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Optimal Land Use Alternatives for Arid to Semi-arid Area in Jordan

عميد كلية الدراسات العليا

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DEDICATION

Dedicated with my love to :

My Parents,

My Brothers

and
My Sisters

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Abstract

Optimal Land Use Alternatives for Arid to Semi-arid Areas in Jordan

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Limited land resources in Jordan and increasing demands of the population growth needs development of natural resources and the application of appropriate planning strategies. This must be associated with proper land use system with the aim of maximizing land utilization and minimizing soil degradation. The objectives of the study were to evaluate the potential and problems of soil in the study area and to asses optimal land use alternatives for land development on a catchment basis.

The study area is located within the Muwaqar catchment which represent the arid to semi-arid regions in Jordan. The FAO framework for land evaluation and the agro-ecological zone approaches were utilized for the evaluation of land use suitability for four land utilization types. The evaluation is carried out by comparing land qualities with the limitation levels of the crop requirements. Detailed inventory of natural resources in the catchment were carried out during 1993/1994. This includes information on soil survey, climatie, vegetation, current land use, land tenure, and water resources.

Assessment of potential land suitability based on matching the requirements of land utilization types to the soil qualities of mapping units reflect different suitability classes. The main soil limitation that preceeds the degradation process is unfavorable soil surface properties that is associated with low infiltration rate.

Potential land use evaluation based on soil constrains and climate conditions indicated that the combination of climate and soil constrains allow very narrow windows of opportunity for sustainable land use unless favorable management practices are applied. Hence, the ability to manage water determine the feasibility of future development. Thus the main available source of water in the catchment can be supplemented by water harvesting techniques.

Rainfall characteristics and soil surface properties favors the opportunity for water harvesting approach. The land ownership system indicates that the size of about 75% of land is more than 50 dunums which is considered suitable for varieties of land utilization types.

Alternative land use scenarios for four land utilization types are proposed taking into consideration soil constrains, water availability and socio-economic conditions. The basic assumption behind these scenarios is the development of the best suitable area for each utilization which have high potential production. Water demands can be met through water harvesting techniques either on-farm interception and/or through earth dams construction. The scenario for fruit tree development provides the opportunity for development of about 15% of the total area. Variability of rainfall makes this utilization very risky under prevailing climatic conditions. The scenario for field crops development provide opportunity for utilization of about 15-20% of the total area. Early growing season makes this utilization less risky under prevailing climatic conditions. The scenario for vegetable development provides opportunity for utilization of about 12% of the total area. The late growing season of vegetable makes this utilization very risky. The scenario for range development provides opportunity for utilization about 40-50% of the total area. This will ensures best water utilization efficiency, low investment cost, minimum soil erosion.

CHAPTER ONE

INTRODUCTION

1: INTRODUCTION

Land resources in Jordan are very limited, since more than 90% of the land is classified as semi - arid to arid area. Thus, if agricultural production is to meet the demands of the increase of the population, then the development of the available resources should be among the priorities of planning strategies. However, development of the available resources only will not be sufficient to meet the population needs at the current rate of population growth and increase. A recent study suggests that Jordan will be only 7% to 8% self - sufficient in cereals and 14% self - sufficient in calories at the end of the century. Therefore, agricultural expansion is expected to intensify towards arid and semi-arid regions as an alternative to meet the demands for agricultural production . In addition to the availability of water, land utilization in arid areas should be based on proper land use to avoid soil degradation. The utilization of the newly cultivated land should thus ensure preservation of land resources.

The evaluation of potential productivity of the land is a prerequisite before determining it's proper utilization. Alternative plans aimed at maximizing land utilization and minimizing soil degradation should be drawn in conjuction with integrating land potential and socio - economic factors.

This study has the main following objectives:

1) To evaluate the potential and problems of soil in the study area.
2) To provide basic land resources information necessary for land use planning for the catchment area..
3) To asses the optimal land use alternatives for land development on a catchment bases.

CHAPTER TWO

LITERATURE REVIEW

2: LITERATURE REVIEW

2:1 Soil survey:

The main purpose of soil survey is to provide the user with information about the soil and landform conditions at site of interest. The ultimate goal of soil survey is to supply information which will assist in decisions about land use and land development planning [1].

The development type survey are conducted with the aim of defining a range of alternative development schemes that are undertaken in areas which appear to have more promising development potential[2]. Hence, the general purpose survey is needed in order to provide information relevant to all types of potential land use, because where the planned development scheme covers a variety of natural resources and require the allocation of areas of different potential for land use development [1,2].

The general purpose survey which may use air photograph interpretation, has a relatively high density of field soil observation. The majority of mapping units are single and are general in purpose, showing soil series or other soil types [3].

Soil maps at 1:50,000 or 1:25,500 scale usually show the distribution of soil series: "A soil series is a group of soils with similar profiles developed on similar parent material and is thus a taxonomic unit" [2,3].

2:1:1 Soil survey and land evaluation:

Land evaluation begins with basic survey of soil, water, climate and other characteristics of bio-physical resources [4]. Land characteristics needed to assess land suitability for crop production can be obtained from soil surveys [5].

Most evaluators recognize that soil survey information is a valuable tool for evaluation and assessment purposes [6]. The primary basis for land evaluation is provided by natural resources data which encompasses soil attributes, land forms, water resources, and socio - economic factors [7].

The use of basic land factors are necessary for land use planning as an indication of limitation to land use which permits the evaluation of feasible land use alternatives and assess the best use of land resources [8].

2:2 Land evaluation :

2:2:1 Objectives of evaluation :

The main objective of land evaluation is to judge the value of an area for defined purposes [9]. The evaluation need not to be limited to assessment of environmental characteristics, but analysis can be extended to examine the economic viability, the social consequences and the environmental impact[10].

Land evaluation is the process of estimating the potential of land for one or several alternative uses [1]. Hence, the evaluation is concerned with the assessment of land performance when used for specific purposes[9]. Also can be used to describe many concepts and analytical procedures, where it has usually focused upon interpreting bio-physical resources inventories and measuring the capability and suitability of the land use[11].

These techniques for land use classification can be used to delimit the different types of land available to identify the bio-physical requirement of specific land uses and to compare or evaluate each type of land for different uses [12].

2:2:2 Principles of Evaluation:

Land suitability can only be evaluated if the intended forms of land use are specified. Furthermore, land suitability for a given form of use as a matter of inputs or costs of production can be taken as an additional aspect [9,12].

The FAO framework for land evaluation procedure is based on the following basic principles:

1- Land suitability is assessed and classified in relation to a particular land uses.
2- Evaluation requires a comparison of the inputs and outputs needed on different types of land.
3- The evaluation is made with careful reference to the physical, economic and social contexts of the area under investigation.
4- A multi - disciplinary approach is required.
5- Suitability refers to use on a sustained basis.
6- Different kinds of land use are compared on a simple economical basis [1,9,12].

It is evident that there is a certain degree of overlap between these principles. However, it is fundamental that the identification of relevant land uses be taken as a first step in order that the evaluation procedure is exctended with specific reference to these land uses. This mean that land use requirements of the various lands have to be established and then the actual characteristics of land mapping units to be assessed in terms of their ability to provide optimum conditions [9,12,13].

2:2:3 Approaches to land evaluation:

Many approaches have been adopted in land evaluation. Among these approaches is the physical land evaluation which is concerned with predicting the performance of specific land use systems as conditioned by physical constraints. This type of evaluation assists in the identification and comparison of potential land use alternatives [12].

This approach goes beyond assessing the performance of alternative uses on particular types of land by providing actual information concerning the potentials and constraints of a particular land utilization types in terms of crop yield and associated land qualities [14,15].

The integral land evaluation approach complements and extends physical land evaluation by incorporating socio - economic requirements with bio - physical aspects in the assessments [13]. Also the integral land evaluation procedure has to be used in order to establish guidelines for land use policies and to provide means for the assessment of the production potential of land units under alternative scenarios of land use [14].

2:2:4 Quantitative vs. qualitative evaluation:

There are different levels of detail in the technical approaches of physical land evaluation ranging from simple to complex [16]. Each level can be defined in terms of the expected degree of details of the results. Additionally, the level of details of field survey and land resources mapping have a strong influence on land evaluation methodology [17,18].

In contrast, qualitative physical land evaluation methods usually are less detailed technical approaches and requires less data and produces quick but broad answers [19,20]. Qualitative classifications are always expressed in physical terms only and are usually employed in reconnaissance surveys [1].

When land use exploration techniques are applied, more quantitative information is needed which can be provided by quantitative physical land evaluation methods [21]. Quantitative physical systems specify the inputs and the production from the forms of land use under consideration. They involve relating environmental characteristics to the technology of land use where economic consideration are taken into account but only as a general back ground[1]. However, quantitative classifications need not necessarily be economic, one of the most useful types especially in feasibility surveys is quantitative physical evaluation in which inputs are specified [1,2].

2:3 Systems of land evaluation :

2:3:1 Land system :

The land system approach is a technique for conducting and presenting the results of reconnaissance survey and it is used more widely than any other methods [2,22]. This means that all factors of the physical environment are mapped simultaneously [2,23].

The landscape approach involve the delimitation and characterization of land mapping units on the basis of distinct ecological complexes being expressed in landscape pattern. Land system approach is the best known landscape approach for providing a rapid inventory of land resources [10,24].

The land system technique is based on the use of aerial photographs as a prediction tool and physiographic land units as a soil mapping unit [25,26,27,28].

The central concepts that are used in specific areas will interrelate all the environmental characteristics, topography, soil, vegetation, geology, geomorphology, and climate resulting in distinctive pattern on aerial photographs [10, 24].

For the planning of agricultural development, such surveys allow us to identify areas of little or no potential, but more detailed investigation are required in areas which seem to offer scope for development[24].

One possible short coming of this approach that is lacks quantitative quidelines and much interpretation necessary to apply this approach. Moss (1985), argues that a major limitation of many ecological land classification techniques is their inability to produce data on relative value [24].

2:3:1:1 Concept of land facet:

The use of the land facet as a soil mapping unit is based on the assumptions that there is a correlation between soil condition and landscape morphology [29]. This is due to its characteristics as a small manageable unit with internal homogeneity that can be used for land use planning [30].

The land facet is the lower level of landscape, small physiographic unit within which variation in soil condition are either not important or is consistence nature [31].

Facets are grouped into units called land systems which contain the same set of land facets with the same interrelation. The main function of the land system in detailed planning is to assist the identification of land facets at some point of interest [28, 32].

The individual occurrence of land facets are of such a size that they can be mapped at scales of 1:10,000 to 1:50,000 and they are recognizable on air photographs at scales of this range or little smaller [28].

2:3:1:2 Usefulness of land system for prediction land use:

The morphology of the land surface is landforms which has many practical implications to land use [22]. The component part of the landscape is sufficiently uniform for many practical purposes, and can be used both to collate a wide range of information on land resources and to subdivide the local landscape for detailed planning [33].

The correlation between the mapped classes of one characteristic and land use potential in a region may be high or low depending partly upon its range of variability[32]. Each land facet is sufficiently homogenous to the extent that it is managed uniformly but not for intensive kinds of land use[28].

Areola (1977) and Christian (1958) recognized that the land system approach can be applied to land use studies in relatively unknown and undeveloped areas where a comprehensive assessment of possibilities has to be made or areas which are well developed but for some economic or other reasons, reassessment is necessary to achieve a better adjustment of actual land use to land capability [27, 32].

2:3:2 Land capability classification:

A comprehensive hand book on land capability classification was published in 1961 by Klingebiel and Montgomery. This technique was developed by the Soil Conservation Service Department of Agriculture, and referred to as USDA method.

The USDA techniques focus on the interpretation of soil mapping units according to degree of constraints to land use. This method is based on the concept of limitation to land use imposed by land characteristics. The prime aim of the method is to assess the degree of limitation to potential land use or imposed by land characteristics on the basis of permanent properties [34]. Information on slope angle, climate, flood and erosion risk, as will as on soil properties are required. There is a great deal of interrelation between these types of information and the soil mapping units which are grouped together to form capability units [2, 10].

Three levels of classification are defined; capability class, capability subclass, and capability unit (In decreasing order of details). Eight classes are described, with class I posing little or no limitation to land use while class VIII is capable of supporting wildlife. Classes I to V offer varying degrees of possibility for arable cultivation [35].

Capability subclass represented by alphabetical suffices indicates the type of limitation encountered within each class; they include wetness, climate, soil factors (such as stoniness), and erosion hazard.

Below the capability subclass lies the capability unit, which has little variation in severity or type of limitation and which is suitable for similar crops under similar farming system.

It will be apparent that different types of soils may be grouped in the same capability class if the degree of limitation is constant. Therefore, classification is based on the severity of limitation and hence not necessarily on the type of soil.

Consequently, the lack of quantitative details on classes, subclasses and units has distinct merit. The disadvantages of the qualitative approach is the high degree of subjectivity where investigators could come to different conclusions about the same area. However, one of its main application is in identifying prime agricultural land to which policies of preservation may be subsequently applied [10, 34].

3:3:3 Land suitability evaluation :

2:3:3:1 The concept :

Land suitability evaluation is a type of land evaluation in which separate assessments are made of the suitability of land units for each number of different defined forms of use [1].

Before the introduction of the FAO framework, general classification system were widely used. Most of these evaluations were adopted issues of the USDA land capability classification [35]. This evaluation method is based on relations between soil, agricultural results and vegetation observed during the soil survey.

Since the FAO background document was published in 1976 for land evaluation. The concept of Land Utilization Types has been widely accepted [13, 36].

The FAO framework established a standardized system for land evaluation that facilitated the exchange of procedure. Where it allowed assessment of the suitability of relatively large scale land mapping unit for land uses within the limitation imposed by the lack of data on crop yields [37].

The framework is a set of methodological guidelines rather than a classification system and the intention is for it to be applied to any land evaluation projects in any environmental situation and at any scale [2]. It is an ecological analysis with reference to defined land utilization type which also incorporate social, economic and technological dimensions [10].

The most important contribution of the approach is the emphasis placed on the fact that different forms of land use have different requirements, and that they must be defined and land suitability must be assessed separately for each [1, 9, 10].

2:3:3:2 Quantitative and qualitative evaluation:

The framework may be applied to qualitative or quantitative physical suitability evaluation or to economic evaluation. And it can be used for the assessment of either current or potential land suitability [1, 2]. Beek (1975) draws a distinction between qualitative and quantitative matching. The quantitative matching uses a conversion table which allows for each utilization type to be graded in terms of degree of limitation imposed by particular land characteristics [38].

Land evaluation procedures such as those based on the framework for land evaluation (FAO 1967) allow interpretation of qualitative data which are useful to broadly defined areas of land that are relatively suitable for a particular type of land use [39].

Although a qualitative evaluation is still currently used, the quantitative approach as developed by FAO in their agro-ecological zone project remain one of the most widely used and the best possible to achieve quantification of the land evaluation system [36].

2:3:3:3 Kinds of land use:

A distinction is made between a major kind of land use and a land utilization type. The former is a major subdivision of rural land use, (such as pasture land, forestry or recreation), while the latter is a type of land use described in greater details according to a set of technical specifications in a given physical, economic and social setting [12].

The term land utilization type has been originally introduced for use in the methodology of land evaluation, where it provides the means for combining the ecological and technical aspect of land use with the economic and social circumstances [12, 40].

A land utilization type provides specific means of classifying and land use modification if necessary. Land utilization types in planning are also called land use alternatives. The land use to which this concept applied may be one or many different major kinds of land use [13].

The task of detailed land evaluation is to assess land mapping units in terms of land utilization types. This makes it necessary to recognize land qualities, which are a component regime of the physical land conditions with a specific influence on land use performance [41].

2:3:3:4 Land qualities :

The central concept of the FAO framework for land evaluation is the use of land qualities "which are a complex attributes of land characteristics that act in a distinct manner on specified land use types " to asses crop performance[9]. Land qualities are dynamic attributes and are assessed from land characteristics [42].

Thus the FAO framework recommends that land units should be evaluated for land uses in terms of land qualities. To achieve such evaluation, diagnostic criteria are recognized. These may be land qualities or characteristics but they are known to have a clear effect on potential land use [41].

2:4 Land use planning:

The term land use planning refers to a scale greater than that of the individual land unit and it usually involves government at one level or another. It is also concerned with reconciling the goals and objectives of individuals as well as groups in the society [43].

Sound land use planning has to use modern scientific knowledge together with the various empirical data which have proved to be effective for soil suitability classification [44].

Smit (1981) describes land evaluation as a synthesizing techniques that offers to planners or policy makers land use systems and performance under a range of possible conditions. The main aim is to provide analytical techniques which bridge the gab between land inventories and land use planning [45].

The relevance of land qualities for land use planning is that this approach focuses on various kinds of land characteristics in their ecological function as interacting factors for plant growth and land use [46].

The concepts of the FAO frame work for land evaluation and the agro - ecological zone project were also used to assess the physical land approaches and this allows for the prediction of alternative scenarios of land use planning [20].

2:5 Evaluation Procedure:

Evaluation procedure, based on the principle of the FAO framework suggests a translation of the limitation levels into land classes. This means that for each quality one can define an S_1 level (very suitable), an S_2 level (moderately suitable), an S_3 level (marginally suitable), an N_s (not suitable). The classification are as follow; no or only slight limitation define the (S_1) level, moderate limitations the (S_2) level, severe limitation the (S_3) level, and very severe limitation (N_s).

A schematic relation is as follow :

Limitation levels	Class level
0, no	S_1
1, slight	S_1
2, moderate	S_2
3, severe	S_3
4, very severe	N_s

According to this procedure, classes should be defined in function of the evaluation procedure therefore three methods have been compared [47].

2:5:1 Simple limitation method:

The simple limitation method defines land classes on the basis of the most severe limitation. This widely used procedure is the most simple method for qualitative land evaluation. A disadvantage of this procedure is that land units presenting only one and other presenting more limitations of a certain level that belong to the same class. Although a situation with more limitation appears less favorable as compared with a situation with only one limitation [47].

The method should therefore be used by all those who have no clear insight in the interactions between land characteristics and qualities.

2:5:2 Parametric method:

The application of parametric method in the evaluation of land qualities consists of attributing numeral ratings to the different limitation levels of the land qualities in a numerical scale from a maximum (normally 100) to minimum values [48]. The successful application of the system implies the application of the following rules :

1- The number of land characteristics to consider has to be reduced to a strict minimum to avoid interaction between related characteristics, leading to a depression of the land index.

2- An important characteristics is rated in a wide scale, a less important characteristics in a narrower scale, this introduces the concept of weighting factor.

3- The rating of 100 is applied for optimal development maximum appearance of a characteristics. If, however, some characteristics are better than the usual optimal, the maximum rating can be chosen higher than 100.

4- The depth to which the land index has to be calculated must be defined for each land utilization type.

5- The land indices is calculated from the individual ratings. The calculation of these indices can be carried by the storie and square root method [47].

Soil potential ratings, which is based on the land index concept give emphasis to the positive attributes and on the performance of soils. A key problem in devising an index of land quality or performance is the identification and appropriate weighting of the controlling factor [49].

The merit of this type of approach is that there can be confidence in the index values given that the method is based on soil - yield correlation. A disadvantage of this approach is that the results will not necessarily be applicable to other crops and other areas, and further calibration of indices would be necessary [48].

2:5:3 Limitation method:

Land qualities influence the suitability of land. This suitability depends on whether some of these qualities are optimal, marginal or unsuitable. Therefore, evaluation of qualities for specific land use is an essential stage in the overall evaluation. Limitation are deviation from the optimal conditions of a land qualities which adversely affect the kind of land use [47].

If the characteristics are optimal for plant growth it caused no limitation, on the other hand when, its unfavorable it causes sever limitation. We suggest the use five level scale in the range of degree of limitation where the severe level is used when the property is very marginal [50].

The evaluation is carried out by comparing the land qualities with the limitation levels of the requirement tables. This method requires great attention for interaction between characteristics/qualities where a minimum set of diagnostic criteria should be used.

The different levels in the degree of limitations are:

- No limitation: The qualities are optimal for plant growth.
- Slight limitation: The qualities are nearly optimal and reduces productivity not more than 20% with regard to optimal yield.
- Moderate limitation: The qualities has a moderate influence on yield decrease, however benefit can still be gained and use of the land remains profitable.
- Severe limitation: The qualities has such as influence on productivity that the use becomes very marginal.
- Very severe limitation: Such limitations will not only decrease the yields below the profitable level but may even totally inhibit the use of the soil for the considered land utilization type [9, 12].

CHAPTER THREE

MATERIALS & METHODS

3: MATERIALS & METHODS

3:1 Study area :

The study area is located within the Muwaqar catchment, 30 Km South East of Amman, (Figure 1), and consists approximately 75 square Km. The approximate geographic coordinates are (266 - 270), East and (130-135), North. Elevation of the area varies from 950 - 776 m a.s.l. The present climate is classified as arid. Annual rainfall is 150-200 mm, and is highly variable, sporadic, and unpredictable. The average annual temperature is 17C°. Mean maximum and minimum air temperature during January is 13C° and 3C°, mean maximum and minimum air temperature during August is about 33C° and 17C°, respectively.

The natural vegetation cover is weak and scattered. The main vegetation cover consisted of small shrubs and grasses. Vegetation composition is not stable and vary seasonally. The dominant land use in the area is range, rainfed agriculture is practiced with some scattered farms of irrigated vegetables, irrigated orchards, and livestock. The population density is low in the area except in two villages located at the border of the catchment with medium population density.

3:2 Steps of land evaluation:

The procedure for physical land evaluation is schematically represented in (Figure 2). This method utilizes the principles and guidelines outlined in the FAO framework for land evaluation and the agro-ecological zoning approaches (FAO, 1976, 1978) [12, 51]. The procedure refers basically to a definition of the crop growth requirements (qualities) expressed in terms of climatic, soils and physiographic criteria, followed by matching of these qualities with the land utilization types [20].

The steps of land evaluation (Figure 2) can be summarized as follows:-

- Land evaluation requires survey of physical resources. The results are presorted in the form of land "mapping units" backed with appropriate analytical data.
- From this basic land inventory "land qualities" can be postulated by a knowledge of the appropriate land use requirement and limitations.
- Comparison of land use with land is the key process in land evaluation since this is the crucial stage when the land and land use data, as well as, economic and social information are brought together and analyzed.

The evaluation is carried out by comparing land qualities with the limitation levels of the crop requirements [47]. Thus, the evaluation procedure is based on the translation of the limitation levels into land classes.

Table (1) : Translation of limitation levels into land classes.

Land classes	Definitions
S1 (very suitable)	Land unit with four or less slight limitation,
S2 (moderately suitable)	Land unit with more than three moderate limitations,
S3 (marginally suitable)	Land unit with more than two severe limitations,
Ns (not suitable)	Land unit with severe limitation, potentially suitable but economically not suitable.

Reference (12, 51).

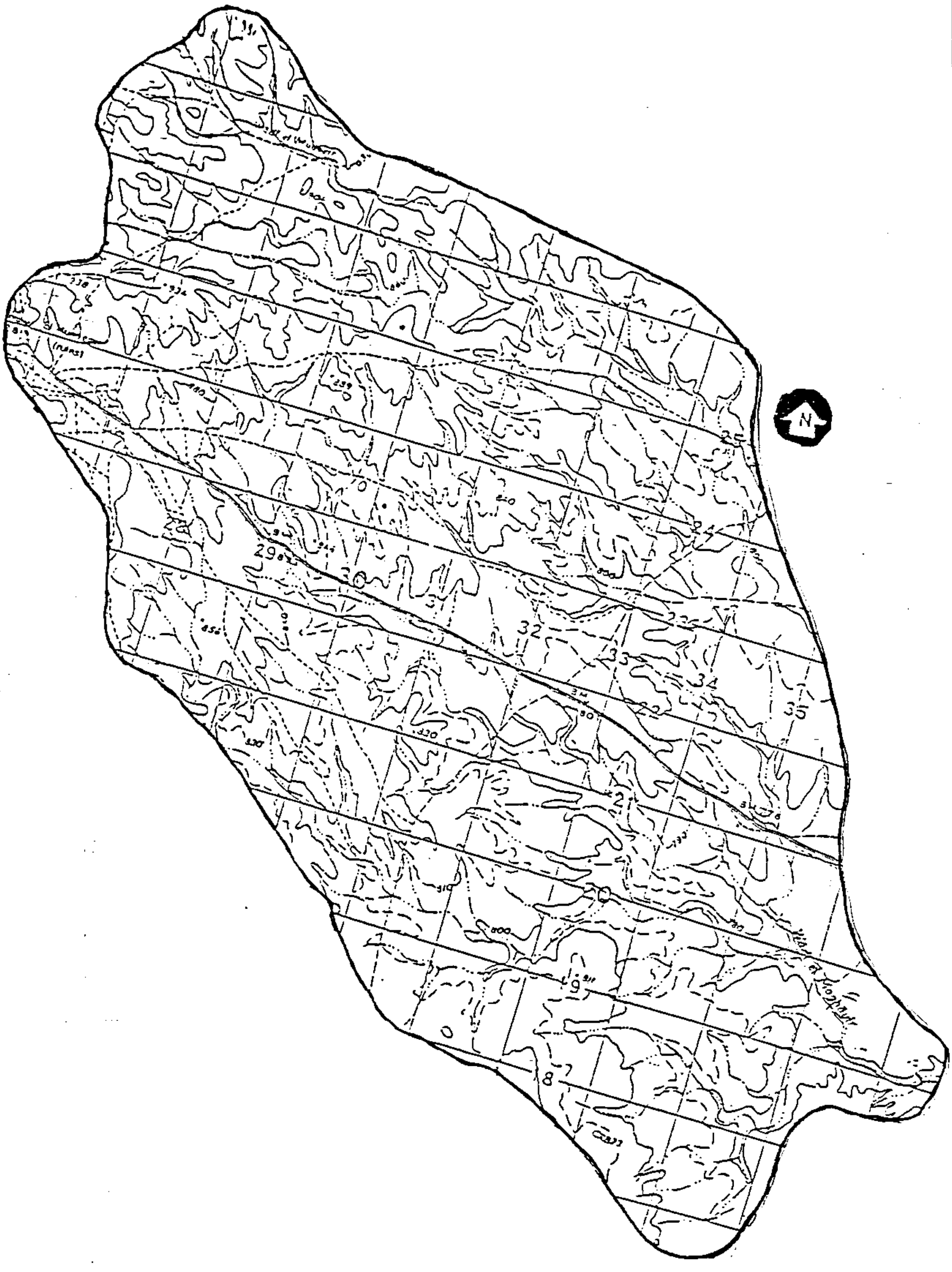


Figure (1) Catchment area of Wadi El-Maghayir / Muwaqar

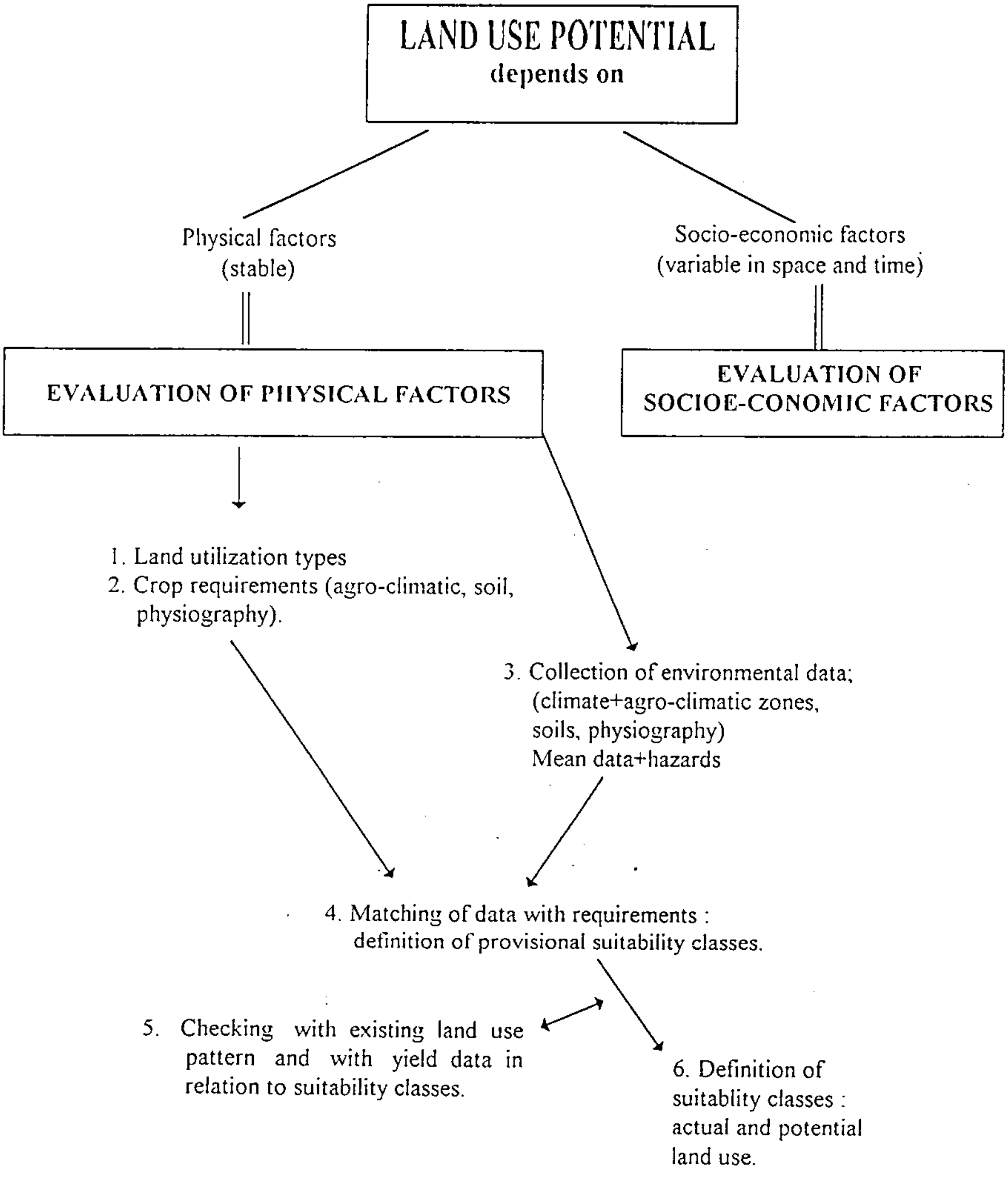


Fig. (2) Steps of land evaluation procedure.

3:3 Data Collection :

Detailed inventory of natural resources in the catchment were carried out during 1993/1994 years. This inventory included different aspect and activities of the natural resources in the catchment. These include soil, climate, vegetation, land use and water resources.

3:3:1 Field investigation

3:3:1:1 Soil Data

Detailed soil survey of the whole catchment area is carried out to obtain the basic soil information necessary for evaluation process.

Soil depth: Detailed soil depth investigation were carried out in 1993 by using auger method. The depth at 500 sites were checked and located on air - photo map Reassessment of depth map unit was carried using deep profiles. Afterword a detailed soil depth map on a scale of 1: 30,000 was produced (Figure 3).

Soil depth categories used in preparing the soil depth map are as follows.

Symbol	Soil depth (cm)
A	>150
B	100 - 150
C	50 - 100
D	25 - 50
E	<25

Slope degree: Detailed slope mapping were carried out in 1994 using Abni - Level. About 1500 observations were measured and cited on air photo map at a scale of 1 : 30,000. Delineation of slope unit was based on dominant maximum slope (Figure 4).

The slope classes used in preparing the slope map are as fallow:

Symbol	Slope degree (%)
A	<2
B	2 - 3
C	3 - 6
D	6 - 9
E	>9

Soil map: Soil survey map was produced on a map at a scale of 1: 30,000 (Figure 5). Adequate number of soil profiles (62 profiles) were studied in the field. Several soil profiles were described in the field. Representative profiles (14) were described, sampled for laboratory analysis[52], and classified [53].

Table (2) shows soil classification for the soils in the catchment [53].

Table (2): Classification of soils occurring in Muwaqar catchment.

Soil	Profile No.	Soil classification
M1	Z5,Z6,Z9,Z10, Z11,Z13, Z14,Z18	Fine, mixed,thermic,Typic Haplocalcids.
M2	Z7	Fine, mixed,thermic,Typic Haplocambids.
M3	Z8, Z16	Fine, mixed,thermic,Typic Petrocalcids.
M4	Z12, Z15	Fine silty, mixed,thermic,Typic petrocambids.
M5		Fine, mixed,thermic,Lithic Haplocambids

The following information were collected, see profile description Appendix (A).

3:3:1:1:1 Site information

1) Slope characteristics.
2) Surface stoniness.

3:3:1:1:2 Morphological properties

1) Soil structure.
2) Soil consistency.
3) Soil color.
4) Effective soil depth.
5) Distribution of secondary carbonate accumulation.
6) Pores distribution.
7) Stoniness percent.
8) Horizon thickness and boundary.
9) Roots distribution.
10) Other normal morphological properties, such as parent material, topography, land use, erosion, crust formation, and other special features.

3:3:1:1:3 Infiltration rate:

Soil infiltration rate for (100) sites were measured. The selected locations represent different soil type in the catchment. Soil infiltration rate were measured using double cylinder rings infiltrometer method [54].

3:3:1:2 Natural vegetation :

The main objective was to study the vegetation cover in relation to the different soil types, to allow the estimation of the potential carrying capacity of the area. This study was carried during 1994 for 25 sites. Soil samples were collected at the time of plant sampling to study the soil plant interactions.

3:3:1:3 Socio - economic data:

3:3:1:3:1 Current land use:

Current land use activity during 1993/1994 years was mapped. The information about major kinds of land use and soil productivity data were collected. The farms location and other activity on the land use were also mapped figure (6).

3:3:1:3:2 Land tenure:

Cadastral map for the catchment was prepared .The cadastral line, were transferred to air - photo base map of a scale of 1: 30,000 figure (7), (55). Land units are classified according to their area into six categories as follows:

Class	A	B	C	D	E	F
Area (du)	<10	10-30	30-50	50-100	100-200	>200

The boundaries between the same neighboring units are removed, this mean that (A) class may have more than one units.

3:3:2 Laboratory analysis :

Soil samples were air dried and passed through a 2.0 mm sieve. Natural clods were saved for physical and chemical analysis.

3:3:2:1 Physical analysis :

Particle size analysis: Soil was soaked in (0.5 N, pH 5.0) sodium acetate to remove carbonate [56]. Organic matter was removed by heating the sample with 30% H_2O_2. Sodium hexameta phosphate 6% and overnight shacking were used to maintain maximum dispersion. Clay and silt were measured by pipette method [57]. Sand fraction was separated by sieving, (0.25, 0.106, 0.05) mm.

Bulk density: Saran resin method was used [58] to measure soil bulk density.

Available water holding capacity : Available water holding capacity was calculated by using the difference between soil moisture at field capacity (0.3 bar) and permanent wilting point (15 bar) [59].

3:3:2:2 Chemical Analysis :

Organic matter content: Organic matter content was determined by Walkely- Black method [60].

Carbonate content: Total carbonate was determined by acid- neutralization method [61].

Available phosphorus: Available phosphorus was extracted using 0.5m sodium-bicarbonate at a nearly constant pH (8.5) [62], and measured with spectrophotometer.

Exchangeable (K, Na, Ca, Mg): Exchangeable K, Na, Ca, Mg was extracted from the soil with ammonium-acetate (1.0N, pH 7.0). Potassium and sodium were measured using flame photometer [63]. Calcium and magnesium were measured using atomic absorption [64].

Micronutrients (Fe, Mn, Cu, Zn) : Micronutrients were extracted by DTPA extraction solution and measured by atomic absorption [65].

pH: Soil pH was measured on 1:1 soil to water ratio [66].

Salinity (EC) : Electrical conductivity was measured on 1:1 soil to water ratio [67].

Cation exchange capacity (CEC): Cation exchange capacity was measured by ammonium acetate method [68].

Sodicity (ESP): Sodium saturation (Exchangeable Sodium Percentage) was calculated by dividing exchangeable sodium by cation exchange capacity.

3:3:3 Climatic data :

Long term climatic data from a representative meteorological station Muwaqar Civil Defence station, and Queen Alia Airport station was used to obtain the following parameters [69, 70].

Parameters include :

1) Monthly air temperature.
2) Rainfall.
3) Sunshine hours.
4) Wind speed.
5) Relative humidity.

3:4 Derivation of land qualities

Land qualities refer mainly to climatic, land form, and soil related parameters[12]. Derivation of land qualities necessary to assess crop performance was carried out using information extracted from the soil survey investigation and climatic information.

Land qualities used to evaluate crop suitability are:

1) Radiation regime.
2) Temperature regime.
3) Climatic hazard.
4) Surface crust.
5) Nutrient availability.
6) Salinity hazard.
7) Soil toxicity.
8) Rooting conditions.
9) Moisture availability.
10) Erosion risk.

The relationships between the land qualities and their characteristics is given in table (3).

3:4:1 Rooting conditions :

Rooting condition is evaluated by calculating effective soil depth. In this method, each horizon is given a weighted depth coefficient of (1), if there is no restriction to (0) if soil is not penetrable, depending on the gravel content. The effective soil depth is calculated as the sum of the products of the depth coefficient and the thickness of the various layers table (4).

3:4:2 Nutrient availability :

The fertility capability classification system (Sanches et al 1982) is used for characterizing the land quality nutrient availability [71]. The rating for chemical soil fertility is carried out for surface layer taking into consideration available nutrient, O.M, pH and CEC.

Table (3): The relationships between soil characteristics and land quality.

No	Land quality	Criteria	Unit
1	Radiation regime (total radiation)	- Mean daily sunshine hour during the growing season.	hr/day
2	Temperature regime	- Mean temperature during the growing season. - Mean temperature during the coldest month of growing season.	C° C°
3	Climatic hazard	- Occurrence of damaging frost during the growing season. - Occurrence of destructive storms during the growing season.	
4	Surface crust	- Field assessment by thickness and strength.	
5	Nutrients availability	**- Nutrient level** - Available P - Exchangeable Ca, Mg, K - Organic matter - Reaction - Cation exchange capacity	 PPM meq/100g % pH meq/100g
6	Salinity hazard	- Electrical conductivity	ds/m
7	Alkalinity hazard	- ESP	%
8	Rooting conditions	- Soil depth - Gravel content	m %
9	Soil moisture availability	-Available moisture holding capacity -Infiltration rate	mm/m mm/hr
10	Erosion risk	-Erodability factor.	class

Reference (9).

Table (4): Estimation of the effective soil depth:

Depth coefficient (ratio)	Gravel content (%)
1.00	<15
0.75	15 -40
0.50	40 - 60
0.25	>60
0.0	---

Reference (72).

- Rating for chemical soil fertility

1) Cation exchange capacity : Group rating (R_1):

Group Rating (R_1)	CEC meq/100g
1	>35
2	20-35
3	10-20
4	6-10
5	<6

2) Available nutrients : Group rating (R_2)

(R_2)	Exch. Ca	Exch. Mg	Exch. K	Available. P	O.M
	meq/100g	meq/100g	meq/100g	PPM	%
1	>6.0	>1.4	>0.56	>40	>1.2
2	3.8-6.0	0.9-1.4	0.35-0.56	20-40	0.8-1.2
3	2.6-3.8	0.6-0.9	0.25-0.35	10-20	<0.8
4	<2.6	<0.6	<0.25	<10	---

3) pH : Group rating (R_3)

Group rating (R_3)	pH
1	7.2 - 7.8
2	7.8 - 8.2
3	8.2 - 8.5
4	8.5 - 8.9
5	>8.9

For final classes of soil fertility based on chemical properties, the group rating R_1, R_2 and R_3 are combined. R_1 and R_3 have five sub classes and R_2 has three subclasses. The following triangle gives the final classes.

Table (5): Triangle for soil fertility rating final combination for R_1, R_2 and R_3.

Rating	Group rating (R_1,R_2,R_3)				
1	1*11	211			V.high
	11**2	212			
2	113***	122	213		High
	121		221		
3	123	222	311	313	Moderate
	131	223	312	321	
4	132		322	331	Low
	133	231	323	332	
5	232	233	333		V.low

* R1, ** R2, ***R3.

The degree of limitation for nutrients availability, cation exchange capacity, and pH for different levels are given in table (6).

Table (6): Rating of nutrients availability.

Criteria	Unit	Degree of limitation			
		No	Slight	Moderate	Severe
		S1	S2	S3	NS
CEC	meq/100g	> 35	20-35	10-20	< 10
Ca	meq/100g	> 6.0	3.8-6.0	2.6-3.8	< 2.6
Mg	meq/100g	> 1.4	0.9-1.4	0.6-0.9	< 0.6
K	meq/100g	> 0.56	0.35-0.56	0.25-0.35	< 0.25
P	PPM	> 40	20-40	10-20	< 10
OM	%	> 1.2	0.8-1.2	<0.8	---

Reference (9, 71)

3:4:3 Soil moisture availability.

The rating of the moisture storage capacity in the root zone depends on the total available moisture, which is a function of soil depth, texture, and structure. To evaluate total available moisture, available moisture is calculated first (moisture at 1/3 bar - moisture at 15 bar) and then the total available moisture is calculated for effective depth.

Table (7): Rating of total available moisture.

Rating	TAM (mm/m)	Moisture class
1	160-200	V. high
2	120-160	High
3	080-120	Moderate
4	040-080	Low
5	<40	V.low

Reference (74).

3:4:4 Erosion hazard :

3:4:4:1 Water erosion : Assessment of water erosion is assessed for erodability map figure (8). Soils with similar erosevity behavior are grouped according to soil type, slope degree, and silt percent. The erodability class were determined by Ziadat [75] using the Washmier nomograph, [76].

3:4:4:2 Wind erosion: This parameter is based on assessment of two factors: wind erosivity (the climatic aggressivety of wind), and the susceptibility of the soil to wind, using surface texture [77]. Soils with similar wind erosion behavior are grouped according to soil surface texture. The groups are established by Soil Conservation Service [77] as fallows:

Table (8): Wind erosion class according to Soil Conservation Services

Wind erosion group	Predominant soil texture class
1	V.FS, F.S, S, or C.S.
2	L V.FS, L. FS, L.S, L.CS.
3	V. FS loam, F.S loam, S.L or C.S loam.
4	C, SIC, non calcareous clay loam or SICLwith >35% clay content.
4L	Calcareous loam and silty loam,calcareous clay loam and silty clay loam with < 35% clay content.
5	Non calcareous loam and silty loam with less than 20% clay content.
6	Non calcareous loam and silty loam with more than 20% clay content.

Reference (77).

3:4:5 Crust hazard :

Soils that seal easily after cultivating the land have two important adverse effect on the establishment of seedlings, namely, the mechanical hindrance of emergence due to crust formation, and reduction of stored moisture due to low infiltration of water.

Susceptibility to surface sealing is related to particle size distribution, bulk density and pore volume, organic matter content and infiltration rate [78]. The assessment of surface crust was carried out in the field by measuring the thickness and strength of the crust the rating of different mapping units with respect to crust hazard is given in table (10).

Table (9): Assessment of crust hazard.

Map unit	Silt %	Crust thickness (cm)	Limitation degree
M1A	54	0.5 W*	Moderate
M1B	57	0.3 W	Moderate
M1C	49	0.5 W	Slight
M1D	56	1.0 W	Slight
M2	54	1-1.5 P**	Severe
M3	55	0.5 W	Moderate
M4A	53	2.0 P	Severe
M4B	54	0.5M***	Slight
M5A	50	0.5W	Slight
M5B	51	0.5W	Slight

*Weak, **platy structure, *** moderate.

3:5 Matching process:

Matching the requirements of the crop to the qualities of land unit and assessing the suitability of land for specific crops with respect to :

1) Soil erodability data.

2) Socio - economic data.

3) Management practices.

3:6 Prediction of land use alternatives:

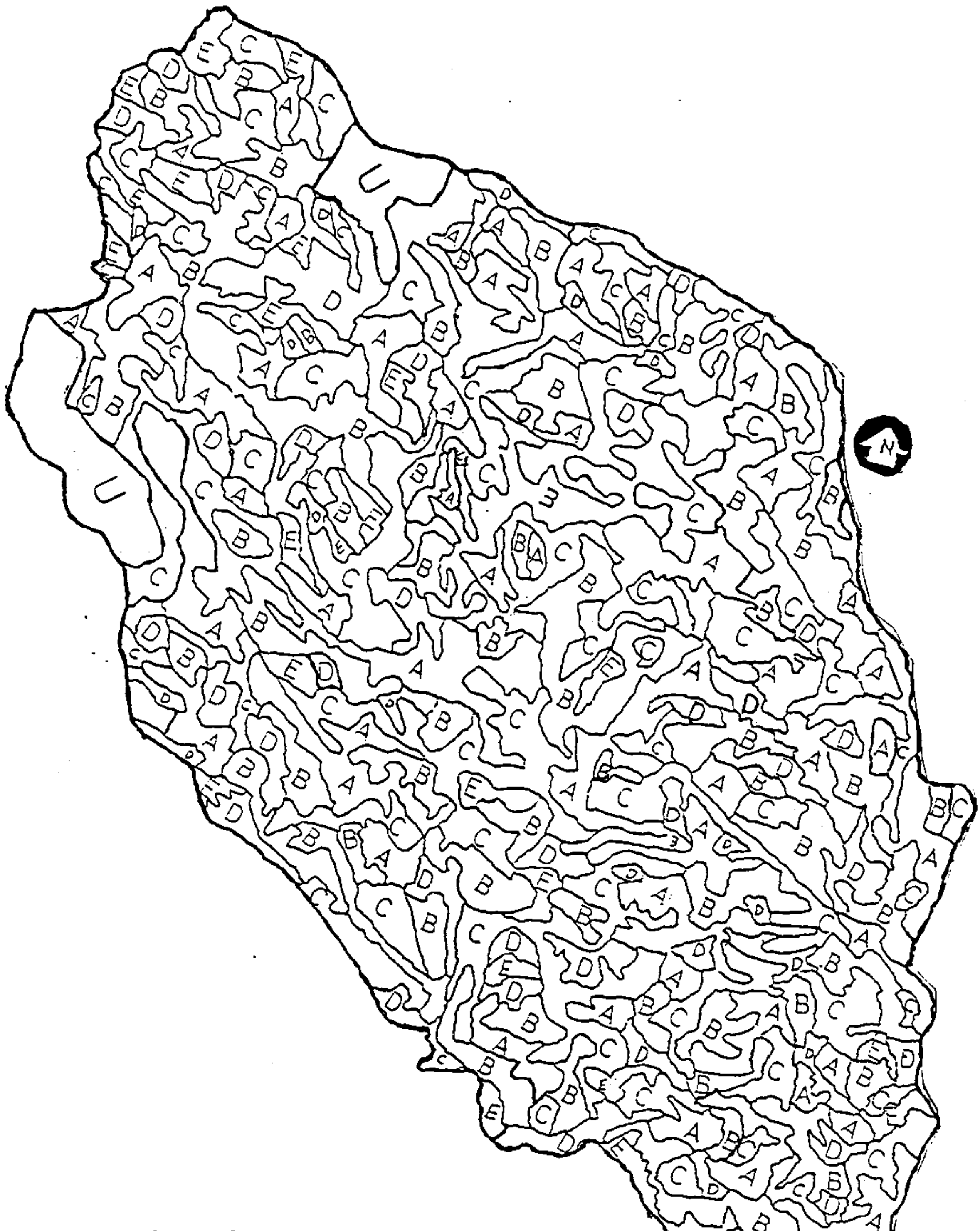
Drawing of the optimal alternative strategies was performed on the basis of different land use scenarios for the catchment taking into consideration the following parameters:

1) Soil constraints.

2) Water requirements.

3) Social and economical constraints.

Figure(3) : Detailed soil depth map for Muwaqar catchment.



Slope classes

A: 1%

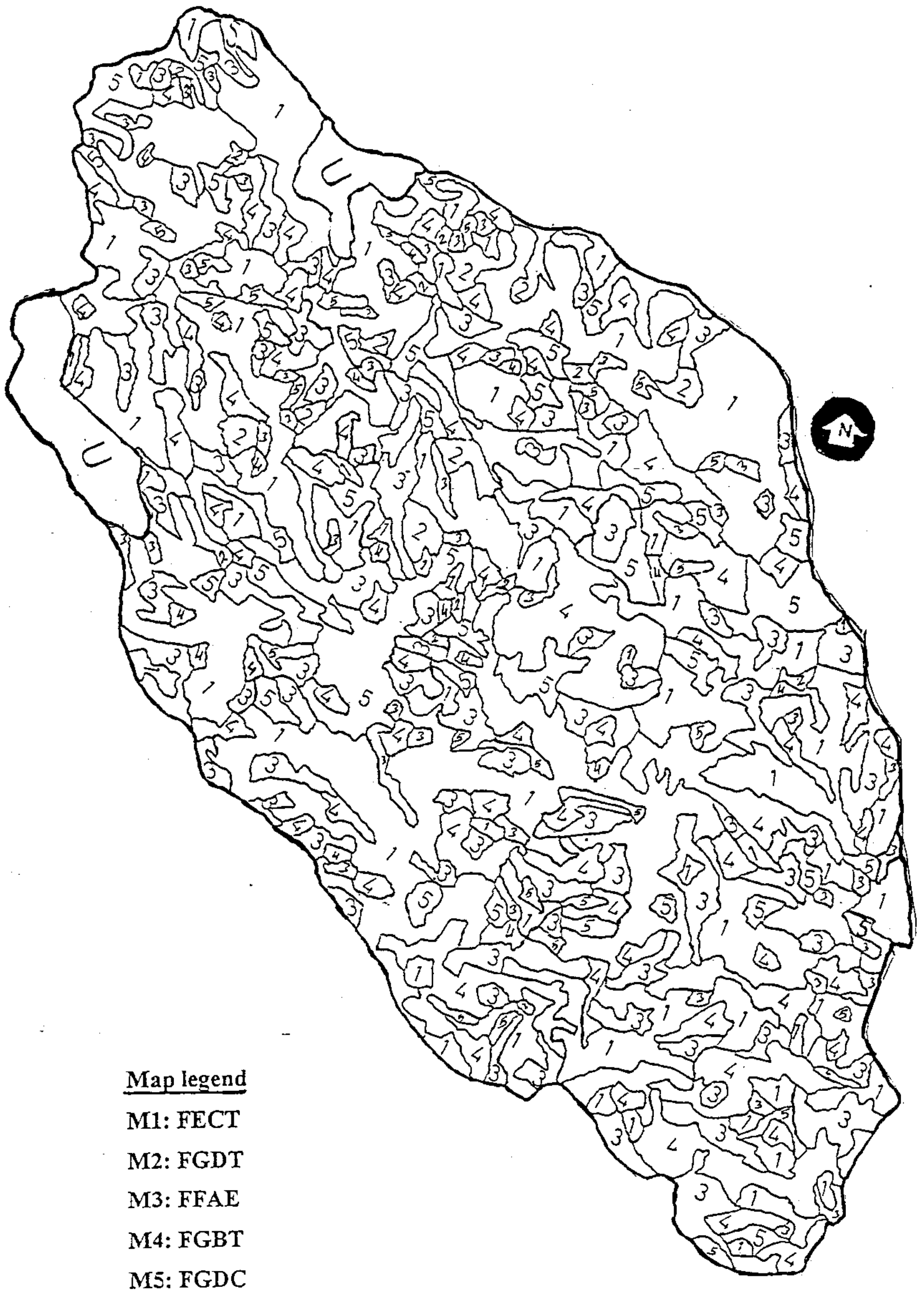
B: 2-3%

C: 3-6%

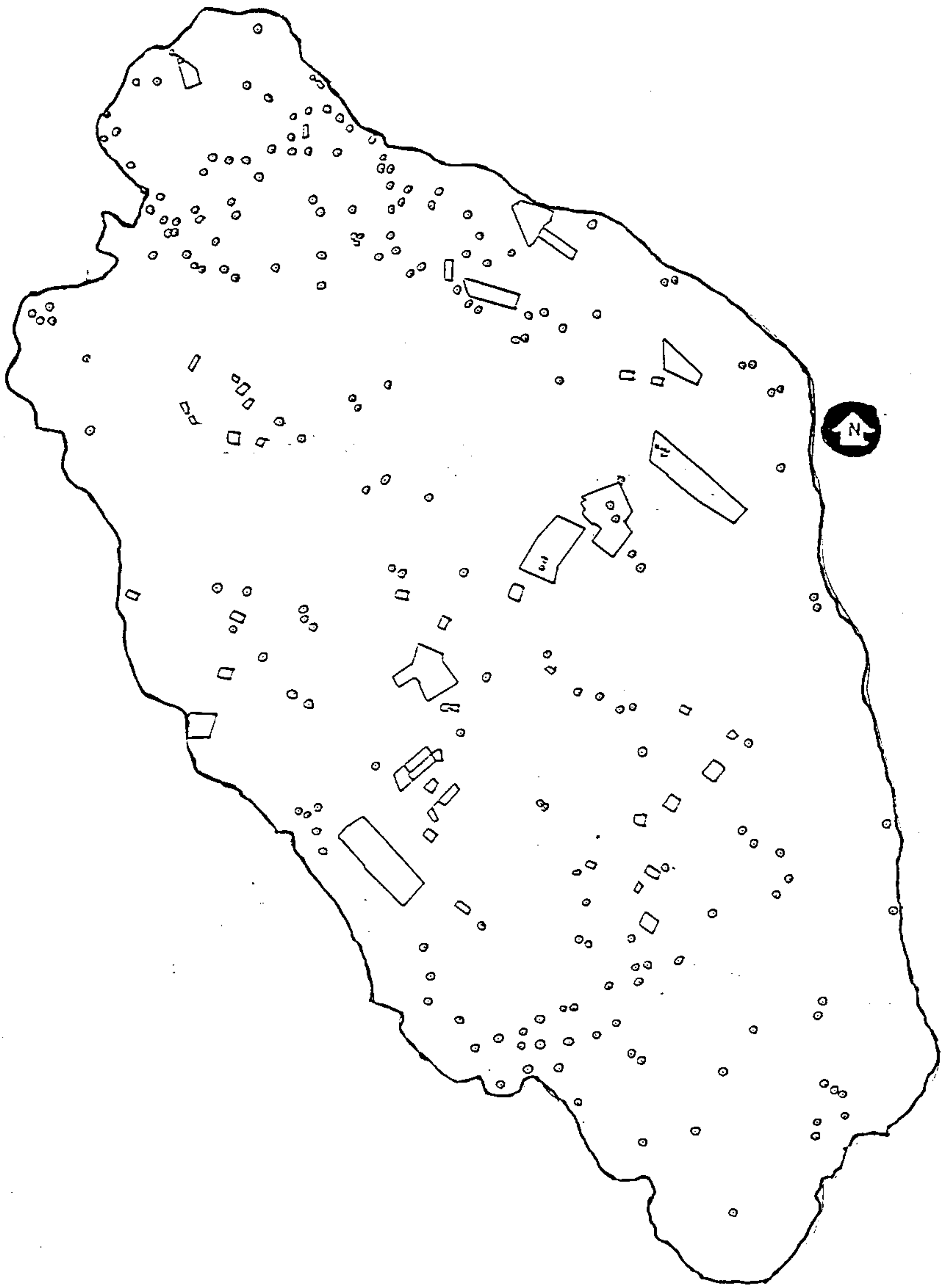
D: 6-9%

E: >9%

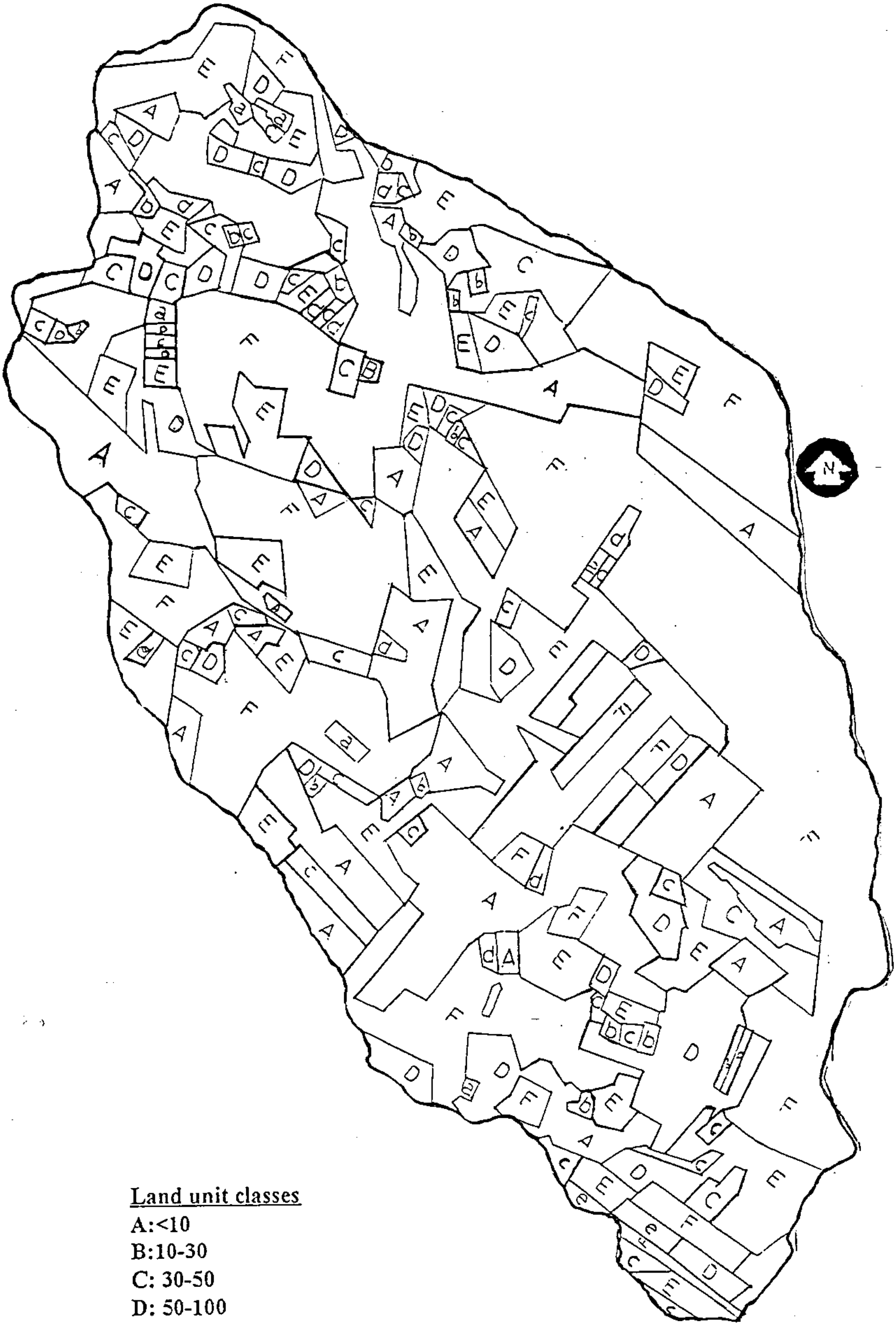
Figure(4): Detailed slope map for Muwaqar catchment.



Figure(5): Soil map for Muwaqar catchment.



Figure(6): Current land use activity within Muwaqar catchment. Irrigation farms □, Locations of wells ⊙.



Land unit classes

A:<10
B:10-30
C: 30-50
D: 50-100
E: 100-200
F: > 200

Figure(7): Land tenure map for Muwaqar catchment, land unit (dunums).

Figure(8): Soil erodability classes for Muwaqar catchment.

CHAPTER FOUR

RESULTS & DISCUSSIONS

4: RESULTS AND DISCUSSION

4:1 Potential land use:

Prediction potential land.

4:1:1 Soil constraints:

Assessment of land suitability classification is based on the soil qualities assuming that the climatic conditions are not limiting factors. The assessment process is based on matching the requirements of land utilization types to the soil qualities, and then assessing the suitability of soil for the following land utilization types: (Rainfed fruit tree,.Field crops, Rangeland, Irrigated vegetables).

The assessment took into consideration the following soil qualities: root conditions, slope degree, nutrient availability, erosion hazard, salinity hazard, alkalinity hazard, carbonate hazard, and soil moisture availability. The evaluation process is done by matching of land use requirements with soil qualities of different mapping units with reference that the (M1, M4, M5) are divided into different soil phases (A,B,C,D) based on differences in soil depth, stoniness content, infiltration rate, soil moisture content and other criteria.

The matching process of nutrient quality to mapping units and requirements of nutrients availability were carried out to obtain the final rating of nutrient quality. The rating of different mapping units for nutrients requirement is given in table (10).

Table (10) : Final rating for nutrient availability.

Map unit	CEC	Ca	Mg	K	P	OM	pH	Nutrient level
M1A	S2	S1	S1	S1	S3	S2	S2	Moderate
M1B	S2	S1	S1	S1	S2	S2	S2	Moderate
M1C	S2	S1	S1	S1	S2	S2	S2	Moderate
M1D	S1	S1	S1	S1	S3	S2	S2	High
M2	S2	S1	S1	S1	S3	S2	S2	Moderate
M3	S2	S1	S1	S1	S3	S2	S2	Moderate
M4A	S2	S1	S1	S1	S3	S2	S2	Moderate
M4B	S2	S1	S1	S1	S3	S2	S2	Moderate
M5A	S3	S1	S1	S1	S3	S2	S2	Low
M5B	S3	S1	S1	S1	S3	S2	S2	Low

The requirement of land utilization types and matching of these requirements to soil qualities are given in tables (11-19).

Table (11): Requirements of fruit trees.

Diagnostic criteria	Unit	Degree of limitation			
		S1	S2	S3	NS
Soil depth	cm	> 150	100 - 150	50 - 100	< 50
Slope degree	%	0 - 10	10 - 20	20 - 30	> 30
Available nutrients		high	moderate	low	v.low
Water erosion		nil,slight	moderate	severe	v.severe
Wind erosion		nil,slight	moderate	severe	v.severe
Salinity hazard(0-100)	ds/m	0 - 2	2 - 4	4 - 8	> 8
Alkalinity (ESP)	%	0 - 15	15 - 25	25 -35	> 50
Carbonate content	%	0 - 30	30 - 40	40 - 60	> 60
Moisture availability	mm/m	> 125	90 - 125	60 - 90	< 60
Infiltration rate	mm/hr	> 16	8 - 16	4 - 8	< 4
Crust thickness	cm	< 1.0	1.0 - 2.0	2.0 - 2.5	---

References : (79, 80, 81).

Table (12) Assessment of different mapping units for fruit tree.

Map unit	Root condition	Available nutrient	Slope degree	Erosion risk	Crust hazard	Salinity EC	Alkalinity ESP	Available water	Carbonate hazard	Final rating
M1A	S1	S2	S1	S1	S1	S1	S1	S2	S1	S1
M1B	S2	S2	S1	S1	S1	S1	S2	S1	S2	S2
M1C	S3	S2	S1	S2	S2	S2	S2	S1	S2	S3
M1D	S1	S1	S1	S3	S1	S1	S1	S2	S1	S1
M2	S1	S2	S1	S2	S1	S1	S1	S2	S1	S1
M3	S1	S2	S1	S1	S1	S1	S2	S2	S3	S2
M4A	S3	S2	S1	S2	S2	S2	S2	S1	S2	S3
M4B	S3	S2	S1	S2	S1	S1	S1	S1	S3	S3
M5A	Ns	S3	S1	S2	S1	S2	S2	S2	S3	Ns
M5B	NS	S3	S1	S3	S1	S1	S1	S2	S1	NS

Table (13): Requirements of field crops.

Diagnostic criteria	Unit	Degree of limitation			
		S1	S2	S3	NS
Soil depth	cm	> 90	60 - 90	30 - 60	< 30
Slope degree	%	< 4	5 - 8	9 - 16	> 16
Available nutrients		high	moderate	low	v.low
Water erosion		nil, slight	moderate	severe	v.severe
Wind erosion		nil,slight	moderate	severe	v.severe
Salinity hazard(0-100)	ds/m	0 - 2	2 - 4	4 - 8	> 8
Alkalinity (ESP)	%	0 - 15	15 - 25	25 -35	> 50
Carbonate content	%	0 - 30	30 - 40	40 - 60	> 60
Moisture availability	mm/m	> 125	90 - 125	60 - 90	< 60
Infiltration rate	mm/hr	> 16	8 - 16	4 - 8	< 4
Crust thickness	cm	0 - 0.5	0.5 - 1.5	> 1.5	----

References (79, 80, 81)

Table (14): Assessment of different mapping units for field crops.

Map unit	Root condition	Available nutrients	Slope degree	Erosion risk	Crust hazard	Salinity EC	Alkalinity ESP	Available water	Carbonate hazard	Final rating
M1A	S1	S2	S1	S1	S1	S1	S1	S2	S1	S1
M1B	S1	S2	S1	S1	S1	S2	S2	S2	S2	S2
M1C	S2	S2	S1	S1	S3	S2	S2	S1	S2	S3
M1D	S1	S1	S1	S2	S2	S1	S1	S2	S1	S2
M2	S1	S2	S1	S1	S1	S1	S2	S2	S2	S2
M3	S1	S2	S1	S1	S2	S1	S1	S2	S2	S2
M4A	S2	S2	S1	S1	S3	S2	S2	S1	S2	S3
M4B	S2	S2	S1	S2	S1	S1	S1	S1	S3	S3
M5A	S3	S3	S1	S3	S1	S2	S3	S2	S3	Ns
M5B	Ns	S3	S3	S3	S1	S1	S1	S2	S1	Ns

Table (15): Requirements of range crops.

Diagnostic criteria	Unit	Degree of limitation			
		S1	S2	S3	NS
Soil depth	cm	>50	35 - 50	10 - 35	< 10
Slope degree	%	<20	20 - 40	40 - 80	> 80
Available nutrients	---	moderate	low	v.low	---
Water erosion	---	nil,slight	moderate	severe	v.severe
Wind erosion	---	nil,slight	moderate	severe	v.severe
Salinity hazard(0-100)	ds/m	0 - 2	2 - 8	8 - 30	> 30
Alkalinity (ESP)	%	< 35	35 - 50	NL	---
Carbonate content	%	< 40	NL	---	---
Moisture availability	mm/m	> 90	60 - 90	30 - 60	< 30
Infiltration rate	mm/hr	> 8	4 - 8	NL	---
Crust thickness	cm	0 -1.0	1.0 - 2.0	> 2.0	---

References: (79, 80, 81)

Table (16): Assessment of different mapping units for range.

Map unit	Root condition	Available nutrients	Slope degree	Erosion risk	Crust hazard	Salinity EC	Alkalinity ESP	Available water	Carbonate hazard	Final rating
M1A	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1
M1B	S1	S1	S1	S1	S2	S1	S2	S2	S1	S1
M1C	S1	S1	S1	S1	S1	S1	S2	S1	S1	S1
M1D	S1	S1	S1	S2	S1	S1	S1	S2	S1	S1
M2	S1	S1	S1	S2	S1	S1	S2	S2	S1	S1
M3	S1	S1	S1	S1	S1	S1	S1	S2	S1	S1
M4A	S1	S1	S1	S1	S2	S2	S2	S1	S1	S2
M4B	S1	S2	S1	S2	S1	S1	S1	S1	S2	S2
M5A	S2	S3	S1	S3	S1	S2	S3	S2	S3	S3
M5B	S3	S3	S1	S3	S1	S1	S1	S2	S1	S3

Table (17): Requirements of irrigated vegetables.

Diagnostic criteria	Unit	Degree of limitation			
		S1	S2	S3	NS
Soil depth	cm	> 100	50-100	25 - 50	> 25
Slope degree	%	0 - 2	2-3	3-5	> 5
Available nutrients	class	high	moderate	low	v.low
Water erosion	class	nil,slight	moderate	severe	v.sev
Wind erosion	class	nil,slight	moderate	severe	v.sev
Salinity hazard (0-100)	ds/m	< 1	1-4	4-8	> 8
Alkalinity (ESP)	%	0-15	15-25	25-35	> 50
Carbonate content	%	0-30	30-40	40-60	> 60
Moisture availability	mm/m	> 90	60-90	30- 60	< 30
Infiltration rate	mm/hr	> 16	8-6	4-8	< 4
Crust thickness	cm	0 - 0.5	0.5-1.5	> 1.5	---

References (79, 80, 81)

Table (18): Assessment of different mapping units for irrigated vegetables.

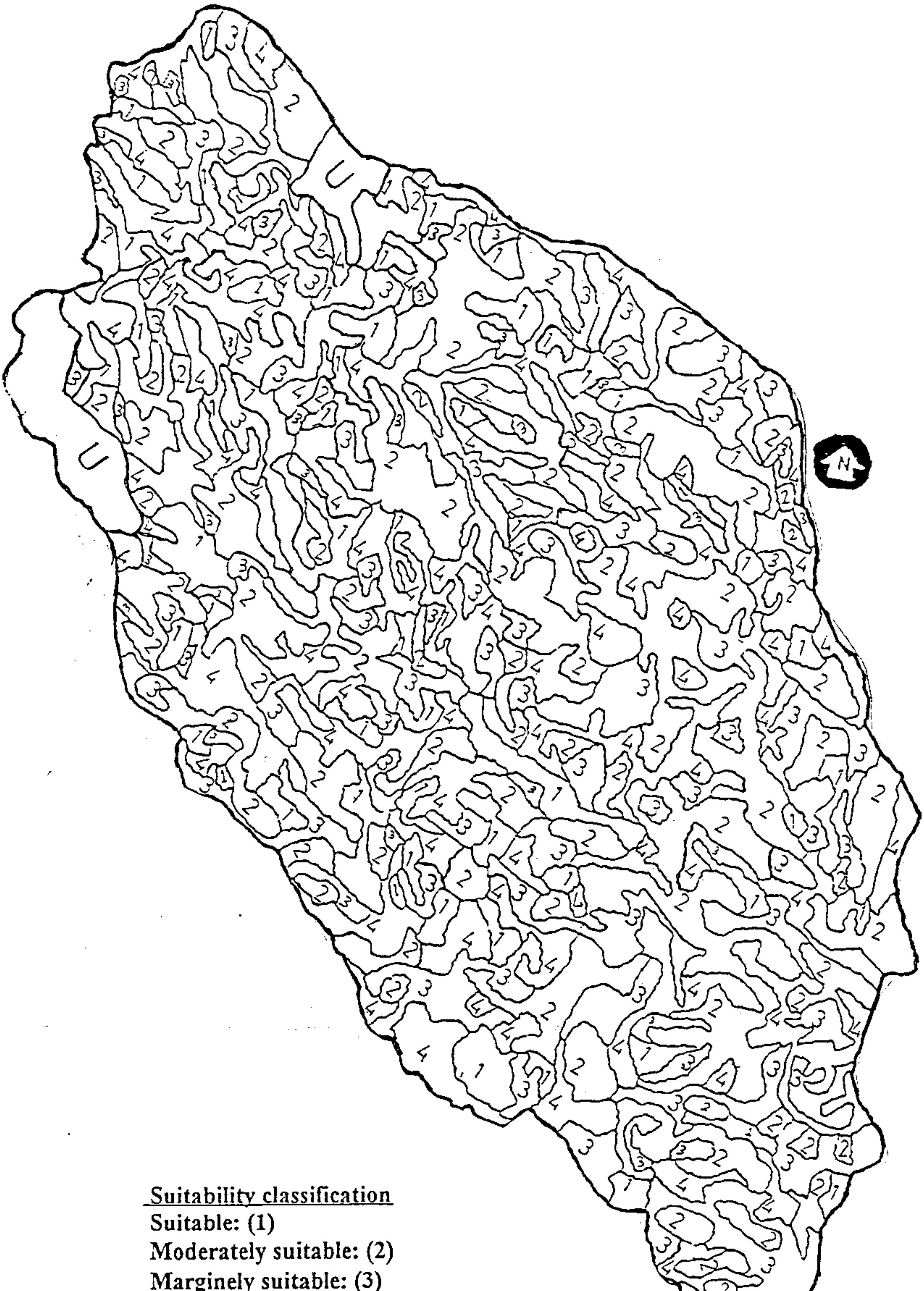
Map unit	Root condition	Available nutrients	Slope degree	Erosion risk	Crust hazard	Salinity EC	Alkalinity ESP	Available water	Carbonate hazard	Final rating
M1A	S1	S2	S1	S1	S1	S1	S1	S2	S1	S1
M1B	S1	S2	S2	S1	S2	S2	S2	S2	S2	S2
M1C	S1	S2	S1	S1	S1	S2	S2	S1	S3	S2
M1D	S1	S1	S3	S3	S1	S1	S1	S2	S1	S3
M2	S1	S2	S1	S2	S1	S2	S2	S2	S1	S1
M3	S1	S2	S1	S1	S1	S2	S1	S2	S3	S2
M4A	S2	S2	S1	S2	S2	S2	S2	S1	S2	S3
M4B	S2	S3	S1	S2	S1	S1	S1	S1	S3	S3
M5A	S3	S3	S2	S3	S1	S2	S3	S2	S3	S3
M5B	NS	S3	NS	S3	S1	S1	S1	S2	S1	NS

Table (19): Land use alternatives based on the soil constraints.

Map unit	Tree	Field crops	Range	Vegetables
M1A	S1	S1	S1	S1
M1B	S2	S2	S1	S3
M1C	S3	S3	S1	S2
M1D	S1	S2	S1	S3
M2	S1	S2	S1	S2
M3	S2	S2	S1	S2
M4A	S3	S3	S2	S3
M4B	S3	S3	S2	S3
M5A	NS	Ns	S3	Ns
M5B	NS	NS	S3	NS

The land suitability maps for the four land utilization types are given on figure (9-12).

From the assessment process, it can be concluded that the main soil limitation that proceeds the degradation process are the unfavorable soil surface properties, which favor the formation of crust layer, associated with low infiltration rate. Since, runoff process accelerate soil erosion and further degradation consequence. Therefore, soil erodability must be given proper attention in the use and development of this area.



Suitability classification
Suitable: (1)
Moderately suitable: (2)
Marginely suitable: (3)
Not suitable: (4)
Urban area: (U)

Figure(9): Soil suitability map for raifned fruit tree in Muwaqar catchment.

Figure (10): Soil suitability map for field crops in Muwaqar catchment.

Figure(11): Soil suitability map for rangeland in Muwaqar catchment.

<u>Suitability classification</u>
Suitable: (1)
Moderately suitable: (2)
Marginely suitable: (3)
Not suitable: (4)
Urban area: (U)

Figure(12): Soil suitability map for irrigated vegetables in Muwaqar catchment.

The erodability classification reflects the influence of current land use system, and management practiced in these area. Furthermore, the current accelerating land fragmentation encourages the misuse of the land and inappropriate management practices that accentuate soil degradation.

Table (20): Soil suitability area for each land utilization types.

Land utilization type / Suitability level	Fruit tree	Field crops	Range	Vegetables
S1 (du)	8820	4590	19980	5940
S2 (du)	19530	21690	46560	12870
Total area	28350	26280	66540	18810
S1 (%)	11.8	6.1	26.6	7.9
S2 (%)	26.0	28.9	62.0	17.2
Total percent (S1, S2)	37.8	35.0	88.6	25

The analysis table (20) and land suitability maps figure (9-12) indicate that small area are suitable for tree, vegetables, and field crops. The distribution of areas suitable for these types of use are scattered in isolated pots which makes large development rather hard to achieve. Furthermore, the utilization of moderately suitable area (S_2) on a sustainable basis must take into consideration the economic factors, besides improved soil conservation practices.

4:1:2 Management practices:

Proper soil management, in rainfed cropping systems, should ensure that the conditions of soil physical properties, at the start of the wet season, favor effective water entry and storage, and proper physical properties [82].

Types of management practices with different levels of agricultural inputs are proposed for the area table (21). Land suitability classes were also formulated for the same land assuming low or high input.

Table (21) : Management practices at different levels of input.

Land quality	Input level		
	ZIL	LIL	HIL
Water availability	None	Man made rainwater catchment and low cost delivery system.	Main delivery system including reservoirs, canals and control structure, and the use of irrigation systems.
Soil tilth	None	Crop residues incorporation.	Crop residue and manure incorporation, fertilizer application and deep plowing.
Nutrient availability	None	Sub optimal application of fertilizer, green manure shifting cultivation.	Application of fertilizers and other amendment to obtain maximum yields.
Soil erodability	None	Cropping systems (rotations inter cropping contouring), manure application, and minimum tillage.	Cropping system (rotation inter cropping, strip cropping, inter cropping), tillage practices, mulching, terracing, waterway and structures.

Reference (5).

ZIL = Zero input level, LIL = Low input level, HIL = High input level.

The suitability classification of land utilization types under high management level are given in tables (22-26)

Table(22): Assessment of different mapping units for fruit tree for high input level.

Map unit	Root condition	Available nutrients	Slope degree	Erosion risk	Surface crust	Salinity EC	Alkalinity ESP	Available water	Carbonate hazard	Final rating
M1A	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M1B	S2	S1	S1	S1	S1	S1	S2	S1	S2	S2
M1C	S3	S1	S1	S1	S1	S2	S2	S1	S2	S2
M1D	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M3	S1	S1	S1	S1	S1	S1	S2	S1	S3	S2
M4A	S3	S1	S1	S1	S2	S2	S2	S1	S2	S3
M4B	S3	S1	S1	S1	S1	S1	S1	S1	S3	S3
M5A	NS	S1	S1	S1	S1	S2	S2	S1	S3	NS
M5B	NS	S1	S1	S2	S1	S1	S1	S1	S1	NS

Table(23): Assessment of different mapping units for field crops for high input level

Map unit	Root condition	Available nutrient	Slope degree	Erosion risk	Crust hazard	Salinity EC	Alkalinity ESP	Available water	Carbonate hazard	Final rating
M1A	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M1B	S1	S1	S1	S1	S1	S2	S2	S1	S2	S1
M1C	S2	S1	S1	S1	S1	S2	S2	S1	S2	S2
M1D	S1	S1	S1	S2	S1	S1	S1	S1	S1	S2
M2	S1	S1	S1	S1	S1	S1	S2	S1	S2	S1
M3	S1	S1	S1	S1	S1	S1	S1	S1	S2	S2
M4A	S2	S1	S1	S1	S2	S2	S2	S1	S2	S2
M4B	S2	S1	S1	S1	S1	S1	S1	S1	S3	S2
M5A	S3	S2	S1	S2	S1	S2	S3	S1	S3	Ns
M5B	NS	S2	S3	S2	S1	S1	S1	S1	S1	Ns

Table (24): Assessment of different mapping units for range for high input level.

Map unit	Root condition	Available nutrients	Slope degree	Erosion risk	Crust hazard	Salinity EC	Alkalinity ESP	Available water	Carbonate hazard	Final rating
M1A	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M1B	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M1C	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M1D	S1	S1	S1	S2	S1	S1	S1	S1	S1	S1
M2	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M3	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M4A	S1	S1	S1	S1	S2	S2	S1	S1	S1	S2
M4B	S1	S1	S1	S1	S1	S1	S1	S1	S2	S1
M5A	S2	S1	S1	S1	S1	S2	S3	S1	S3	S3
M5B	S3	S2	S1	S1	S1	S1	S1	S2	S1	S3

Table(25): Assessment of different mapping units for irrigated vegetables for high input level.

Map unit	Root condition	Available nutrients	Slope degree	Erosion risk	Crust hazard	Salinity EC	Alkalinity ESP	Available water	Carbonate hazard	Final rating
M1A	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
M1B	S1	S1	S2	S1	S1	S2	S2	S1	S2	S2
M1C	S1	S1	S1	S1	S1	S2	S2	S1	S3	S2
M1D	S1	S1	S3	S2	S1	S1	S1	S1	S1	S3
M2	S1	S1	S1	S1	S1	S2	S1	S1	S1	S1
M3	S1	S1	S1	S1	S1	S2	S2	S1	S3	S1
M4A	S2	S1	S1	S1	S2	S2	S2	S1	S2	S3
M4B	S2	S1	S1	S1	S1	S1	S1	S1	S3	S2
M5A	S3	S2	S2	S2	S1	S2	S3	S1	S2	Ns
M5B	NS	S2	NS	S2	S1	S1	S1	S2	S1	Ns

Table (26): Land use alternatives for different land utilization types for high input level.

Map unit	Fruit trees	Field crops	Range land	Vegetables
M1A	S1	S1	S1	S1
M1B	S2	S1	S1	S2
M1C	S2	S2	S1	S2
M1D	S1	S2	S1	S3
M2	S1	S1	S1	S1
M3	S2	S2	S1	S1
M4A	S3	S2	S2	S3
M4B	S3	S2	S1	S2
M5A	Ns	Ns	S3	Ns
M5B	Ns	Ns	S3	Ns

Land suitability maps of four land utilization types under different inputs level are shown in maps (13-16).

The assessment of land use requirement for different land utilization type offers different suitability levels for each utilization. The criteria for the different classes is as follows:

Highly suitable (S_1): Land having no significant limitations to the sustained application of the defined use.

Moderately suitable(S_2): Land having limitation which will reduce production level and/or increase costs, but is physically and economically suitable for the defined use.

Marginally suitable (S_3): Land having limitations which will reduce yield levels and/or increase costs such that it is economically marginal for the defined use.

Not suitable (N_s): Land having limitations so severe as to prevent the possibility of successful sustained use in the defined manner.

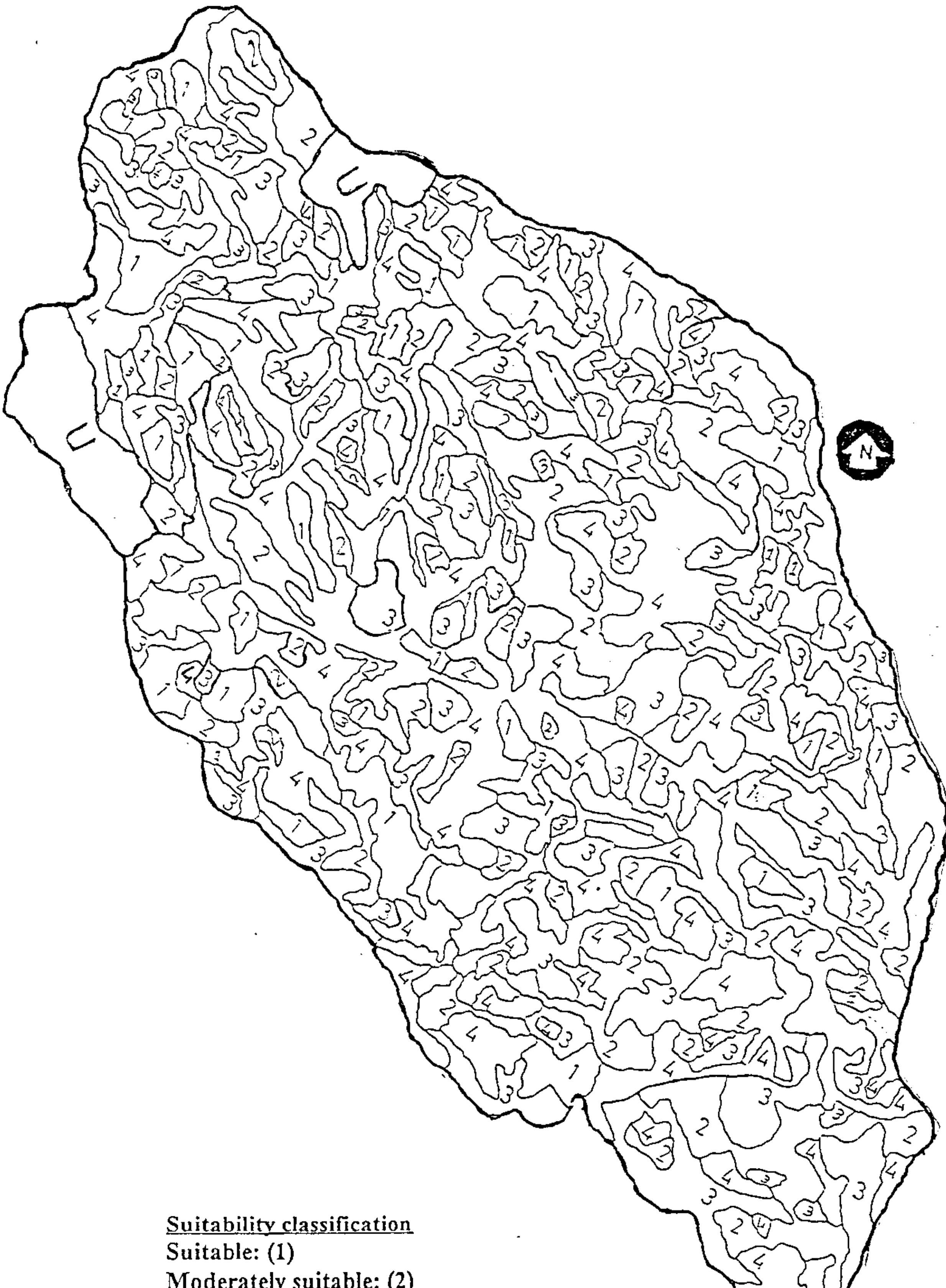
The assessment process indicates that :

1) The major soil qualities that should be considered as constraints for the fruit trees production for (S1,S2) classes are soil depth, carbonate hazard, alkalinity hazard.

2) The major soil qualities that should be considered as constraints for the field crops production for (S1,S2) classes are slope degree, crust formation, carbonate hazard, alkalinity hazards, soil erosion, and low nutrient level. Field crops are the start-point of land use planning while deciding whether land is to be cultivated for (S1, S2) level depends on the management to improve fertility, water availability and reduce soil erosion.

3) The major soil qualities that should be considered as constraints for the vegetables production for (S1,S2) classes are slope degree, salinity, alkalinity hazard, and soil erosion. Also the climatic conditions play an important role in determining the suitability of these level especially (temperature, wind, water). Therefore, the utilization of vegetable under these conditions is under question.

4) Rangelands: Permanent grassland is satisfactory from a soil conservation view point even on steep slope and shallow soils. The soils that are suited for cultivation are considered suitable for ranges. According to the suitability assessment the major soil constraints is crust formation, soil erosion and low nutrient levels.



Figure(13): Soil suitability map for rainfed fruit tree (HIL) in Muwaqar catchment.

Suitability classification
Suitable: (1)
Moderately suitable: (2)
Marginely suitable: (3)
Not suitable: (4)
Urban area: (U)

Figure(14): Soil suitability map for field crops (HIL) in Muwaqar catchment.

Figure(15): Soil suitability map for rangeland (HIL) in Muwaqar catchment.

Suitability classification
Suitable: (1)
Moderately suitable: (2)
Marginely suitable: (3)
Not suitable: (4)
Urban area: (U)

Figure(16):Soil suitability map for irrigated vegetables (HIL) in Muwaqar catchment.

4:1:3 Climatic condition:

Climate is an important part of land scape qualities, climate together with other factors determines its suitability for use. This part examine the influence of agroclimatic characteristics and hazard on land utilization types in the area. The relationships between climatic characteristics and land qualities are presented in table (27).

Table (27): Relationships between climatic characteristics and land qualities.

Land quality	Diagnostic factor	Unit	Value
Radiation regime	- Mean daily sunshine hour during growing season.	hr/day	6.8
Temperature regime	- Mean temperature during growing season.	C°	15.5
	- Mean temperature during coldest months of growing season.	C°	1.4
Moisture availability	- Total rainfall during growing season.	mm	150
	- Relative evapotranspiration during growing season.	ratio	0.2-0.4

Reference (9).

4:1:3:1 Precipitation :

The analysis of long term rainfall data for Muwaqar catchment indicated high annual variation[83]. The annual amounts varied from 150-200 mm. Short intensive storm occurrence characterized the rainfall pattern. Plotting rainfall as a normalized distribution figure (17) provides a visual estimate of the relative occurrence of high and low rainfall years. The figure suggests that rainfall I to II standard deviation above the mean occurs about every (4-6) years[84]. In dry areas such occasional occurrences of higher than normal rainfall will, non the less, remain inadequate for any thing other than marginal production. Thus crop failure is common.

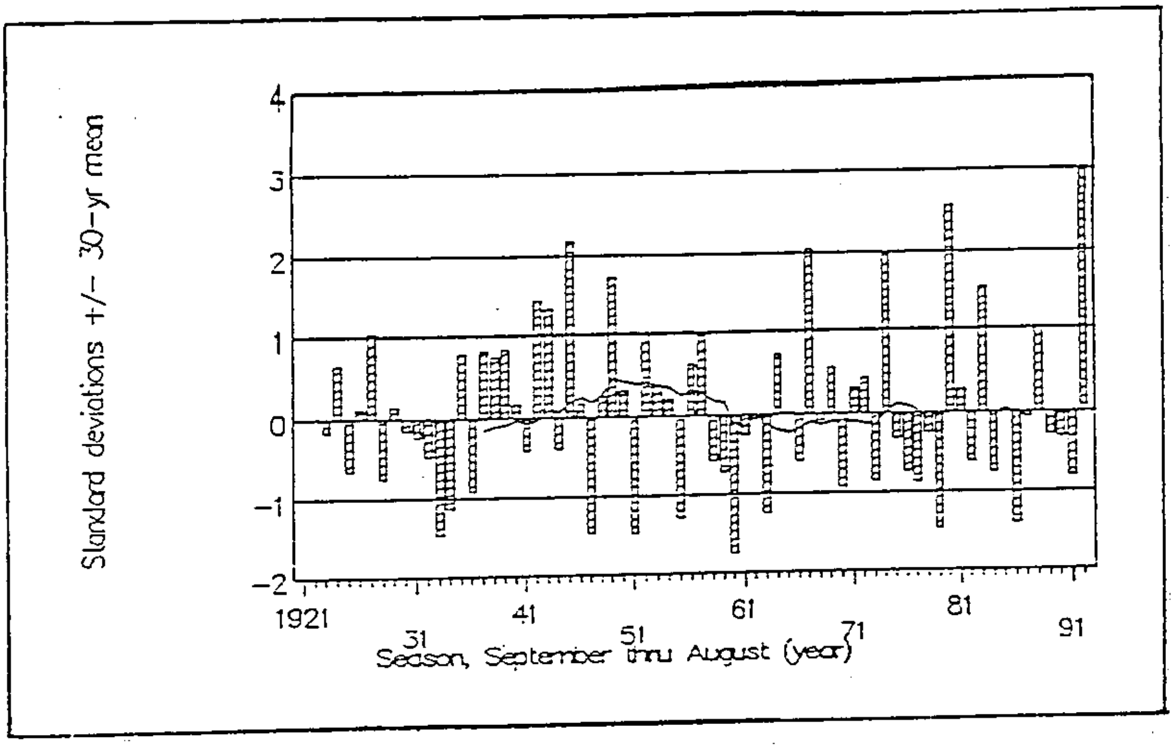


Figure (17) : Rainfall normalized distribution.

4:3:1:2 Temperature:

The analysis of mean lowest and highest temperature degree for Queen Alia Airport indicates the following characteristics:

The lowest temperature during December to February is sufficiently low. The possibility of frost occurrence are very high. This is sufficient to reduce plant growth and cause crop damage. While the highest temperature during June-August accompanied with low relative humidity have adverse effects on plant growth and quality of crop production.

4:3:1:3 Wind velocity :

Wind velocities in excess of 2.78 knots (5.4 m/s) exceed the threshold velocity of soil transport [85].Table (28) lists wind speed frequencies for the Queen Alia Airport station, it indicates that (50-70)% of winds are capable of transporting soil. This effect accompanied with improper soil surface conditions favors high wind hazards.

Table (28) : Wind frequency for Queen Alia Airport.

Speed (knots)					
Calm	1- 10	11 - 21	22 - 33	34 >	prevailing direction
0.23	0.53	0.21	0.01	0.01	288°

Reference (84).

The sediment load as a result of high wind velocity influence flowering stage of the plant and decreases crop production. Also high wind velocity restrict the use of some irrigation such as sprinkler system as a result of wind gust which might interrupt irrigation scheduling and causes low distribution efficiency.

4:1:3:4 Evapotranspiration :

Evapotranspiration provides means of understanding plant productivity. Since the assessment of the minimum water requirements for the irrigation of a specific crop was carried using the soil water balance method proposed by Doorenbos and Kassam [86]. This procedure gives climatic maximum of crop production without taking into consideration the soil.

The analysis of the data suggest the occurrence of different agroclimatic zones. Each agroclimatic zone is defined by the class of water deficit during the growing season (D) for each crop.

The crop water requirement classes as defined by the different values of D, are considered as agroclimatic suitability classes (W1,W2,W3, W4). The class limits are determined by the theoretical crop productivity reduction without irrigation [87].

Table (29): Classes of minimum water requirements.

W1	Water deficit between (0-150 mm); without irrigation obtainable production between 100% and 80% of maximum.
W2	Water deficit between (150-275mm); without irrigation obtainable production between 80% and 60% of maximum.
W3	Water deficit between (275-400mm); without irrigation obtainable production between 60% and 40% of maximum.
W4	Water deficit is higher than 400 mm; without irrigation obtainable production is lower than 40% of maximum.

According to criteria given in table (29) the classification of the agroclimtic classes for different land utilization types are as fallows:

Table (30) : Agroclimatic suitability classes.

Land utilization types.	Class
Rainfed fruit tree.	W4
Rainfed field crops.	W4
Rangeland.	W3
Irrigated vegetables.	W4

The combination of climate and soil factors suggest that there is very narrow windows of opportunity for the success of crops. Although there has been research on land use management to resolve these problems.

El-swaify et al (1984) concluded that an improved land use system will be technically feasible if it satisfies some of the following objectives [88].

1) Improved water use efficiency and access to available water.

2) Maintained or enhanced soil fertility.

3) Improved soil aggregation and reduced surface sealing and crusting.

4) Decrease run off and soil erosion.

5) Increased structural stability of the soil.

Table (31) Analyses of the annual water balance for barley under mean annual rainfalls of 100, 150, 200 and 250 mm/a (84,89).

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
(P=100) Rainfall	5.34	13.44	18.85	19.30	12.90	18.26	8.85	3.07
Crop ETP	83.16	47.03	56.01	45.83	57.43	88.73	100.55	79.37
Precip - ETP	-77.83	-33.5	-37.16	-26.53	-44.54	-70.47	-91.70	-76.30
Soil moisture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(P=150) Rainfall	8.01	20.06	28.28	28.95	19.34	27.39	13.28	4.61
Crop ETP	83.16	47.03	56.01	45.83	57.43	88.73	100.55	79.37
Precip - ETP	-75.16	-26.8	-27.73	-16.88	-38.09	-61.34	-87.27	-74.76
Soil moisture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(P=200) Rainfall	10.67	26.88	37.70	38.60	25.79	36.52	17.70	6.14
Crop ETP	96.97	62.10	31.94	54.07	79.38	96.60	67.20	135.47
Precip - ETP	-86.296	-35.2	5.76	-15.46	-53.59	-60.08	-49.50	-129.33
Soil moisture	0.0	0.0	5.76	0.0	0.0	0.0	0.0	0.0
(P=250) Rainfall	13.34	33.60	47.13	48.25	32.24	45.65	22.13	7.68
Crop ETP	96.97	62.10	31.94	54.07	79.38	96.60	67.20	135.47
Precip - ETP	-83.63	-28.5	15.19	-5.81	-47.14	-50.95	-45.07	-127.79
Soil moisture	0.0	0.0	15.19	9.37	0.0	0.0	0.0	0.0

Table (32) is derived from the data listed in table (31) and gives the ratio of rainfall to crop evapotranspirational values during growing months of December through April. The data indicated that even rainfalls of 250 mm/a is able to meet only 59% of evapotranspirationl requirements. Accordingly [89] only 35% of potential production would be obtained if no other limiting factors were present.

Table (32) : Crop yield as a function of soil moisture deficit :

Mean annual precipitation	Precipitation duringcropping period	Cropping period evapotranspirational	Ratio / Cropping period ET/PPT	Yields as percent of potential
mm	mm	mm	ratio	%
100	78.2	348.6	0.22	none
150	117.2	348.6	0.34	none
200	156.3	329.2	0.47	14
250	195.4	329.2	0.59	35

Yield derived from fig (31) according to FAO, 1977 (89).

The analysis of the data table (32) indicated that barley yields on the land normally designated as range are marginal at best. Thus, cultivation of crops with yield less than 40% of optimal is usually regarded as an unsuitable practice.

Accordingly, the utilization of the land considered marginal for field crops, fruit trees, and vegetables is unsuitable practices. The combination of climate conditions and soil constraints suggest that there is very narrow windows of opportunity for sustainable land utilization unless favorable management practices are introduced.

4:2 Land use alternatives :

The establishment of land use alternatives takes into consideration socio- economic factors, water requirement, and soil constraints.

4:2:1 Socio-economic constraints:

4:2:1:1 Current Land Use :

The main land use in the catchment is rainfed agriculture and consisted mainly of barley production. Barley productivity is very low under traditional management practices and crop failure is common. Some scattered livestock farms are present in the catchment and consisted mainly of cattels and poultry farms (Figure 7). Many farmers, however, have sheep and goats herds which depend on feeds and partly on the grazing. Data on the current land use activates for the catchment indicates that, if non-productive and rangelands are excluded, then the 93% of the agricultural land is used for cereal crops, 3% for orchards, 3% for vegetables, and 1% for poultry farms [90]. Thus the development for these area must take into consideration the requirements of livestock from water and feeds.

4:2:1:2 Productivity data :

The study of vegetative cover in Muwaqar catchment during 1994 showed that about 85% of the plant cover belong to Anabasis spp, followed by Poa ssp, with few insignificant number of plant species. Plant population changed with time, and generally the total weight of the plant available in the summer was higher than those available during the winter season. This was mainly due to the new growth of the Anabasis species [91].

It is important to indicate that large area of the catchment is under cultivation practices, which exposes the soil to further degradation due to ergrazing and absence of vegetative cover.

The investigation revealed that the average dry weight during 1994) gm/m^2, and the average dry weight from March to June was (140) e Anabasis species which dominate the plant cover is unfavorable feeds except partly in winter months. Since, the result obtained months represent potential production under presents ts could be concluded that the soils have high potential for abilitation of rangeland.

carried out in Muwaqar station indicated a good ality, and good productivity of local species such as spontaneum, Loium rigidum, and Atriplex ons [92].

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It is important to indicate that large area of the catchment is under cultivation practices, which exposes the soil to further degradation due to overgrazing and absence of vegetative cover.

The investigation revealed that the average dry weight during 1994 was (120) gm/m^2, and the average dry weight from March to June was (140) gm/m^2. The Anabasis species which dominate the plant cover is unfavorable for livestock feeds except partly in winter months. Since, the result obtained during summer months represent potential production under presents conditions. This its could be concluded that the soils have high potential for development and rehabilitation of rangeland.

Previous study carried out in Muwaqar station indicated a good chance for the adaptability, and good productivity of local species such as Hordeum vulgar, Hordeum spontaneum, Loium rigidum, and Atriplex halimus to the Muwaqar conditions [92].

4:2:1:3 Land tenure:

The most important socio - economic constraints that determine the suitability of land for their use are related to size of land ownership, and location of the land units. System was established to facilitate the influence of land tenure on the development options in this area. The land unit classification is given in table (33). The division of the units according to the proposed system is given in map figure (7).

Table (33) : Land unit classifications for Muwaqar catchment:

Land unit class	Land unit area (du)	Total area (du)	Area percent
A	<10	7955	10.9
B	10 - 30	6967	9.5
C	30 - 50	3496	4.8
D	50 - 100	9468	13.0
E	100 - 200	13031	17.8
F	>200	34158	44.0
Total	---	75075	100.0

The data indicate that about 61.8% of land have area more than (100) dunums which is considered very suitable for varieties of land utilization types. While 13.0% of area is occupied between (50-100) dunum which is considered moderately suitable for production. Furthermore 20.4% have area less than (30) dunums which considered is marginally suitable for most utilization types under rainfed conditions.

4:2:2 Water Requirements

Water resources is the main constraint to land utilization. The ability to manage water can often determine the feasibility of development and the land use system. In rainfed farming system, where lack of moisture limits crop production, innovative management practices in terms of water use efficiency are necessary [93]. Since, the only possible ways in which WUE (the ratio of dry matter production to water used for the production of the crop) of dry matter production can be increased by:

1) Improving transpiration efficiency.

2) Improve transpiration / evaporation.

3)Efficient soil moisture conservation techniques.

The nature of the rainfall distribution and intensity in the area can't support a crop growth and establishment under the present conditions. on the other hand, the high runoff coefficient and high rainfall intensity favors the introduction of different water harvesting techniques. Such approach is considered the only option to increase the amount of water to meet the demand of possible cropping system.

The surface crust associated with low infiltration rate is considered very favorable for water harvesting purposes [94].

Possible dam locations was proposed based on the topographies, characteristics of the area, the definition of the outlet and wades, the size of subcatchment, the size of expected discharge, land use and land ownership's figure (18).

Small earth dams are common type of man-made storage, if constructed on favorable sites they are effective and economical [95]. Their efficiency depend largely on rainfall, and runoff characteristics. The analysis of long term data for Muwaqar catchment were carried to identify the distribution of rainfall amounts and intensity during the rainy season and the possibility of utilizing water under different land utilization types. The distribution of rainfall amounts during rainy season from October to May are shown in table (34).

Table (34): Distribution of rainfall amounts for Muwaqar catchment.

Month	Oct.	Nov.	Dec	Jan	Feb	Mar	Apr	May	Total
Rainfall (mm)	3.2	13.3	28.5	37.1	31.0	31.6	12.3	1.3	158.3
Rainfall (%)	2.0	8.4	18.0	23.4	19.6	20.0	7.8	0.8	100

The investigation revealed that the nature of rainfall characteristics in relation to runoff behavior are may be used to classify the rainfall amounts into five classes as follows: (0-3mm, 3-6mm, 6-8mm, 8-11mm, > 11mm). The distribution of rainfall amounts and rainfall events for long term data are also examined table (35).

Table : (35) Average rainfall amounts and event numbers for each class.

Class	0-3	3-6	6-8	8-11	> 11	Total
Rainfall (mm)	17.3	29.9	17.4	18.8	75.0	158.3
Rainfall (%)	10.9	18.9	11.0	11.9	47.3	100
Event numbers	8.2	6.2	2.4	1.6	2.7	22.1
Event (%)	37.1	28.1	10.9	7.2	16.7	100

Table (35) indicates that there is an average of seven events per year of high rainfall amounts and intensity that have high probability of producing runoff events.

The average runoff coefficients for each class were derived, taken into consideration the average runoff coefficients for different sites in Muwaqar catchment [90, 96] and for different rainfall characteristics. These data are related to the distribution of rainfall amounts, intensity, events number the influence of soil surface properties, and management practices. The final value for each class are given in table (36). The distribution of rainfall amounts for each class on monthly basis are given in table (37).

Table (36): Average runoff coefficients for each class.

Class	0-3	3-6	6-8	8-11	> 11
Runoff coefficient	0.0	0.25	0.27	0.31	0.43

Table : (37) Distribution of rainfall amounts for each month and class.

Rainfall		Month								Annual
Class	%	Oct.	Nov.	Dec.	Jan	Feb.	Mar.	Apr.	May	Total
0-3	10.9	0.3	1.4	3.1	4.1	3.4	3.4	1.3	0.15	17.15
3-6	18.9	0.6	2.5	5.4	7.0	5.9	6.0	2.3	0.25	29.95
6-8	11.0	0.4	1.5	3.1	4.1	3.4	3.5	1.4	0.15	17.55
8-11	11.9	0.4	1.6	3.4	4.4	3.7	.08	1.5	0.15	18.95
> 11	47.3	1.5	6.3	13.5	17.5	14.6	14.9	5.8	0.6	74.7
Total	100	3.2	13.3	28.5	37.1	31.0	31.6	12.3	1.3	158.3

Table (38) derived from table (36, 37). Thus give the distribution of runoff amounts for each class and month.

Table (38) Distribution of runoff amounts per each month and class (mm).

Class	R.C	Oct.	Nov.	Dec.	Jan	Feb.	Mar.	Apr.	May	Total
0-3	0.0	0.0	0.0.	0.0.	0.0	0.0	0.0	0.0	0.0	0.0
3-6	0.25	0.16	0.6	1.4	1.8	1.5	1.5	0.6	0.05	7.7
6-8	0.27	0.085	0.4	0.85	1.1	0.9	0.9	0.4	0.04	4.8
8-11	0.31	0.13	0.5	1.0	1.4	1.1	1.2	0.4	0.05	5.8
> 11	0.43	0.7	2.7	5.8	7.5	6.2	6.4	2.5	0.3	32.0
Total	0.32	1.1	4.3	9.0	11.8	9.7	10.0	3.9	0.5	50.2

R.C: Runoff coefficient.

Runoff occurring during October to May are excluded from the calculations due high evaporation and insignificant runoff. Table (36,37) indicates the highest rainfall amounts that can be collected occurs in December, January, February and March. The data also show that the highest rainfall percentage of more than 11 mm have moderate to high intensity. This advantages plays an important role in determining the expected runoff volume and the appropriate water harvesting techniques.

The distribution of rainfall as runoff, storage, and losses parts are analyzed taking into consideration the soil and climatic conditions. Such as soil infiltration rate, water holding capacity (about 100 sites represent different soil types in the catchment are used in calculations), potential evapotranspiration, number of rainfall events and management practices. According to this analysis the distribution of each rainfall part during the rainy season are given in table (39).

Table (39): Distribution of rainfall during rainy season.

Month	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Run off(mm)	1.0	4.3	9.1	11.8	9.8	10.1	3.9	0.4	50.2
Storage (mm)	1.3	5.1	10.8	14.1	11.9	12.1	4.8	0.5	60.5
Losses (mm)	0.9	3.9	8.6	11.2	9.3	9.4	3.6	0.4	47.5
Total (mm)	3.2	13.3	28.5	37.1	31.0	31.6	12.3	1.3	158.2

This proposed water harvesting method which includes construction of small reservoirs to collect water, is subject to further losses due to evaporation and deep seepage. This must be taken into consideration in the utilization of water. The main causes of water losses from dams is deep seepage through leaking from the basin or dam wall and evaporation from dam surface. Thus, the surface area of the dam is a major contributing factor to water losses [(95)].

Therefore, the most important criteria that must be taken into consideration if earth dam were used as a storage facility should deal with management of these two parts. Losses as deep seepage can to some extent, be reduced by site selection and by a cheap method that works to increase the compaction of the reservoir surface by working it while moist [(95)]. When evaporation is high, it is better to have deep water and a small surface area rather than a large surface area of shallow water.

Table (40) shows the water losses from dam surface (evaporation and deep seepage) for each subcatchment. This table is based on the calculation of infiltration rate and evaporation from dams located in Al-Muwaqar station [(96)]. Assuming that the infiltration rate is (3×10^{-6}) cm/sec, Pan evaporation (1.3) times dam evaporation and the dam surface area (0.3) times the water volume [(96, 97)].

The size of the proposed dam is based on the occurrence of highest rainfall events and their contribution to runoff volume and the water storage period. The calculation of net available water for crop utilization are carried out for the catchment is based on the pervious criteria and assumptions. The area of each subcathments, runoff amounts, amounts of losses and net available water volume are given in table (40).

Table (40) : Annual available water for each subcatchment.

Subcatchment No.	Area (du)	Total runoff volume. m^3	Losses volume. m^3	Net available volume. m^3
1	1877	94601	3748	90853
2	1374	69244	2742	66507
3	2059	103774	4111	99663
4	2629	132502	5258	127244
5	1698	85579	3382	82197
6	2149	108310	4296	104014
7	1878	94651	3748	90903
8	2633	132703	5258	127445
9	2586	130334	5166	125168
10	3523	177559	7040	170519
11	2975	149911	5944	143996
12	1349	67989	2696	65293
13	874	44050	1738	42312
14	5375	270900	10744	260156
15	3546	178718	7086	171632
16	4689	236326	9372	226954
17	2883	145303	5760	139543
18	5032	253613	10058	243555
19	4118	207547	8230	199317
20	3546	178718	7086	171632
21	3089	155685	6172	149513
22	2449	123429	4892	118537
23	3272	164909	6538	158371
24	2791	140666	5578	135088
25	2174	109570	4344	105226
26	3065	154476	6126	148350
27	1444	72778	2880	69898
Total	75075	3783780	149996	3633784

4:3 Land use alternative scenarios for land utilization:

Based on the previous assessment of soil, climate, socio-economic factors, and water availability, the possible land use alternatives are presented through the following five scenario.

4:3:1 Scenario (A): Current potential utilization

Sound land use planning must take into consideration the requirements of land use activity, the available resources, and the land ownership characteristics in the catchment. This scenario is based on the assumptions that available resources is adequate to support livestock production.

Table (41) : Current land use activity in Muwaqar catchment.

Population	Livestock		Sheep & Goats	Farms		
	Poultry	Cattle		Tree	Vegetables	Mixed
6165	6×10^5	250	46923	11	3	6

Livestock water consumption depends on several factors such as temperature, feed type, animal size, management practices. Table (42) give the average livestock water consumption.

Table (42) Average water consumption in liters per day per animal.

Period of the year	Average consumption (l/day/a)
June-August	8
Sept.-Nov	6
Dec.-Feb.	4
Mar.-May	2
Average	5

Reference (90).

According to tables (41,42), the average livestock water consumption is about 100,000 m^3/ year excluding the requirements of poultry farms.

Another important available resources in the catchment are the presence of cisterns distributed in the catchment. About 200 collection wells are distributed in the catchment. These wells are used mainly to meet the livestock requirements. The size of each well is $50m^3$. Part of it is filled directly from rainfall. The estimated storage capacities of these wells is 10,000 m^3, and can be filled more than one time each year. Since these cistern are designed to be filled directly from rainfall, thus they must be enhanced and developed. Another alternative method to increase water storage is by direct pumping from dams to these cisterns.

It is obvious that the cistern capacity is not enough to satisfy the requirement of livestock. Thus cisterns must be filled several times and additional water must be made available by constructing small earth dams. Small earth dams distributed in the catchment can satisfy the current water requirments of livestock production. The average livestock water consumption of about 100,000 m^3/year which support 47,000 sheep number. The water resources in the catchment capable for supporting all livestock water requirment but the main issue is the capability of soils to support required production by appropriate land use sysytem. The location of farms, cisterns and possible dam sites are given in (Figures 6, 18).

4:3:2 Scenario (B) : Development of fruit trees

This scenario proposes the utilization of fruit trees. According to soil suitability assessment for tree utilization, the major soil limitations are soil depth, soil erosion, effect of carbonate and alkalinity hazards in lower soil layers.

Therefore, the possible utilization of classes (S_1, S_2) for fruit tree depends on appropriate management practices for soil erosion and water utilization. The total area that is classified as (S_1, S_2) is about 8820 and 19530 dunums : respectively. The distribution of these area is shown in map (Figure 9).

This scenario is based on the assumption that water demands is made available through on-farm water interception, and earth dams construction. Several methods have been developed to increase the amounts of water available for tree production using on-farm water interception, including micro-catchment method were developed [95]. A typical design is to use the basins as a catchment with the tree seedling planted at the lowest point. The system has been successfully used for the establishment of fruit trees. The S3 and Ns suitability area proposed to use as water harvesting areas to collect water in small earth dams, and then the water storage in the dams used to irrigate fruit trees as supplemental irrigation.

Water requirements for fruit trees under rainfed conditions are calculated for olive and almond with two level of productions (100% and 75%) assuming that all proposed varieties are drought resistant. This information is based on result recommended for similar area in the region using empirical equations. Proposed optimal irrigation system for trees are trickle irrigation with performance efficiency of 0.9 is assumed.

Different methods of on-farm approaches is proposed to collect water for fruit tree utilization. The recommended cathchment ratio of 3:1 give an effective rainfall at the plant site about 150 mm, the rest water requirements must be satisfied by supplemental irrigation. Table (43) indicate gross water requirement for fruit tree under two levels of production 100% and 75% .

Table (43) : Gross water requirements for fruit trees.

Water requirements	Almond	Olive
100% Eta (mm).	450	400
75% Eta (mm).	338	300
Water stored in soil (mm).	150	150
Net supplemental irrigation (100% Eta).	300	250
Net supplemental irrigation (75% Eta).	188	150
Gross supplemental irrigation (100% Eta).	333	278
Gross supplemental irrigation (75% Eta).	210	170

References(89,90).

The possible area that could be utilized for fruit tree within each subcatchment is given in table (44). Their distribution as shown on map (19).

Table (50) and map (19) indicates about (12-15) % of the area at 100% production level, and (20-24)% of the area at 75% production level from the total catchment area can be utilized.

Table (44): Possible utilized area for fruit tree.

Subcatchment No.	Olive. 100%	Olive. 75%	Almond. 100%	Almond. 75%
1	278	454	232	368
2	203	332	170	269
3	305	498	254	403
4	389	636	325	515
5	251	411	210	333
6	440	720	367	583
7	278	454	232	368
8	390	637	325	516
9	383	626	319	506
10	521	853	435	690
11	440	720	367	583
12	200	326	167	264
13	129	211	108	171
14	795	1300	664	1053
15	524	858	438	695
16	694	1135	579	918
17	427	698	356	565
18	745	1218	622	986
19	609	997	509	807
20	525	858	438	695
21	457	747	382	605
22	362	593	303	480
23	484	792	404	641
24	413	675	345	547
25	322	526	268	426
26	454	742	378	600
27	213	349	178	283
Total	11110	18169	9275	14708

Area (du).

Discussion :

Fruit trees considered perennial plants. The major constraints for utilizing (S1,S2) classes are : water availability, wind hazard, and high evapotranspiration during summer periods. Water harvesting techniques on-farm interception is suggested. Earth dam approach must be adopted to satisfy the requirements of fruit tree as suplemental irrigation. Due to the high losses by evaporation during summer months, water might not available during this period.

The variability of rainfall is high from one year to another. Therefore, the proposed utilization is very risky under prevailing rainfall conditions.

4:3:3 Scenario (C): Development of field crops

This scenario proposes the utilization of the area for field crops production (Barley, Sorghum, Legumes). According to soil suitability assessment for field crops, the main soil constraints are slope degree, soil erosion, and crust formation which affects germination.

Classes S_1, and parts of S_2 that can be developed without leveling, and with proper management practices for soil erosion and water utilization. The total area that can be utilized for the proposed crops is about 4590 dunums of S_1, and 12674 dunums of S_2. Their distribution as shown in map (figure 10). The S_3, Ns and part of S_2 suitability area proposed to use as water harvesting areas to collect water in small earth dams. The water storage in the dams used to irrigate field crops as supplemental irrigation.

The proposed management practices for field crops should be based on water collection behind earth dams. Furrows has been widely used as a soil conservation, this can intercept about 100 mm, while the rest water requirement must be satisfied by supplemental irrigation.

Water requirements for field crops is calculated for barley, sorghum, and legumes assumes using drought resistance varieties. The calculations is based on result obtained for similar area. The proposed optimal irrigation system for field crops is sprinkler system with performace efficiency of 0.75 is assumed. The gross water requirements for field crops is as given in table (45).

The area that could be developed within each subcathchment is given in table 46 and distributed as indicated on map 20.

Table 50 and map 20 indicates about (14-17)% of the area at 100% production level and (22-28)% of the area at 75% production level can be utilized. The distribution pattern of these area support such development if successful collective management schemes between farmers to utilize land on a cooperative basis is practiced.

Table (45) : Gross water requirements for field crops.

Water requirements	Barley	Sorghum	Legumes
100% Eta (mm).	320	300	280
75% Eta (mm).	240	225	210
Water stored in soil (mm).	100	100	100
Net supplemental irrigation (100% Eta).	220	200	180
Net spplemental irrigation (75% Eta).	140	125	110
Gross spplemental irrigation (100% Eta).	294	267	240
Gross spplemental irrigation (75% Eta).	187	167	147

References(89,90).

Table (46) : Possible utilized area for field crops.

catchment No.	Barley. 100% production	Barley. 75% production	Sorghum. 100% production	Sorghum. 75% production	Legumes 100% production	Legumes. 75% production
1	263	412	288	463	321	523
2	192	302	211	339	236	382
3	288	452	317	507	352	574
4	367	577	404	648	451	733
5	237	373	261	419	291	473
6	416	653	457	666	510	829
7	263	412	288	463	332	523
8	369	578	405	649	451	734
9	362	568	397	637	443	721
10	493	774	541	869	604	981
11	417	653	457	734	510	829

Cont. Table (46)

catchment No.	Barley. 100% production	Barley. 75% production	Sorghum. 100% production	Sorghum. 75% production	Legumes 100% production	Legumes. 75% production
12	188	297	207	332	231	376
13	122	180	134	216	150	243
14	752	1003	826	1325	921	1498
15	496	779	545	874	607	988
16	656	1030	721	1156	803	1306
17	403	633	443	710	494	803
18	704	1105	773	1240	862	1402
19	576	905	633	1015	706	1147
20	469	779	545	874	607	988
21	432	679	475	761	529	860
22	342	538	377	604	420	682
23	457	719	503	806	561	911
24	407	613	429	688	478	777
25	304	477	334	536	372	606
26	429	673	471	756	525	854
27	285	317	222	356	247	402
Total	10502	16493	11545	18510	12864	20917

Area (du).

Discussion:

The growing period of field crops fits to some extent the rainfall periods and has the following advantages.

- Requires small earth dams for water storage. Therefore water losses from dams is decreased.
- The stored water can be used at the same peroid for irrigation of crops. This should permit efficient water utilization and reduce the investment cost.
- Minimize soil erosion because field crops provide highest soil surface protection against rainfall impact.

This utilization is the least risky under prevailing climate conditions. Hence, the possibility of crop failure is reduced to the point that a serious damage would not occur.

The productivity of barley crop under similar conditions in Muwaqar station with appropriate management practices may give yield about (150-200 kg/du),[92]. This support the utilization of barley on an sustainable and economical basis.

4:3:4 Scenario (D): Development of vegetables

This scenario proposes the utilization of this area for vegetable production. According to soil suitability assessment for vegetable utilization, the major soil limiting factors are crust formation, slope degree, soil erosion, and nutrients availability.

The possible area that can be developed (classes S_1, S_2) requires proper management practices for soil erosion, water availability, soil fertility and improvement of soil physical properties. The total area classified as (S_1, S_2) about 5940, and 12870 dunums respectively; The S3 and Ns suitability area proposed to use as water harvesting areas to collect water in earth dams for irrigating vegetables area. Their distribution as shown in map(12).

Water requirements for cabbage, watermelon, tomato, and onion under rainfed conditions assumes that all varieties are drought resistant. The requirements calculated based on result of similar area in the region using empirical equations. The proposed optimal irrigation system for vegetables is trickle irrigation with total performance efficiency of 0.9 is assumed. Table (47) indicates the water requirements of vegetables for two percentage of potential production 100%, and 75%.

Table (47) : Gross water requirements for vegetables.

Water requirements	Onion	Watermelon	Tomato	Cabbage
100% Eta (mm).	540	420	450	430
75% Eta (mm).	405	315	338	322
Water stored in soil (mm).	60	60	60	60
Net spplemental irrigation (100% Eta).	480	360	390	370
Net supplemental irrigation (75% Eta).	345	255	278	262
Gross supplemental irrigation (100% Eta).	533	400	434	411
Gross supplemental irrigation (75% Eta).	384	284	309	291

References(89,90).

The proposed growing period of vegetables is March, to avoid the inappropriate climatic conditions in December, January and February. This requires a certain management of available water supply. Earth dam is proposed as a means for securing required water.

The possible area that can be developed within each subcatchment is given in table 48. Their distribution is indicated on map 21.

Table 50 and map 21 indicates about 12% of the area at 100% production level, and 15% of the area at 75% production from the total catchment area can be utilized.

Table (48) : Possible utilized area for vegetables.

catchment No.	Onion 100%	Onion. 75%	Water melon 100%	Water melon 75%	Tomato 100%	Tomato 75%	Cabbage 100%	Cabbage 75%
1	170	237	277	320	209	294	221	312
2	125	173	166	234	153	215	162	228
3	187	259	249	351	229	322	242	342
4	239	331	318	448	293	412	310	437
5	154	214	205	289	189	266	200	282
6	195	271	260	366	240	373	253	357
7	170	237	227	320	209	294	221	312
8	239	332	319	449	294	412	310	438
9	235	326	313	441	288	408	304	430
10	320	444	426	600	393	552	415	586
11	270	375	360	507	332	466	350	495
12	122	170	163	230	150	211	159	224
13	80	110	106	149	97	137	103	145
14	488	677	650	916	599	842	633	894
15	322	447	429	604	395	555	417	590
16	426	591	567	799	523	734	552	780
17	262	363	349	491	321	452	339	479
18	457	634	609	858	561	788	593	837
19	374	519	498	702	459	645	485	685
20	322	447	429	604	395	555	418	590
21	280	389	374	526	344	484	364	514
22	222	308	296	417	273	384	288	407
23	292	412	396	558	365	512	385	544
24	253	352	338	476	311	437	329	464
25	197	274	263	370	242	340	256	362
26	278	386	371	522	342	480	361	510
27	131	182	175	246	161	226	170	240
Total	6817	9463	9084	12795	8377	11760	8841	12487

Area (du).

Discussion :

The late growing season of vegetables suggests that most of the rainfall that contributes to runoff volume at the beginning of rainy period must be stored in large reservoirs and then used for irrigation. Since, water use efficiency decreases as the dam size increases, therefore, the investment cost is expect to be high.

Furthermore, the soil surface is left unprotected during the rainfall period, which expose soil to various degradation process. Therefore, measures to reduce soil erosion must be undertaken to sustain soil productivity.

The probability of partial failure is high because of the sensitivity of vegetables to climatic conditions. Consequently vegetables utilization are not highly recommended.

4:3:5 Scenario (E): Development of range

The land suitability assessment indicates that about (88%) of the area is suitable for range production. The proposed utilization assumes the use of on-farm water interception methods.

4:3:5:1 On - farm water interception.

This scenario proposes the utilization of range. The soils in the area are best suited for range production. According to the suitability assessment for ranges, the main soil limitations are crust formation, soil erosion, water availability and low nutrients level. The area suitable for (S1, S2, S3) classes are about 19980, 46560, and 8535 dunums; respectively. Their distribution is indicated on map (11).

The method of development depends on the collection of water from small subcatchment to target area. This method needs suitable management practices for both run - on and run - off areas to reduce water erosion and to increase the availability of water.

Water management is the key to increase the productivity of grazing land, in addition to appropriate stocking rate. Rotational grazing with resting period, but water management is usually the most important. A number of methods are used to reduce surface run-off by manipulating soil surface so as to slow down the run-off or to increase surface depressions storage. These methods usually involve catching and holding water temporarily in furrows (98) and can be used to assist productivity and improve species compositions.

Furrows catchs and spreads small runoff. If the run - off exceeds the storage, it spills over down hill edge without causing an erosion problem. In flat lands, small pasture furrows have been used in rectangular pattern to encourages pounding and infiltration process.

The concept of rainfall multipliers (the run - off from an uncultivated part of the land is diverted to a cultivated part, thus giving it the benefit of more water than it receives directly as rain) can be used for management and utilizes water in arid areas (95).

Water requirements of ranges for drought varieties for two percentages of potential production 100% and 75% is calculated based on result of similar area in the regions using empirical equations.

The possible utilized area that can be developed within each subcatchment as given in table (49).

Table (49): Possible utilized area for ranges.

Water requirement	Grass	Improved pasture	Shrubs
ETa 100% (mm)	200	280	340
ETa 75% (mm)	150	210	255
Ratio 100%	2.5	6.2	9.0
Ratio75%	2.0	3.0	5.0
Area 100% (du)	30000	12097	8333
Area 75% (du)	37555	25000	15000

Rangeland production seems to be the best utilization choice that suits the development of about (40-50) % of the catchment area in most efficient way of water utilization and which offers minimum investment cost. such utilization also offer the best practice to protect soil from degradation and develop maximum possible utilized area.

Table 50 summarize the possible development area for each utilization and the percent of utilized area per total catchment area.

Table(50): Possible utilized area for different land utilization types.

Land utilization types	Suitability level (S1)	Suitability level (S2)	Utilized area (S1)	Utilized area (S2)	Utilized %(S1)	Utilized % (S2)	Utilized area per total area
Olive 100%	8820	19530	8820	2290	100	11.7	14.8
Olive 75%	8820	19530	8820	9349	100	48	24.2
Fruit tree 100%	8820	19530	8820	455	100	2.3	12.4
Fruit tree 75%	8820	19530	8820	5888	100	30	19.6
Onion 100%	5940	12870	5940	877	100	6.8	9.1
Onion 75%	5940	12870	5940	3523	100	27.3	12.6
Tomato 100%	5940	12870	5940	2430	100	18.9	11.1
Tomato 75%	5940	12870	5940	5820	100	45.2	15.7
Cabbage 100%	5940	12870	5940	2901	100	22.5	11.8
Cabbage 75%	5940	12870	5940	6547	100	50.9	16.6
Watermelon 100%	5940	12870	5940	3144	100	34.6	12.1
Watermelon 75%	5940	12870	5940	6855	100	53.6	17.0
Barley 100%	4590	21690	4590	5912	100	27.3	14.0
Barley 75%	4590	21690	4590	11903	100	54.9	22.0
Sorghum 100%	4590	21690	4590	6955	100	32.0	15.4
Sorghum 75%	4590	21690	4590	13920	100	64.2	24.7
Legumes100%	4590	21690	4590	8274	100	38.2	17.1
Legumes 75%	4590	21690	4590	16327	100	75.3	27.9

Area (du)

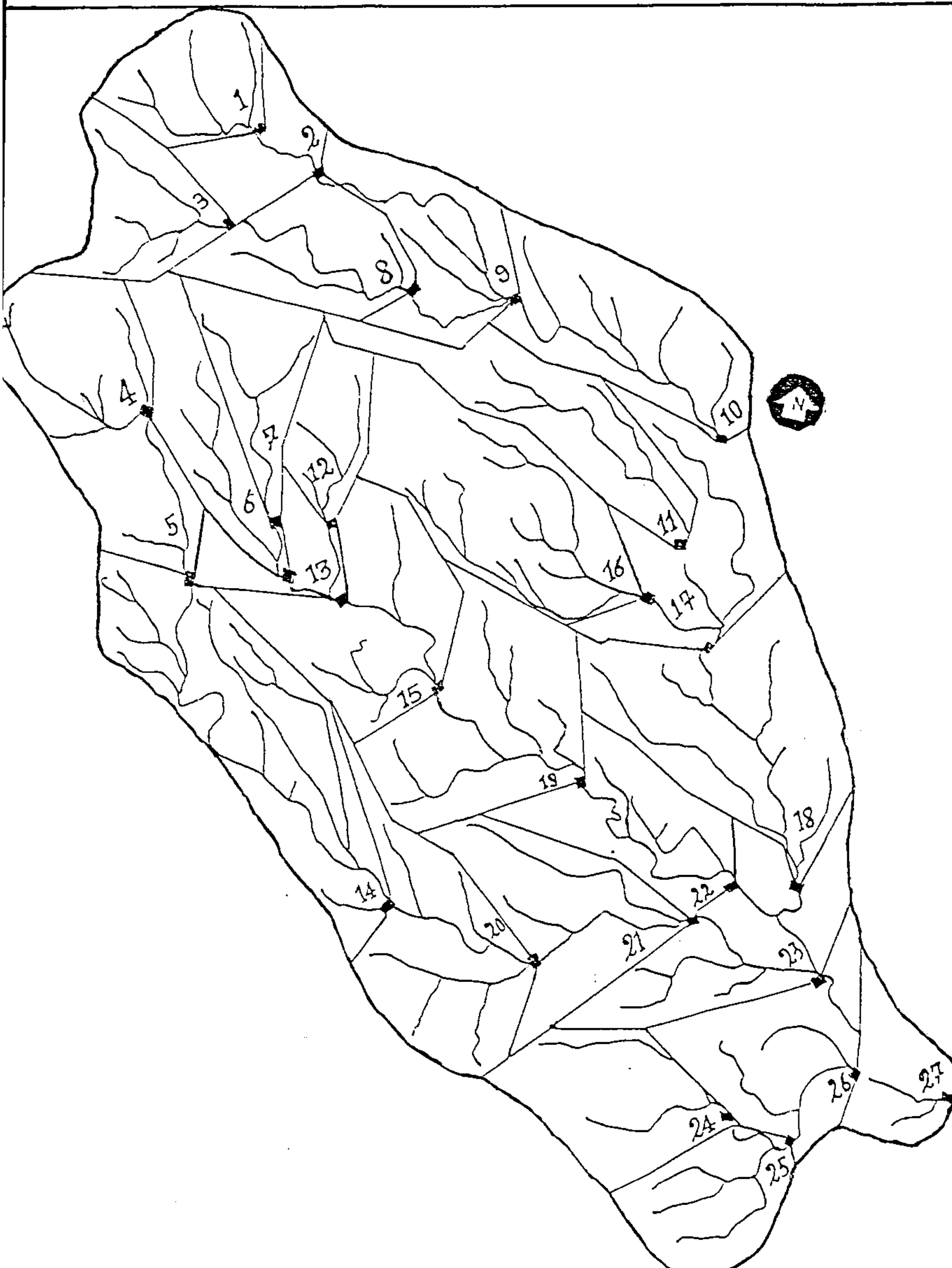

Figure (18): Division of Muwaqar catchment into small subcatchment, definition of the wades out let, and locations of proposed dam.

Figure (19): The utilized area of fruit tree , land tenure constraints dam location and water catchment

Figure (20): The utilized area of field crops [legend symbol], land tenure constraints [legend symbol], dam location [legend symbol], water subcatchment [legend symbol].

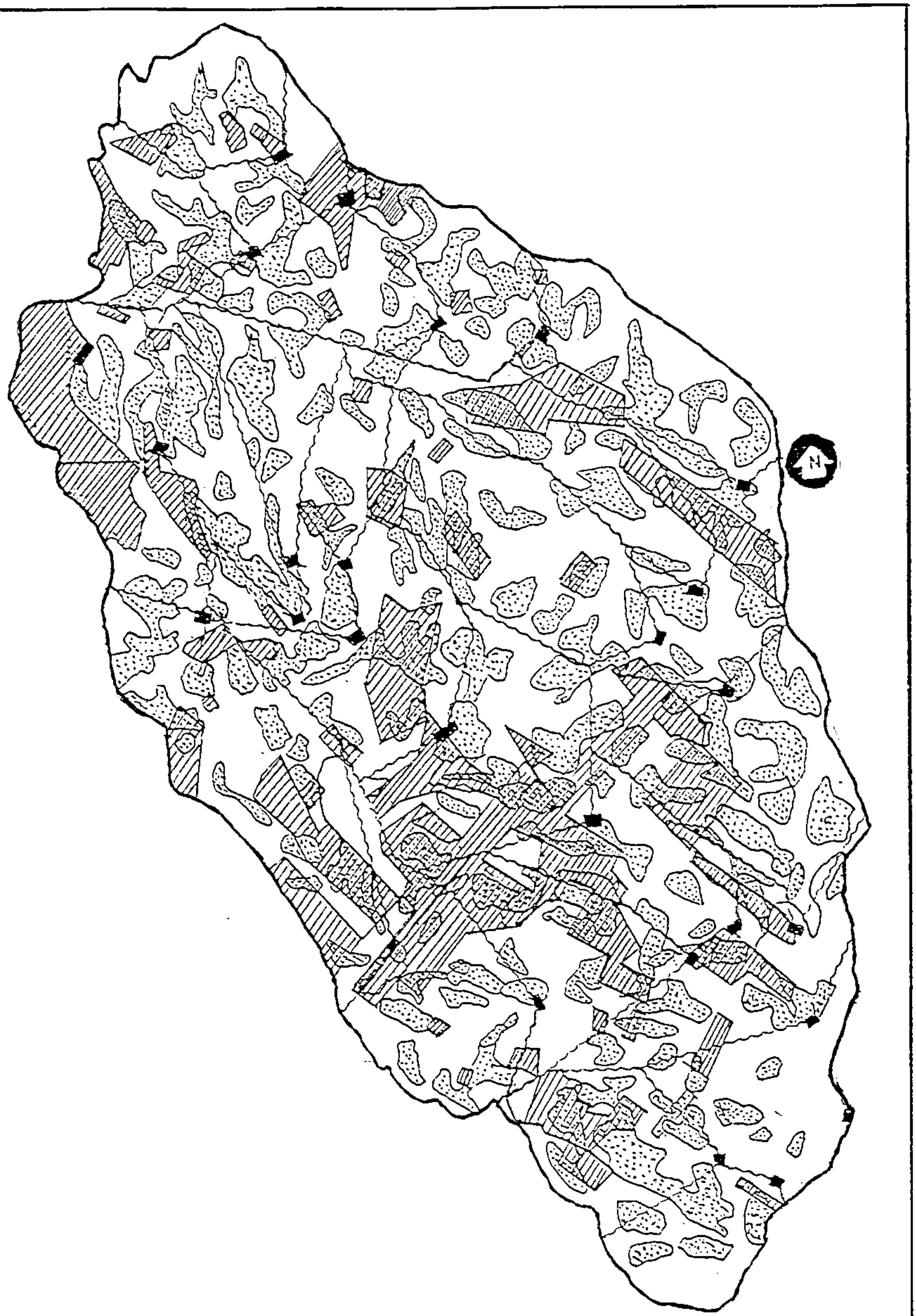

Figure (21): Possible utilized area of vegetables, land tenure constraints
dam location ;and water subcatchment.

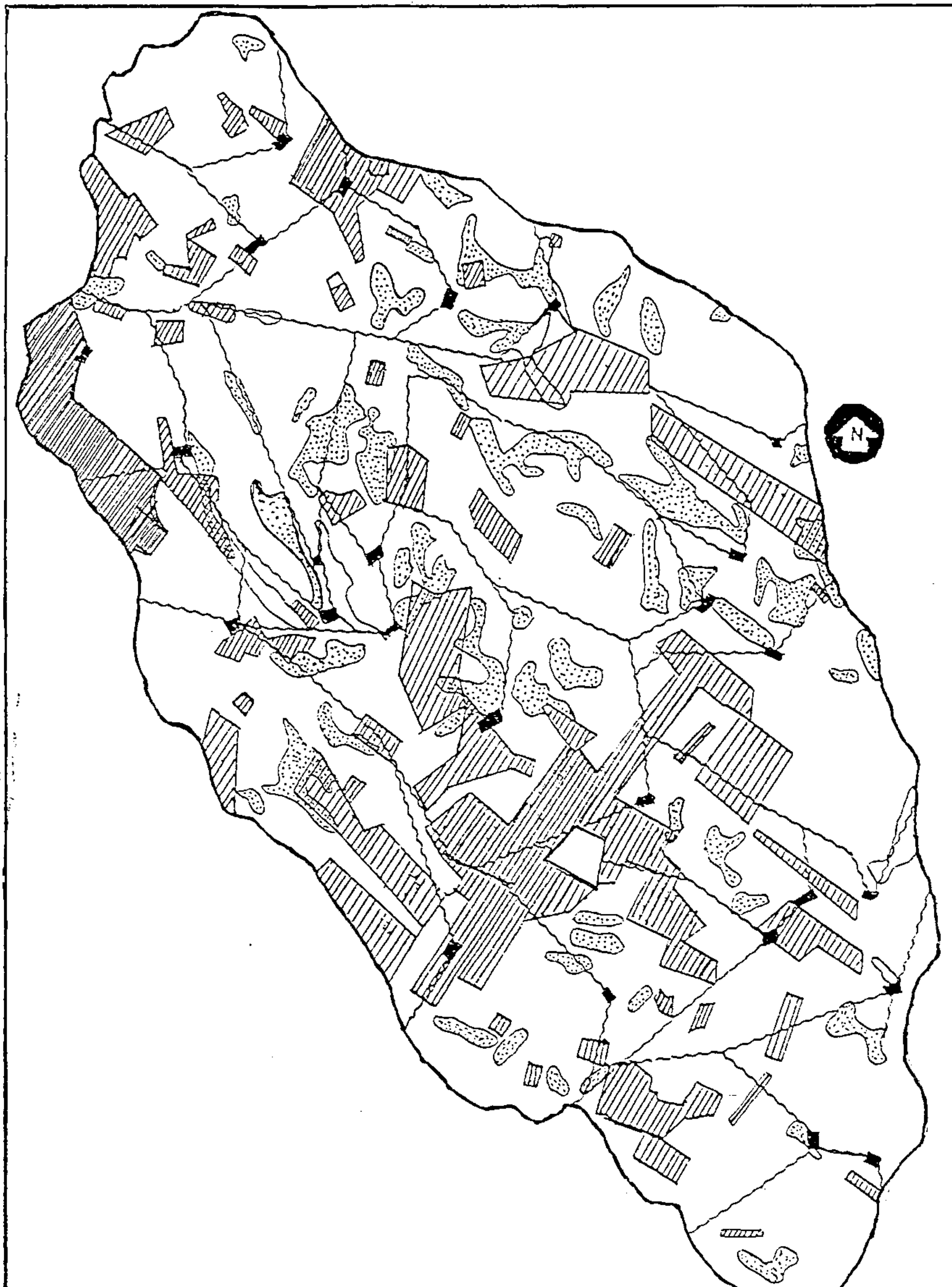

Figure (22) Possible utilized area for range , land tenure constraints , dam location , and water subcatchment.

CHAPTER FIVE

CONCLUSIONS & RECOMMENDATIONS

5:1 Summary and Conclusions

The study was carried out within Muwaqar catchment to evaluate potential land use, and proper land utilization based on the principles of FAO framework. Detailed survey of the natural resources in the catchment were conducted which includes : soil, climate, water resources, current land use, and land tenure.

Four land utilization types were assessed and evaluated according to soil constraints, climatic conditions and management practices. Different land use scenarios were investigated taking into consideration different limitations. The main conclusions are summarized as follows:

1- The main soil constraints for fruit tree production are soil depth, carbonate level, alkalinity hazard, and soil erosivity.

2- The main soil constraints for field crops production are slope degree, crust formation, and soil erosivity.

3- The main soil constraints for vegetable production are slope degree, carbonate level, alkalinity hazard, and soil erosivity.

4- The main soil constraints for range utilization are soil erosion, crust formation, and low nutrients level.

5- The main soil problems causing degradation are unfavorable surface properties. Therefore, soil erodability must be given proper attention in soil management practices.

6- Proper soil mangement, in rainfed cropping system should ensure that the conditions of soil physical properties, at the start of wet season, favor effective water entery and storage, and proper physical properties.

7- Low temperature during winter season and high probability of frost hazard are sufficient to reduce plant growth and cause crop damage.

While the high temperature during summer season accompanied with low relative humidity affects production quality.

8- The classification of agro-climatic classes for different land utilization types are as follows: rainfed fruit tree, rainfed field crops, and irrigated vegetables as (W4). While rangeland production classify as (W3).This mean that the combination of climate conditions and soil constraints allow very narrow windows of opportunity for sustainable land use unless improved land use management practices are introduced.

9- The nature and distribution of rainfall in the area can't support crop growth under present conditions. Since, the ability to manage water determine the feasibility of development.

10- The land tenure system indicates that about 96% of the land is private ownerships, and 75% of land has area more than 50 dunums which considered suitable for varieties of land utilization types.

11- The main land use in the catchment is rainfed agriculture and consisted mainly of barley production. Some scattered livestock farms are present in the catchment and consisted of cattles, poultry farms, sheep and goats.

12- The scenario for fruit tree production proposes to utilize water by on-farm interception and earth dams construction. This will provide apportunity for development of about 15% of the area. Variability of rainfall, however makes this utilization very risky under prevailing climatic conditions.

13- The scenario for field crops development proposes to utilize water by on-farm interception and earth dams construction. This will provide apportunity for development of about (15-20)% of total area.

14- The scenario for vegetable development proposes to utilize water resources in the area through earth dams construction. This will provide apportunity for development of about 12% of the area. The late growing season of vegetables lead to increase dam size, high investment cost, lower water utilization efficiency, and accelerate soil erosion. Therefore, the production of vegetables will be of high risk.

15- The scenario for ranges development proposes utilization of water by on-farm interception. This will provide apportunity for development of about (40-50)% of the area. This will ensures best water utilization efficiency, low investment cost, and minimizes, soil erosion and degradation.

5:2 Recommendations

1- Applying FAO framework approaches for land evaluation. This system facilitate the exchange of procedure and applied under different situations. The most contribution of the approach is that land suitability defined and assessed for different forms of land use, which permit prediction of different land use alternatives.

2- The rainfall characteristics and soil surface properties favors the introduction of water harvesting techniques. Such approach is considered the only option to increase water availability.

3- Maintain and develop cisterns on a proper sites to increase the available water required for livestock production.

4- The appropriate utilization of soil must interest in reducing soil erosion through the following:

A- Replacing conventional tillage by conservational tillage (apply no-tillage system for water harvesting area, and minimum tillage with furrows for utilizing area).

B- Plowing with the countorlines.

C- Applying appropriate runoff management techniques that enhance water conservation and reduce erosion.

5- Development of fruit tree suggests utilization of suitable area based on both on-farm interception and earth dams construction. Variability of rainfall makes this utilization highly risky. Therefore, large area development is not recommended.

6- Development of field crops suggest utilization of suitable area through collection of water behind earth dams construction with introduction of conservational management practices such as furrow planting.

7- Development of vegetable crops suggest utilization of suitable areas based on earth dams construction as the best means for securing required water. The constrains of climate and the expected high investment cost makes this utilization unviable.

8- Development of ranges based on farm water interception with suitable management for both run-on and run-off areas. Rangeland utilization seems to be the best choice which offers high social acceptance, most water utilization method and minimum cost.

9- To prevent land fragmentation below 30 dunums for fruit tree, and 50 dunums for field crops, ranges and vegetable production.

10- Studies of the socio-economic feasibility of water harvesting techniques under proposed land utilization types are required.

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APPENDICES

Field description :

Profile Description for Muwaqar Cathment :

PROFILE NUMBER Z5

Site Description :

Parent Material : Hard limestone associated with chert,eaolian, collivium
Vegetation : Cultivated, barley.
Topography : Linear - Concave . Slope 2%.
Erosion : Sheet erosion..
Special featur : Bottom Land, Top 0.5 Cm weak crust, influence of wind sediment is
: clear in top layers.
Sampled by : Awni y.Taimeh, Makhamreh .Z.M ,Ziadat .F.M.
Sampling date : 23-11-1994.

Profile Description:

Hor. Depth/cm

Ap 0-28 Brown - dark brown, 7.5YR4/4 (m), (SiCl), weak coarse subangular blocky and massive, breaks to fine and medium subangular blocky and single grain, Top 0.5 cm weak crust, friable, soft to s.hard, sticky, s.plastic, few to common, very fine roots, very few very fine pores, clear smooth boundary.

Bwk1 28 - 48 Brown - dark brown,7.5YR4/4 to reddish brown, 5YR4/6 (m),(SiC), moderate medium angular blocky breaks to fine and medium Angular and subangular blocky, hard, s.friable,v.sticky,v.plastic,common very fine roots,few medium distinct secondary carbonate accumulation, some rounded stony gravels, ants secretion ,some clay tabular structure, few fine pores, diffuse boundary.

Bwk2 48 - 110 Strong brown, 7.5YR5/6 (m),(C), moderate medium angular blocky, breaks to fine and medium angular and subangular blocky, v.hard, s.firm, v.sticky, v. plastic, v.few very fine roots, common fine and medium secondary carbonate, some accumulation, soft and hard concretions, some clay tabules, v.few dark coating, rounded small gravels, calcic horizon, few fine and medium pores.

Notation: SiCL, SiL.SiC and Si is Silty Clay Loam, Silt Loam, Silty Clay and Silt are soil texture classes. d or m is dry or moist soil color.
This notation is used throughout this description.

PROFILE NUMBER Z6

Site Description

Parent Material . Colluvium hard limestone associated with chert.
Vegetation : Cultivated barley.
Topography : Linear - Convex. Slope is 1-2 %.
Erosion : Sheet erosion.
Special feature : Slightly gravely, Top 0.5cm weak platy structure abundant native plants,ant nest, forth horizon qualified for calcic.
Sampled by Awni y.Taimeh, Makhamreh . Z.M , Ziadat.F.M.
Sampling date 23-11-1994.

Profile Description :

Hor. Depth/cm

Ap 0-19 Brown, 7.5YR5/4 to brown - dark brown, 7.5YR4/4 (m), (SiCl), weak coarse subangular blocky and massive, breaks to fine and medium subangular blocky and single grain, s.firm, s.hard, sticky, plastic, common very fine roots, v.few v.fine pores, gradual smooth boundary.

Bw1 19-39 Brown-dark brown, 7.5YR4/4, to Strong brown, 7.5YR5/6 (m),(SiCl), moderate medium and coarse subangular blocky, few -common v.fine roots, friable to s.firm, s.hard to hard,v. sticky, v.plastic, v.few fine to medium distinct concretions, ant secretion, few fine and medium pores, clear wavy boundary.

Bwk1 39-62 Brown-dark brown, 7.5YR4/4 to yellowish red, 5YR4/6,(m), (SiC) coarse prismatic, breaks to moderate medium subangular blocky and v.fine angular blocky, few v.fine roots, s.firm, v.hard v.sticky, v.plastic, common medium and coarse distinct secondary carbonate accumulation, soft and hard in the center concretions, some dark coating and smooth surfaces, like clay coating, few fine - v.fine pores,clear smooth boundary, suspect argillic horizon.

Bwk2 62-120 Yellowish red, 7.5YR4/4 (m),(SiC), moderate medium angular and subangular blocky, breaks to fine angular and subangular blocky, s. firm, ex.hard, v.sticky, v.plastic, v.few v.fine roots, few-common fine and medium soft distinct secondary carbonate accumulation, soft and hard concretions, v.few dark coating, some tabules structure , some dark coating and spots, few fine pores, suspect calcic horizon, gradual-diffuse boundary.

PROFILE NUMBER Z7

Site Description

Parent Material	Hard limestone .
Vegetation	Cultivated, irrigated vegetables.
Topography	Linear-Concave. Slope is 2.0 %.
Erosion	Sheet and rill.
Special feature	None gravely , weak crust 0.3 cm thick .
Sampled by	Awni y.Taimeh, Makhamreh .Z.M ,Ziadat .F.M.
Sampling date	23-11-1994 .

Profile Description:

Hor. Depth/cm

Ap 0-16 Strong brown, 7.5YR5/6, (m) ,weak coarse subangular blocky and massive breaks to weak fine subangular blocky and single grain, few fine and v.fine roots, 0.3 cm weak crust, friable, soft, s.sticky, s.plastic, non - v.few v.fine pores, gradual wavy boundary.

Bw1 16-35 Yellowish red, 5YR5/6 (m), moderate medium subangular blocky, breaks to fine and medium subangular and angular blocky, common fine and v.fine roots, v.few fine - medium distinct secondary carbonate accumulation, friable, soft - s.hard, v.sticky, v.plastic, many v.fine pores, internal erosion, some tabular structure, smooth boundary.

Bw2 35-67 Yellowish red, 5YR4/6 (m), moderate medium subangular blocky, breaks to fine and medium angular and subangular blocky, few fine roots, s.firm, s.hard, v.sticky, v.plastic, crotovina, internal erosion, few - common fine pores, diffuse smooth boundary.

Bwk1 67-100 Reddish brown, 5YR4/4 to yellowish red, 5YR4/6 (m), moderate medium angular and subangular blocky , breaks to fine angular and subangular blocky, v.few fine roots, firm, s.hard, v.sticky, v.plastic, few fine faint secondary carbonate accumulation, few fine and medium pores, carbonate in mycelium,
decomposed roots, earth worm cast, tabular structure.

PROFILE NUMBER Z8

Site Description

Parent Material	Hard limestone associated with chert.
Vegetation	Cultivated barley.
Topography	Linear-convex. Plain. Slope is 1.0 %.
Erosion	Sheet erosion.
Special feature	Top 0.5cm weak crust, wind sediment is very clear in the surface, abundant native plants (grass), forth horizon qualifies for hypercalcic.
Sampled by	Awni y.Taimeh, Makhamreh .Z.M . Ziadat.F.M.
Sampling date	23-11-1994 .

Profile Description:

Hor. Depth/cm

Ap 0-14 Strong brown, 7.5YR5/4 to brown - dark brown 7.5YR4/4,(m), (SiCl), weak coarse subangular blocky and massive, breaks to medium, fine and v.fine subangular blocky,few v.fine roots, s.friable, s.hard, s.sticky, s.plastic, v.few v.fine pores, abrupt smooth boundary.

Bwkl **14-54** Yellowish red, 5YR5/6 to brown - dark brown, 7.5YR5/6 (m),(SiC), moderate medium-coarse subangular blocky breaks to fine and v. fine angular and subangular blocky, few fine and v.fine roots, s.firm, hard, v.sticky, v.plastic, few fine -medium soft, and hard in the center concretions, v.few dark coating, v.few v.fine pores, gradual smooth boundary.

Bwk2 **54-120** Reddish yellow, 7.5YR7/6 to reddish yellow, 7.5YR6/6 (m), (C), weak medium subangular blocky, breaks to fine subangulblocky, v.few v.fine and medium roots, s.firm, hard, v.sticky, v.plastic, abundant distinct soft and hard secondary carbonate accumulation, soft and hard concretions, some tabular structure, qualifies for hypercalcic, v.few v.fine pores.

PROFILE NUMBER Z9

Site Description

Parent Material	Hard limestone , colluvium in the subsurface .
Vegetation	Plowed irrigated .
Topography	Linear-concave . Slope is 2.0 - 3.0 %.
Erosion	Recent sheet erosion .
Special feature	Top 1.5 cm platy structure, lots of silt sediment, thick A horizon, third horizon suspect argillic, forth horizon bed rock.
Sampled by	Awni y.Taimeh, Makhamreh, Z.M. Ziadat, F.M.
Sampling date	23-11-1994.

Profile Description:

Hor. Depth/cm

Ap 0-32 Strong brown, 7.5YR5/6,(m),(SiCl), coarse weak subangular blocky and massive structure, breaks to v.fine subangular blocky and single grains, top 1.0 cm moderate platy structure, few fine roots, s.friable, hard, s.sticky, s.plastic,v.few v.fine pores, gradual-abrupt boundary.

Bwk1 32-69 Yellowish red, 5YR5/6 to yellowish red, 4/6(m),(C), weak medium prism and moderate medium subangular blocky, breaks to v.fine and fine subangular blocky, few -common fine roots, s.firm, ex.hard,v.sticky,v.plastic, coarse and medium distinct secondary carbonate accumulation, soft v.hard in the center concretions, common fine pores, gradual - diffuse smooth boundary.

Bwk2 69-110 Strong brown, 7.5YR5/6 (m) ,(C), moderate medium subangular blocky, breaks to fine and v.fine subangular and angular blocky, few v.fine roots, s.firm, v.hard v.sticky, v.plastic, few-common fine and medium secondary carbonate accumulation, soft and hard in center, abundant dark coating, some shiny surfaces, broken chalichi, suspect argillic horizon, few v.fine pores.

PROFILE NUMBER Z10

Site description :

Parent Material	Hard limestone associated with chert.
Vegetation	Cultivated vegetables ,irrigated.
Topography	Linear-concave.Slope is 1.0 %.
Erosion	Sheet erosion.
Special feature	Top 0.5 cm weak crust.
Sampled by	Awni y.Taimeh, Makhamreh ,Z.M . Ziadat, F.M
Sampling date	23-11-1994 .

Profile Description:

Hor. Depth/cm

Ap 0-21 Strong brown, 7.5YR5/6 (m), weak coarse subangular blocky and massive, breaks to fine subangular blocky and single grain, top 0.5 cm crust, few v.fine roots, soft, firm, sticky, plastic, v.few v.fine pores, gradual wavy boundary.

Bwk1 21-60 Strong brown, 7.5YR5/6 to yellowish red, 5YR4/6 (m), moderate coarse subangular blocky, breaks to fine and medium angular and subangular blocky, few fine and v.fine roots, soft, firm, sticky, plastic, few - common fine and medium distinct secondary carbonate accumulation, carbonate in mycelium, internal erosion, insect secretion, v.few fine pores, clear wavy boundary.

Bwk2 60-110+. Strong brown, 7.5YR5/6 to reddish yellow (m), moderate fine - medium subangular and angular blocky, breaks to fine angular and subangular blocky, v.few v.fine roots, firm, hard - v.hard, s.sticky, s.plastic, abundant medium and coarse distinct secondary carbonate accumulation, carbonate in mycelium, longitudinal tabular structure, 50% by volume stones, lots of broken chalichi, v.few v.fine and fine pores .

PROFILE NUMBER Z11

Site Description

Parent Material	Hard limestone.
Vegetation	Plowed barley.
Topography	Linear - concave,Slope is 3.0 -4.0 %.
Erosion	Sheet and rill erosion.
Special feature	Top 2.0 cm is platy if are plowed, 1.0 cm moderate crust, wind sediment is very clear in the whole profile, forth horizon weak dark coatings.
Sampled by	Awni y.Taimeh, Makhamreh, Z.M, Ziadat.F.M.
Sampling date	23-11-1994 .

Profile Description:

Hor. Depth/cm

Ap 0-19 Strong Brown, 7.5YR5/6 (m), (SiCl), weak subangular blocky and massive, breaks to v.fine subangular blocky and single grain, top 2.5 cm strong platy structure, v.few fine roots, s.firm, soft, v.sticky, v.plastic, few fine and medium pores, diffuse boundary.

Bw1 19-40 Strong brown, 7.5YR5/6 (m),(SiC), weak - moderate medium subangular blocky, breaks to v.fine subangular blocky, v.few v.fine roots, s.hard, s.firm, v.sticky, v.plastic, v.few v.fine faint to distinct secondary carbonate accumulation, internal erosion, few fine and medium pores, diffuse boundary.

Bwk1 40-60 Strong brown, 7.5YR5/6 (m),(SiC), weak-moderate medium subangular blocky, breaks to v.fine subangular blocky, v.few v.fine roots, s.hard, s.firm, v.sticky, v.plastic, few fine and medium distinct secondary carbonate accumulation, few v.fine pores, gradual boundary.

BwK2 60-110 Strong brown, 7.5YR5/6 (m),(C), moderate medium subangular blocky breaks to fine and v.fine subangular blocky, v.few v.fine roots, s.firm, hard, v.sticky, v.plastic, common medium and coarse soft and hard concretions, weak some dark coatings, qualifies for calcic horizon, few fine pores.

PROFILE NUMBER Z12

Site description

Parent Material	Hard limestone .
Vegetation	Plowed, very weak native plants coverage compared to surrounding areas.
Topography	Linear -(Concave and convex).Slope is 2.0 %.
Erosion	Sheet, some gully erosion.
Special feature	Wind sediment is clear in the surface, top 2.0 cm is platy structure, broken chalichi at 80 cm, (5 - 7) cm thick cap layer, prevailing wind is S.E,lots of dusty.
Sampled by	Awni y.Taimeh, Makhamreh .Z.M, Ziadat.F.M.
Sampling date	23-11-1994 .

Profile Description:

Hor. Depth/cm

Ap 0-13 Strong brown, 7.5YR5/6(m), (SiCl), weak medium - coarse subangular blocky and massive, breaks to v.fine subangular blocky and single grain, top 2.0 is platy structure, few v.fine roots, s.friable, soft - s.hard s.sticky, s.plastic, v.few v.fine pores, gradual boundary.

Bw1 13-33 Strong brown, 7.5YR5/6,to brown-dark brown, 7.5YR4/4 (m), (SiCl), weak medium subangular blocky, breaks to fine subangular blocky and single grain, few - common v.fine roots, hard, s.friable, v.sticky, v.plastic, v.few fine faint secondary carbonate accumulation, fine and medium some earth worm cast, some fine tabules, v.few fine pores, clear boundary, 30% by volume stones and broken chalichi.

Bwk1 33-80 Strong brown, 7.5YR5/6 (m), (SiC), weak - moderäte medium and fine subangular blocky, breaks to v.fine subangular blocky and single grain, v.few v.fine roots, s.friable, s.hard - hard, sticky, plastic, few medium distinct secondary carbonate accumulation soft and hard concretions, few fine and medium shells (calichi).

PROFILE NUMBER Z13

Site Description :

Parent Material	Hard limestone associated with chert.
Vegetation	Cultivated barley.
Topography	Convex.Slope is 5.0 %.
Erosion	Sheet and rill, some gully.
Special feature	Back slope, 1.0 cm weak crust.
Sampled by	Awni y.Taimeh, Makhamreh. Z.M, Ziadat.F.M.
Sampling date	30-11-1994 .

Profile Description:

Hor. Depth/cm

Ap 0-19 Brown - dark brown, 7.5YR4/4, to reddish brown,5YR4/4 (m), weak - moderate medium and coarse subangular blocky to massive, breaks to fine and v.fine subangular blocky and fine granules, v.few v.fine roots, s.firm, s.hard, sticky, plastic, v.few v.fine pores, diffuse boundary.

Bwk1 19-44 Reddish brown, 5YR4/4 (m), moderate coarse subangular blocky to massive, breaks to fine and v.fine subangular blocky and fine granules, common v.fine and fine roots, s.firm, v.hard, v.sticky, plastic, v.few fine faint secondary carbonate accumulation, internal erosion, decomposed roots, v.few v.fine pores, clear wavy boundary.

Bwk2 44-70 Reddish brown, 5YR4/4, (m), moderate medium and coarse subangular blocky breaks to fine and v.fine subangular and angular blocky, v.few v.fine roots, ex.hard s.firm, v.sticky, v.plastic, few - common fine distinct soft secondary caccumulation, tabular structure, v.few v.fine pores, diffuse boundary.

BwK3 70-110+ Yellowish red, 5YR4/6 (m), moderate medium and fine subangular blocky, breaks to v.fine and fine subangular blocky, v.few v.fine roots, s.firm, ex.hard, v.sticky, v.plastic, abundant fine and medium faint-distinct secondary carbonate accumulation and medium concretions, earth worm cast, weak dark coating, qualifies for calcic, v.few fine pores.

PROFILE NUMBER Z14

Site Description :

Parent Material	Hard limestone .
Vegetation	Cultivated .
Topography	Linear - Concave . Slope is 3.0 %.
Erosion	Sheet and rill erosion .
Special feature	moderate 0.2 cm crust, some silt sediment at top horizon, ant insecretion in second horizon.
Sampled by	Awni y.Taimeh, Makhamreh. Z.M, Ziadat .F.M.
Sampling date	30-11-1994 .

Profile Description:

Hor. Depth/cm

Ap 0-15 Brown-dark brown, 7.5YR4/4, to strong brown, 7.5YR5/6 (m), weak coarse subangular blocky to massive, breaks to fine subangular blocky and single grain, few-common fine and v.fine roots, friable - s.friable, soft - s.hard, sticky, plastic, v.few fine and coarse pores, clear - gradual boundary.

BwK1 15-40 Strong brown, 7.5YR5/6 (m), moderate medium subangular blocky, breaks to v.fine and fine angular and subangular blocky, common v.fine roots, friable -s.firm, hard - v.hard, v.sticky, v.plastic, v.few - few medium faint - distinct secondary carbonate accumulation, few fine pores, gradual wavy boundary.

BwK2 40-74 Brown-dark brown, 7.5YR4/4 (m), moderate - strong medium subangular blocky breaks to fine and medium angular and subangular blocky, few - common v.fine roots, s.friable, v.hard, v.sticky, plastic, few - common medium and coarse distinct secondary carbonate accumulation, dark coating, internal erosion, shiny surfaces, v.few v.fine pores, diffuse boundary.

BwK3 74-110 Strong brown, 7.5YR5/6, to brown - dark brown 7.5YR4/4, (m), moderate fine and medium subangular blocky, breaks to fine and very fine subangular and angular blocky, v.few v.fine roots, s.firm, v.hard, v.sticky, v.plastic, common - abundant medium and coarse soft and hard distinct secondary carbonate accumulation, internal erosion, some longitudinal tabules, v.little dark coating in spots, v.few v.fine pores.

PROFILE NUMBER Z15

Site Description :

Parent Material	Hard limestone .
Vegetation	Cultivated barley.
Topography	Linear-concave.Slope is 1.0 - 2.0%.
Erosion	Sheet and rill some gully erosion.
Special feature	Top 0.5 cm moderate surface crust, plain, 80 cm is upper boundary of chalichi cap (5cm).
Sampled by	Awni y.Taimeh,Makhamreh. Z.M, Ziadat. F.M.
Sampling date	30-11-1994 .

Profile Description :

Hor. Depth/cm

Ap 0-19 Strong brown, 7.5YR5/6 - 5/8, (m), weak medium subangular blocky to massive breaks to v.fine subangular blocky and fine granular, v.few fine root, friable, s.hard, sticky, plastic, v.few fine pores, gradual - diffuse boundary.

Bwk1 19-40 Strong brown, 7.5YR5/6, to yellowish red, 7.5YR4/6(m), moderate medium subangular blocky, breaks to fine and medium angular and subangular blocky, few v.fine roots, friable - s.firm, hard, s.sticky, plastic, few fine and medium faint-distinct secondary carbonate accumulation, few fine pores, gradual boundary.

Bwk2 40-80+ Strong brown, 7.5YR5/6 to yellowish red, 7.5YR4/6 (m), moderate fine and medium angular and subangular blocky breaks to medium and fine angular and subangular blocky, friable s.firm, v.hard, sticky, plastic, few - common medium and coarse distinct secondary carbonate accumulation, soft and hard concretion, some carbonate in mycelium, upper part 40% stones , lower part very rich in carbonate and broken chalichi, 20% broken chalichi, v.few v.fine pores.

PROFILE NUMBER Z16

Site Description :

Parent Material	Hard limestone .
Vegetation	Cultivated, abundant native plants.
Topography	Linear - concave.Slope is 3.0 % .
Erosion	Sheet and rill.
Special feature	Shoulder, top 0.3 cm weak - moderate crust, third horizon suspect destroyed argilliic, broken calichi cap at the top of the forth horizon, slightly gravely.
Sampled by	Awni y.Taimeh, Makhamreh, Z.M. Ziadat,F.M.
Sampling date	30-11-1994 .

Profile Description :

Hor. Depth/cm

Ap 0-17 Brown - dark brown, 7.5YR4/4 (m), weak coarse subangular blocky to massive, breaks to fine subangular blocky and granules, few fine roots, friable - s.firm, s.hard, sticky, plastic, v.few v.fine pores, clear boundary.

Bwk1 17-40 Brown-dark brown, 7.5YR4/4, to strong brown, 7.5YR5/6 (m), moderate medium subangular blocky, breaks to medium and fine angular and subangular blocky, few v.fine roots, v.hard, sticky-v.sticky, plastic, v.few fine faint secondary carbonate accumulation, longitudinal (vertical) clay tabules, few fine and medium pores, gradual boundary.

Bwk2 40-60 Brown-dark brown, 7.5YR4/4, to yellowish red, 5YR5/6 (m), moderate-strong medium and coarse angular and subangular blocky, breaks to fine and medium angular and subangular blocky, v.few v.fine roots, ex.hard, v.sticky, v.plastic, few medium distinct secondary carbonate accumulation, dark coating, shiny surfaces, obliterated argillic horizon (suspect), 20 % by volume stones, v.few v.fine pores, clear boundary.

Bwk3 60-85+ Reddish yellow, 7.5YR7/6 to reddish yellow 8/6 (m), moderate medium subangular blocky, breaks to fine and medium angular and subangular blocky, ex.hard, v.sticky, v.plastic, abundant medium and coarse soft and hard secondary carbonate accumulation, broken calichi, 30 % by volume stones, v.few fine and medium pores, suspect calcic horizon.

PROFILE NUMBER Z17

Site Description :

Parent Material	Hard limestone associated with colluvium .
Vegetation	Cultivated barley.
Topography	Linear-concave.Slope is 2.0 %.
Erosion	Sheet erosion.
Special feature	Silt sediment is clear in the whole profile, moderate platy at surface, chalichi broken at upper site, soil above chalichi is not related to this layer no carbonate on it, apparent high sediment.
Sampled by	Awni y.Taimeh, Makhamreh, Z.M. Ziadat,F.M.
Sampling date	30-11-1994 .

Profile Description:

Hor. Depth/cm

Ap 0-19 Strong brown, 7.5YR5/6 (m), weak - moderate coarse subangular blocky and massive, breaks to medium and fine subangular blocky and single grain, top 1.0 cm platy, few fine and medium roots, friable, soft, sticky, plastic, v.few v.fine pores, gradual - diffuse smooth boundary.

Bw1 19-44 Strong brown, 7.5YR5/6, to yellowish red 7.5YR4/6 (m), weak-moderate fine and medium subangular blocky, breaks to v.fine granules, few - common v.fine roots, friable, s.hard, .sticky, plastic , v.few fine faint secondary carbonate accumulation, clay tabules, some ants insecretions, v.few v.fine pores, abrupt boundary.

Bwk1 44-75 Strong brown, 7.5YR5/6 - 5/8, (m), weak fine and medium subangular blocky, breaks to v.fine subangular blocky, v.few v.fine roots, friable, v.hard, sticky, plastic, few fine and medium faint - distinct secondary carbonate accumulation, carbonate in mycelium, 20% by volume stones, few fine and medium pores, gradual boundary.

Bwk2 75-118+ Calcic v.seminted, seminted carbonate, chalichi cap at the top (impermeable), upper 30 cm is broken chalichi, (C).

PROFILE NUMBER Z18

Site Description :

Parent Material	Hard limestone .
Vegetation	Plowed previous year.
Topography	Linear. Slope is 4-5 %.
Erosion	Sheet and rill erosion .
Special feature	Slightly gravely, top 1.0 cm platy, silt deposition very clear in first two horizon, qualified for calcic, barley stand is extremely poor, back slope - toe.
Sampled by	Awni y.Taimeh, Makhamreh, Z.M. Zia,F.M.
Sampling date	30-11-1994.

Profile Description:

Hor. Depth/cm

Ap 0-18 Yellowish brown 10YR5/6 - 5/8, (m), weak coarse subangular blocky to massive, breaks to fine subangular blocky and single grain , top 1.0 cm platy structure, few-common v.fine roots, friable, s.hard-hard, sticky, plastic, few v.fine pores, gradual boundary.

Bw1 18-42 Strong brown, 7.5YR5/6 (m), weak - moderate medium subangular blocky and massive, breaks to fine and medium subangular blocky and nearly single grain, few v.fine roots, friable, hard, sticky, plastic, v.few fine-medium distinct carbonate accumulation, v.few v.fine pores, clear boundary.

Bwk1 42-66 Strong brown, 7.5YR 5/6, to brown - dark brown, 7.5YR4/4 (m), moderate medium subangular blocky, breaks to medium and fine angular and subangular blocky, v.few v.fine roots, s.firm, hard, s - v.sticky, plastic, common medium distinct soft and hard in center secondary carbonate accumulation, earth worm cast, clay tabules, internal erosion , few fine and medium pores, clear boundary.

BwK2 66-110+ Strong brown, 7.5YR5/6 (m), moderate medium subangular blocky breaks to fine and medium subangular and angular blocky, few fine decomposed roots, s.firm, ex.hard, v.sticky, v.plastic, common - abundant medium distinct carbonate soft and hard in the center, few dark coating in spots, few fine and medium pores, qualified for calcic.

Annex -B: Chemical analysis ---------------------------- Page

Table(1) Particle size distribution for the soils of Muwaqar catchment.

HOR	Depth	C.S.	F.S.	VF.S.	SI.	CL.*	TEXTURE
DESIG		>0.25	0.25-0.1	0.1-0.05	0.05-0.002	<0.002	CLASS
				mm			
	cm			%			
			PROFILE	NUMBER	Z5		
Ap	00-28	1.1	0.4	7.8	54.0	36.7	SiCL
Bwk 1	28-48	0.9	0.2	4.4	49.3	45.2	SiC
Bwk 2	48-110+	0.9	0.3	4.3	39.3	55.2	C
			PROFILE	NUMBER	Z6		
Ap	00-19	1.3	0.3	9.7	50.6	38.1	SiCL
BW 1	19-39	0.6	0.3	7.2	52.5	39.4	SiCL
Bwk 1	39-62	1.1	0.9	3.8	51.2	43.0	SiC
Bwk 2	62-120+	-2.6	0.3	5.3	40.9	50.9	SiC
			PROFILE	NUMBER	Z7		
Ap	00-16	0.1	0.8	6.3	57.0	35.8	SiCL
BW 1	16-35	0.1	0.2	5.8	56.2	37.7	SiCL
BW 2	35-67	0.2	0.6	9.2	53.0	37.0	SiCL
BWK 1	67-100+	1.7	0.3	4.5	49.0	45.5	SiC
			PROFILE	NUMBER	Z8		
Ap	00-14	0.01	0.5	7.9	55.0	35.6	SiCL
BWK 1	14-54	0.9	0.3	7.7	46.2	45.0	SiC
BWK 2	54-120+	0.5	1.1	3.7	40.2	54.5	C
			PROFILE	NUMBER	Z9		
Ap	00-32	2.1	0.6	6.7	54.2	36.4	SiCL
BWK 1	32-69	0.3	0.2	3.7	29.7	66.1	C
BWK 2	69-110+	8.0	0.6	2.7	32.4	56.3	C
			PROFILE	NUMBER	Z10		
Ap	00-21	2.5	2.1	7.3	49.2	38.9	SiCL
BWK 1	21-60	1.00	1.3	5.2	42.4	50.1	SiC
BWK 2	60-110+	4.0	1.3	2.8	29.3	62.6	C
			PROFILE	NUMBER	Z11		
Ap	00-19	0.2	0.4	4.7	56.0	38.7	SiCL
BW 1	19-40	3.3	0.4	4.7	49.6	43.8	SiC
BWK 1	40-60	0.1	0.6	4.9	44.8	49.6	SiC
BWK 2	60-110+	0.0	1.0	6.7	39.7	52.5	C
			PROFILE	NUMBER	Z12		
Ap	00-13	3.0	1.0	5.0	52.5	38.5	SiCL
BW 1	13-33	0.2	0.2	2.7	63.4	33.5	SiCL
BWK 1	33-80+	0.0	0.3	4.9	48.3	46.4	SiC

Table (1) cont.

HOR	Depth	C.S.	F.S.	VF.S.	SI.	CL.	TEXTURE
DESIG		>0.25	0.25-0.1	0.1-0.05	0.05-0.002	<0.002	CLASS
				mm			
	cm			%			
			PROFILE	NUMBER	Z13		
Ap	00-19	0.3	0.3	5.1	55.9	38.4	SiCL
BWK 1	19-44	0.2	0.1	4.6	51.8	43.3	SiC
BWK 2	44-70	0.3	0.2	6.3	44.7	48.5	SiC
BWK 3	70-110+	2.6	0.3	4.9	39.6	52.6	C
			PROFILE	NUMBER	Z14		
Ap	00-15	0.2	0.2	5.3	57.8	36.5	SiCL
BWK 1	15-40	0.2	0.1	4.0	59.2	36.5	SiCL
BWK 2	40-74	0.1	0.1	4.3	50.6	44.9	SiC
BWK 3	74-110	0.1	0.1	5.0	41.6	53.2	SiC
			PROFILE	NUMBER	Z15		
Ap	00-19	1.1	0.6	7.9	54.1	36.3	SiCL
BWK 1	19-40	0.5	0.4	6.0	49.7	43.4	SiC
BWK 2	40 80+	1.2	0.4	5.0	47.7	45.7	SiC
			PROFILE	NUMBER	Z16		
Ap	00-17	1.2	0.6	7.7	51.3	39.2	SiCL
BWK 1	17-40	1.0	0.2	5.7	54.2	39.8	SiCL
BWK 2	40-60	1.0	0.1	4.6	46.9	48.3	SiC
BWK 3	60 - 85+	0.05	0.2	3.9	39.6	56.3	C
			PROFILE	NUMBER	Z17		
Ap	00-19	1.7	0.6	6.0	60.0	31.7	SiCL
BWK 1	19-44	0.5	0.3	6.0	55.6	37.6	SiCL
BWK 2	44-75	0.7	0.5	7.2	50.6	41.0	SiC
BWK 3	75-118+	0.5	0.2	1.7	29.3	68.3	C
			PROFILE	NUMBER	Z18		
Ap	00-18	0.3	0.5	7.3	53.4	38.5	SiCL
BWK 1	18-42	0.2	0.2	5.6	49.5	44.5	SiC
BWK 2	42-66	0.2	0.2	8.4	47.0	44.2	SiC
BWK 3	66 - 110+	0.2	0.2	8.0	43.6	48.0	SiC

* Carbonate free.

Table (2) Chemical properties for the soils of Muwaqar catchment.

Hor	Depth	Total		Extractable	Cations			
Desig		Carbo						
		Equi	Na	K	Ca	Mg	OM	CEC
	Cm	%		Meq/100gm			%	meq\100g
			PROFILE	NUMBER	Z5			
AP	00-28	19.9	0.84	1.91	15.95	4.78	1.06	30.6
BWK 1	28-48	22.8	1.64	0.64	15.05	9.93	0.81	31.8
BWK 2	48-110+	30.2	3.28	0.40	13.21	10.16	0.58	35.4
			PROFILE	NUMBER	Z6			
AP	00-19	17.9	1.13	1.19	16.09	5.48	1.01	28.4
BW 1	19-39	17.5	3.02	0.58	15.07	8.30	0.73	32.8
BWK 1	39-62	24.5	3.32	0.36	13.57	12.01	0.86	35.3
BWK 2	62-120+	36.3	7.85	0.31	13.73	15.29	0.60	31.2
			PROFILE	NUMBER	Z7			
AP	00-16	19.3	0.93	2.25	14.90	6.56	1.07	30.6
BW 1	16-35	18.2	1.51	1.15	15.59	7.35	0.78	32.0
BW 2	35-67	16.8	2.35	0.54	15.47	6.84	0.65	32.6
BWK 1	67-100+	19.7	2.90	0.53	15.34	6.21	0.63	35.0
			PROFILE	NUMBER	Z8			
AP	00-14	19.7	0.89	1.11	15.59	6.24	0.90	28.8
BWK 1	14-54	22.1	1.92	0.33	15.50	9.84	0.68	35.4
BWK 2	54-120+	53.9	4.70	0.11	12.68	9.49	0.62	27.2
			PROFILE	NUMBER	Z9			
AP	00-32	22.8	1.08	1.34	14.26	6.34	1.15	28.6
BWK 1	32-69	35.3	3.43	0.45	15.88	9.77	0.65	38.2
BWK 2	69-110+	30.7	8.00	0.25	16.73	9.74	0.56	44.2
			PROFILE	NUMBER	Z10			
AP	00-21	28.0	1.38	2.22	13.42	8.01	1.19	29.2
BWK 1	21-60	30.2	6.26	0.52	15.12	9.16	0.71	36.6
BWK 2	60-110+	49.6	3.57	0.20	13.13	9.02	0.55	33.8
			PROFILE	NUMBER	Z11			
AP	00-19	27.2	1.48	2.91	12.63	6.03	0.95	26.4
BW 1	19-40	25.4	3.74	1.42	13.51	8.44	0.62	31.6
BWK 1	40-60	26.9	7.29	0.77	13.84	9.68	0.67	32.2
BWK 2	60-110+	40.6	8.27	0.24	12.71	10.41	0.57	33.0
			PROFILE	NUMBER	Z12			
AP	00-13	38.0	1.56	2.23	13.11	5.97	0.95	29.0
BW 1	13-33	30.8	1.90	1.43	14.36	7.51	0.90	31.8
BWK 1	33-80+	32.3	6.80	0.40	13.18	10.06	0.81	30.8

Table (2) cont.

Hor	Depth	Total		Extractable	Cations			
Desig		Carbo						
		Equi.	Na	K	Ca	Mg	OM	CEC
	Cm	%		Meq/100gm			%	meq\100g
			PROFILE	NUMBER	Z13			
AP	00-19	21.6	1.13	1.83	14.36	5.53	1.02	36.4
BWK 1	19-44	18.9	0.91	1.02	15.23	7.54	0.74	34.6
BWK 2	44-70	26.3	1.01	0.36	14.58	11.49	0.42	32.4
BWK 3	70-110+	30.5	1.26	0.24	14.82	12.12	0.30	30.4
			PROFILE	NUMBER	Z14			
AP	00-15	27.6	1.30	2.30	13.74	5.02	1.05	28.9
BWK 1	15-40	21.7	3.90	1.41	14.94	8.78	0.68	28.2
BWK 2	40-74	27.2	7.75	0.50	13.31	10.67	0.50	27.6
BWK 3	74-110	30.5	6.94	0.24	12.59	11.12	0.35	27.0
			PROFILE	NUMBER	Z15			
AP	00-19	25.1	0.83	1.34	14.45	5.59	1.17	23.0
BWK 1	19-40	23.5	1.21	0.88	15.26	8.48	0.66	28.2
BWK 2	40-80+	44.2	1.86	0.22	14.77	9.62	0.45	27.6
			PROFILE	NUMBER	Z16			
AP	00-17	28.5	0.84	1.37	14.68	6.33	1.05	30.1
BWK 1	17-40	22.8	2.58	0.93	14.06	10.44	0.43	
BWK 2	40-60	28.1	3.43	0.46	14.09	10.98	0.46	31.0
BWK 3	60-85+	62.0	7.40	0.71	11.53	7.28	0.39	21.6
			PROFILE	NUMBER	Z17			
AP	00-19	32.0	1.04	1.81	14.71	5.16	1.03	20.0
BWK 1	49-44	33.2	1.58	1.33	14.69	6.98	0.64	22.6
BWK 2	44-75	34.3	3.02	0.30	12.66	8.52	0.56	24.0
BWK 3	75-118+	73.4	2.41	0.06	11.93	5.51	0.32	14.9
			PROFILE	NUMBER	Z18			
AP	00-18	28.4	1.34	2.33	14.06	6.67	0.94	20.6
BWK 1	18-42	.25.2	4.03	0.86	13.62	8.49	0.55	20.0
BWK 2	42-66	30.1	8.03	0.28	13.84	10.96	0.31	25.0
BWK 3	66 110+	31.1	7.22	0.39	12.07	8.71	0.25	26.4

Table(3) Chemical properties for soils of Muwaqar catchment.

Hor	Depth		Available	Nutrients				
Desig		P	Mn	Fe	Zn	Cu	PH	EC
	Cm			PPM			1:1	ds/m
			PROFILE	NUMBER	Z5			
AP	00-28	12.9	2.1	4.8	1.2	1.3	8.2	0.3
BWK 1	28-48	4.6	1.0	3.6	0.6	0.9	8.5	0.4
BWK 2	48-110+	4.5	1.0	5.9	11.7	1.0	8.6	0.7
			PROFILE	NUMBER	Z6			
AP	00-19	11.6	1.7	2.1	0.5	1.1	8.4	0.3
BW 1	19-39	1.6	1.0	3.5	0.6	1.0	8.2	0.2
BWK 1	39-62	2.6	1.2	3.0	0.7	1.1	8.4	1.9
BWK 2	62-120+	7.8	0.5	2.0	0.3	0.7	8.3	3.9
			PROFILE	NUMBER	Z7			
AP	00-16	15.3	4.0	3.6	1.1	1.3	8.2	0.3
BW 1	16-35	5.8	1.5	4.1	1.3	1.9	8.5	0.2
BW 2	35-67	9.3	1.1	2.3	0.6	1.5	8.6	0.4
BWK 1	67-100+	14.5	1.4	3.3	0.7	1.1	8.8	1.3
			PROFILE	NUMBER	Z8			
AP	00-14	14.5	3.2	3.7	0.6	1.2	8.3	0.3
BWK 1	14-54	8.8	1.0	3.0	0.6	1.8	8.4	0.4
BWK 2	54-120+	8.9	0.5	1.5	0.3	0.6	8.1	1.9
			PROFILE	NUMBER	Z9			
AP	00-32	20.9	7.8	7.6	0.8	1.3	8.2	0.5
BWK 1	32-69	1.9	0.8	2.4	1.3	1.3	8.3	1.1
BWK 2	69-110+	2.6	2.6	3.7	0.5	0.8	8.2	1.5
			PROFILE	NUMBER	Z10			
AP	00-21	22.2	1.8	2.6	0.7	0.7	8.4	0.4
BWK 1	21-60	9.5	2.2	5.1	0.4	1.0	8.4	0.5
BWK 2	60-110+	5.7	0.7	3.4	0.5.	0.8	8.7	3.0
			PROFILE	NUMBER	Z11			
AP	00-19	21.8	5.8	3.6	0.7	1.3	8.4	0.2
BW 1	19-40	1.4	2.3	2.2	1.2	2.3	8.2	1.6
BWK 1	40-60	1.6	3.1	5.1	5.2	1.0	8.5	2.4
BWK 2	60-110+	2.6	1.7	2.2	0.9	1.1	8.6	2.7
			PROFILE	NUMBER	Z12			
AP	00-13	18.8	5.9	3.6	0.5	1.2	8.3	0.4
BW 1	13-33	1.7	3.0	2.3	0.4	1.0	8.5	0.5
BWK 1	33-80+	6.0	3.4	5.1	0.4	1.1	8.2	2.1

Table (3) cont.

Hor	Depth		Available	Nutrients				
Desig		P	Mn	Fe	Zn	Cu	PH	EC
	Cm			PPM			1:1	ds/m
			PROFILE	NUMBER	Z13			
AP	00-19	13.9	16.1	3.9	0.8	1.3	8.3	0.3
BWK 1	19-44	6.9	3.5	2.2	0.4	0.9	8.1	0.2
BWK 2	44-70	1.8	4.2	2.7	0.5	1.3	8.3	0.2
BWK 3	70-110+	1.6	2.6	2.3	0.7	1.7	8.7	0.3
			PROFILE	NUMBER	Z14			
AP	00-15	16.3	2.5	10.2	1.0	2.0	8.2	0.4
BWK 1	15-40	7.1	3.3	3.8	0.7	0.9	8.6	0.5
BWK 2	40-74	2.1	2.9	4.8	0.4	0.9	8.4	0.6
BWK 3	74-110	2.1	2.0	2.6	0.6	1.3	8.9	0.6
			PROFILE	NUMBER	Z15			
AP	00-19	15.5	4.4	2.2	0.6	0.9	8.2	0.4
BW 1	19-40	6.5	3.9	4.1	0.9	1.3	8.3	0.4
BWK 1	40-80+	8.0	3.6	1.9	0.4	0.7	8.5	0.5
			PROFILE	NUMBER	Z16			
AP	00-17	18.2	3.3	2.2	0.6	1.0	8.3	0.3
BW 1	17-40	6.1	3.8	3.9	0.8	1.6	8.8	0.5
BWK 1	40-60	1.7	4.0	6.0	2.3	1.7	9.0	1.6
BWK 2	60-85+	7.9	2.2	2.2	1.8	0.6	9.2	0.6
			PROFILE	NUMBER	Z17			
AP	00-19	20.2	3.8	2.3	5.6	1.1	8.2	0.4
BWK 1	19-44	4.8	4.5	2.2	1.8	1.4	8.7	0.6
BWK 2	44-75	1.7	3.9	3.1	1.3	1.4	8.9	0.7
BWK 3	75-118+	7.2	1.1	1.2	1.2	1.1	9.2	0.3
			PROFILE	NUMBER	Z18			
AP	00-18	23.2	4.6	2.4	1.3	1.1	8.4	0.4
BWK 1	18-42	11.7	4.2	3.2	2.1	1.3	8.6	1.7
BWK 2	42-66	2.2	2.9	2.2	1.1	0.7	8.8	4.1
BWK 3	66-110+	4.1	4.4	0.9	1.1	1.8	9.1	1.2

Moisture Content

HOR DES	DEPTH	D.D	Pw	db	Ov	AW	AW
	cm	cm	%	gm/cm3	%	mm	mm/m
		PROFILE	NUMBER	Z5			
Ap	00-28	28	4.7	1.31	6.2	17.3	102
BWK1	28-48	20	7.1	1.52	10.8	21.6	
BWK2	48-110+	62	7.5	1.59	11.9	73.8	
		PROFILE	NUMBER	Z6			
Ap	00-19	19	8.0	1.43	11.4	21.6	121
BW1	19-39	20	12.8	1.64	21.1	42.2	
BWK1	39-62	23	8.4	1.62	13.6	31.3	
BWK2	62-120+	58	5.5	1.58	8.7	50.5	
		PROFILE	NUMBER	Z8			
Ap	00-14	14	5.9	1.32	7.8	10.9	97
BWK1	14-54	40	3.3	1.53	5.1	20.4	
BWK2	54-120+	66	8.4	1.54	12.9	85.1	
		PROFILE	NUMBER	Z9			
Ap	00-32	32	10.9	1.42	15.5	49.6	96
BWK1	32-69	37	4.8	1.62	7.8	28.9	
BWK2	69-110+	41	4.0	1.59	6.4	26.2	
		PROFILE	NUMBER	Z10			
Ap	00-21	21	6.7	1.39	9.3	19.5	96
BWK1	21-60	39	11.3	1.60	18.1	70.6	
BWK2	60-110+	25	4.4	1.56	6.9	17.2	
		PROFILE	NUMBER	Z11			
Ap	00-19	19	9.1	1.44	13.1	24.9	132
BW1	19-40	21	6.3	1.38	8.7	18.3	
BWK1	40-60	20	11.8	1.36	16.0	32.0	
BWK2	60-110+	50	8.3	1.51	14.2	71.0	
		PROFILE	NUMBER	Z12			
Ap	00-13	13	7.3	1.32	9.6	12.5	147
BW1	13-33	15	15.5	1.33	20.6	31.0	
BWK1	33-80+	42	14.6	1.22	17.8	74.7	

Moisture Content

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HOR	DEPTH	D.D	Pw	db		AW	AW
DES							
	cm	cm	%	gm/cm3		mm	mm/m
		PROFILE	NUMBER	Z13			
Ap	00-19	19	3.4	1.37	4.7	8.9	107
BWK1	19-44	25	8.1	1.52	12.3	30.8	
BWK2	44-70	26	7.0	1.43	10.0	26.0	
BWK3	70-110+	40	8.4	1.54	12.9	51.7	
		PROFILE	NUMBER	Z14			
Ap	00-15	15	17.3	1.18	20.4	30.6	163
BWK1	15-40	25	14.7	1.48	21.7	54.5	
BWK2	40-74	34	8.9	1.55	13.8	46.9	
BWK3	74-110	36	8.5	1.57	13.3	47.8	
		PROFILE	NUMBER	Z15			
Ap	00-19	19	13.6	1.31	17.8	33.8	135
BWK1	19-40	21	10.5	1.47	15.4	32.3	
BWK2	40-80+	30	8.1	1.62	13.1	39.0	
		PROFILE	NUMBER	Z16			
Ap	00-17	17	11.6	1.38	16.0	27.2	101
BWK1	17-40	23	5.0	1.47	7.4	17.0	
BWK2	40-60	15	9.3	1.71	15.9	24.0	
BWK3	60-65+	20	6.5	1.40	9.1	18.0	
		PROFILE	NUMBER	Z17			
Ap	00-19	19	9.8	1.24	12.2	23.2	116
BWK1	19-44	25	10.2	1.60	16.3	40.8	
BWK2	44-75	31	9.5	1.58	15.0	46.5	
BWK3	75-118+	43	4.7	1.30	6.1	26.2	
		PROFILE	NUMBER	Z18			
Ap	00-18	18	5.2	1.38	7.2	12.9	102
BWK1	18-42	24	7.9	1.61	12.7	30.8	
BWK2	42-66	24	7.1	1.52	10.8	25.9	
BWK3	66-110+	44	6.2	1.57	9.7	42.7	

الملخص

البدائل الافضل لاستخدام الاراضي في المناطق الجافة - شبه الجافة في الاردن

إعداد
زياد مخامرة

إشراف
أ.د عوني طعيمة

ندرة المصادر الطبيعية المتوفرة في الاردن وزيادة الطلب نتيجة لزيادة النمو السكاني، يتطلب تطوير المصادر الطبيعية وتطبيق استراتيجية مناسبة للتخطيط المستقبلي. هذا العمل يجب ان يرتبط باستخدام نظام مناسب لاستعمال الاراضي والذي يهدف الى تعظيم الاستخدام وتقليل تدهور التربة. لذلك تهدف هذه الدراسة الى تحقيق ما يلي :-

١. تقييم امكانية ومشاكل التربة الموجودة في منطقة الدراسة.
٢. ايجاد البدائل المثلى لاستعمال الاراضي باستخدام ما يسمى "بالمنطقة الاقطة"ز

تشمل هذه الدراسة منطقة الموقر والتي تمثل المنطقة الجافة - شبه الجافة في الاردن، تم استخدام مبادئ ال FAO عام ١٩٧٦، ومشروع مناطق البيئة الزراعية عام ١٩٧٨ لتقييم مستويات الاستخدام الملائمة لاربعة انواع من الاستعمالات المحتملة. عملية التقييم تمت بواسطة مقارنة خصائص التربة واحتياجات الاستخدام المختلفة. جرت دراسة شاملة للمصادر الطبيعية في منطقة الدراسة خلال عامي ٩٣/٩٤. هذا المسح يشمل مسح التربة، المعلومات المناخية، الغطاء النباتي، الاستخدام الحالي للاراضي، ملكية الاراض ومصادر المياه.

بينت الدراسة ان تقييم درجة الملائمة الممكنة اعتمادا على مقارنة احتياجات الاستخدام المختلفة وخصائص الترب الموجودة تعكس مستويات مختلفة من درجات الملائمة. محددات

التربة الرئيسية التي تؤدي الى تدهور هي عدم ملائمة خصائص التربة السطحية والتي ترتبط بمعدل نفاذية منخفض.

تقييم الاستعمال الممكن باستخدام خصائص التربة والمناخ تشير الى توفر فرص ضئيلة لديمومة الاستخدام الا اذا طبقت طرق ادارة مناسبة لتفادي هذه المشاكل، لذا فان القدرة على ادارة مصادر المياه تحدد امكانية التطوير المستقبلي، المصدر الرئيسي للمياه في المنطقة يمكن ان يلبى بواسطة تقنية الحصاد المائي. خصائص الامطار وطبيعة الطبقة السطحية توفر فرصة مناسبة لتطبيق تقنيات الحصاد المائي في المنطقة. خصائص نظام توزيع الاراضي في المنطقة يشير الى أن ٧٥٪ من الاراضي تملك مساحة اكبر من ٥٠ دونم والتي يمكن اعتبارها مناسبة لانواع مختلفة من الاستعمالات الزراعية.

تم اقتراح عدة سيناريوهات لتطوير الاراضي في المنطقة تأخذ بعين الاعتبار مشاكل التربة، توفر الماء، الظروف الاجتماعية والاقتصادية. الافتراض الرئيسي لهذه السيناريوهات هي استخدام افضل منطقة مناسبة لكل نوع من انواع الاستعمالات والتي تملك امكانية انتاجية عالية. متطلبات المياه يمكن توفيرها بواسطة تقنيات الحصاد المائي، اما مباشرة في الحقل او بواسطة بناء سدود ترابية.

سيناريو تطوير الاشجار المثمرة توفر فرص لاستغلال ١٥٪ من المساحة الكلية، لكن تذبذب الامطار تجعل درجة المخاطرة لهذا الاستخدام عالية تحت الظروف الجوية الحالية. سيناريو تطوير المحاصيل الحقلية توفر فرص لاستغلالا حوالي (١٥-٢٠٪) من المساحة الكلية، الزراعة المبكرة للمحاصيل الحقلية توفر فرص جيدة لاستغلال المياه بكفاءة عالية وتقليل انجراف التربة. سيناريو تطوير الخضروات توفر فرص لاستغلال حوالي (١٢-١٥٪) من المساحة الكلية لكن العوامل الجوية تجعل هذا الاستخدام غير مناسب. سيناريو تطوير المراعي توفر فرص لاستغلال ما يقارب (٤٠-٥٠٪) من المساحة الكلية بافضل تقنية ممكنة لاستخدام المياه والمحافظة على التربة.