1	N2	N1
17	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1
18	N1	N2	N2	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1
19	N1	S3	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1
23	N1	S3	S3	S2	N1	N1	N1	N1	S3	S3	N1	N1	N1
24	N1	N2	N2	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1
25	N1	N2	N2	S3	N1	S3	N1	N1	S3	S3	N1	N1	N1
26	N1	S3	S3	S3	N1	N1	N1	S3	S3	S3	N1	N1	N1
27	N1	N2	N2	N1	N1	N2	N1	S3	N2	N2	N1	N2	N1
28	N1	N1	S3	S3	N1	N1	N1	S3	S3	S3	N1	N1	N1
29	N1	N1	S3	S3	N1	N1	N1	N1	N2	N1	N1	N1	N1
30	N1	N2	N2	N2	N2	N2	N1	N2	N2	N2	N2	N2	N2
31	N1	S3	S3	S3	N1	N1	N1	N1	N2	N1	N1	N1	S3
32	N1	N2	N2	N2	N2	N2	N1	N2	N2	N2	N2	N2	N2
35	N1	N2	N2	S3	N1	N1	N1	N1	S3	S3	N1	N1	N1
36	N1	N2	N2	S3	N1	S3	N1	S3	S3	S3	S3	N1	N1
37	N1	N2	N2	S3	N1	S3	N1	S3	S3	S3	S3	N1	N1
38	N1	S3	S3	S2	N1	N1	N1	N1	S3	S3	N1	N1	N1
39	N1	N2	N2	S3	N1	N1	N1	N1	N1	N1	N1	N1	N1
40	N1	N2	N2	S3	N1	N1	N1	N1	S3	S3	N1	N1	N1
41	N1	N2	N2	N1	N1	N1	N1	N1	N1	N1	N1	N1	N1
42	N1	S3	S3	S3	N1	N1	N1	N1	S3	S3	N1	N1	N1
43	N1	N1	S3	S3	N1	N1	N1	N1	N1	N1	N1	N1	N1

Ma= maiza Wh= Wheat Ba= Barely So = Sorghum Po= Potato To= Tomato On= Onion Gr = Groundnut Fi = Fig Ol= Olive Gu = Guava Man= Mango Ci = Citrus

S1= highly suitable, S2= moderate suitable, S3= marginally suitable, N1= currently not suitable, N2= permantly not suitable