Potential Utilization of Barley And Rangelands In Arid To Semi- Arid Region In Jordan

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DEDICATION

Dedicated with gratitude to:

The memory of my father
Abed Al-Majeed Al-Rashdan

&

My Mother, and My Wife for their tolerance and patience

Also dedicated to my brothers and sister

&

My Son Mohammed, My daughters
Nadeen, Haneen, Heba

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ABSTRACT

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The study area is located 40 kms south east of Amman, it covers an area of 131km^2 which represent the arid to semi-arid regions in Jordan to evaluate potential land use and assess the most suitable land use alternatives for the area.

Geographic information system (GIS) was the tool in conducting suitability analysis by which modeling language has been used.

The FAO framework was used for land evaluation, FAO framework is dynamic in concept and aims to predict the effect of changes in land use through an understanding of the relationships, both physical and socio-economic.

Suitability analysis depend on a semi-detailed soil survey level at scale of 1:50,000. 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.

Potential land use was carried out for three land utilization types, arable rainfed, barley, and range taking into consideration soil and climate constrains and socio-economic conditions.

The area could be suitable for different land utilization types under different management practices. Therefore, alternative land use scenarios are proposed. These scenarios are drawn to develop the best suitable area for proper land utilization types which have high potential production.

The first scenario is based on the assumption that no management practices could be applied. This shows that 12% of the total area could be used for barley production. The analysis shows that 98% of the total area could be used as natural rangeland.

The second scenario is proposed for range development through introducing contour furrows techniques and this provides opportunity for improving 90 % (105,909 dunums) of the total area.

In addition, water spreading is not a suitable method to use it in the area due to steep slopes and soil depth restriction.

1. Introduction

Soil and climate are the two major factors that affect agricultural uses. Shortage of water is the important problem in arid and semi-arid region of Jordan. About 91 % of Jordan receives less than 200 mm of rain annually, 6 % of the total area receives 200-300 mm, and less than 2 % receives 350-500 mm, while about 1 % receives more than 500 mm.

Limited land resources in Jordan and increasing demands of the growing population requires agricultural expansion to intensify towards arid and semi-arid regions as an alternative. However, land utilization in arid areas should be based on proper land use to avoid soil degradation, and optimum use of scarce water resources.

The yield of barley is very low because of selecting the low potential land for barley or conversion of rangeland to barley production. The conversion of natural rangelands to barley or cropped lands in an attempt to increase production has resulted in soil erosion and expansion of the degraded land.

Potential land use evaluation based on soil constraints and climate conditions indicated that the combination of climate and soil constraints allow very narrow windows of opportunity for sustainable land use unless favorable management practices are applied. However, the ability to manage the available scarce water resources determines the feasibility of future development.

The utilization of the newly cultivated land should ensure preservation of land resources.

The objectives of this investigation are :

- To evaluate the potential use of land for barley and range.
- Assess the most suitable land use alternatives of the study area.

2. Literature Review

2.1. Soil survey and land evaluation

Land evaluation begins with basic survey of soil, climate, water, and other characteristics of biophysical resources (Miller, 1978). The basic survey identify the major soil units (Chinene, 1992)

The primary basis for land evaluation is provided by natural resource data, which encompass soil survey, landform, and hydrology. The aggregate biophysical data enables investigator to determine the suitability of land for alternative purposes (Turner, 1985).

2.1.1. Purpose of survey

Soil survey is one of the activities collectively known as natural resources surveys (Young, 1976). The purpose of a soil survey is to provide the user with information about the soil and land for any site of interest (Young, 1976).

The primary task of soil survey is synthesis rather than analysis. The approach is based on logical correlation, using empirical knowledge and sound judgment (Diepen et al., 1991).

The standard soil survey map shows the different kinds of soils that are significant in an area and their relationship to landscape features. These maps are intended to suit the needs of users (Flaherty and Simth , 1982).

The field survey consists of two paralled sets of activities: Studies directed towards the identification and description of land use, and surveys of the available resources of the land (Dent and Young, 1981).

One of the end-products of soil survey should be a map showing units of land which have a defined quantitative value for agricultural development (Young, 1973).

2.1.2. Scales

The chosen map scale depends on the objective of the soil survey, and the level of details of the field work being carried out.

Reconnaissance survey is conducted at a scale of 1:100,000 and smaller, mapping units are mostly based on land forms; soil units, or land systems.

Semi-detailed surveys are carried out at a scale of 1:50,000 at which soil series can be mapped. While detailed surveys are carried at a scale of 1:25,000-1:10,000. Soil series are employed as a map units (Young, 1973).

2.2. Concept of land evaluation

Land evaluation is an interpretation of soil survey data. It investigates how relevant or irrelevant those data are for a certain purpose (FAO, 1977).

The central concept of suitability evaluation is that the various activities are directed towards assessment of land for specified kinds of use (Dent and Young, 1981)

Land evaluation offers a framework for agroecological integration, within which observational and experimental information can be used to improve our understanding of sustainable agricultural systems. Land evaluation makes it possible to use land according to its biophysical potentialities and limitations (Rosa et al., 1992).

Land evaluation is an interpretation of land properties in terms of suitability of the land for different land use types or crop types (Arens, 1977).

A fundamental process in land evaluation is the comparison or matching of land-use requirements with the attributes of land mapping units (Theocharopoulos et al., 1995).

Land evaluation is a process of predicting the use potential of land on the basis of its attribute. A variety of analytical models can be used in these predictions, ranging from qualitative to quantitative, functional to mechanistic, and specific to general (Rossiter, 1996). It does not include optimal land allocation. However, land evaluation supplies the technical coefficients necessary for optimal land allocation (Rossiter, 1996).

Land evaluation is a tool for strategic land-use planning. It predicts and performs, both in terms of the expected benefits from and constraints to productive and use, as well as the expected environmental degradation due to these uses (Rossiter, 1996).

Land evaluation gives information on the suitability of different tracts of land for selected land uses. Most land evaluations are biophysical (Huizing and Bronsveld, 1994).

2.2.1. Purpose of land evaluation

Beek (1978, 1980) stated that the function of land evaluation is to bring about an understanding of the relationships between the conditions of the land and the manner in which it is utilized. Also Dumanski et al.,(1979) stated the need to predict favorable and adverse effects (outputs) resulting from the use of the land, as well as the required management inputs.

According to (FAO, 1976) land evaluation is concerned with the percent performance of land, it provide land managers with information that improve land use decisions (Johnson et al., 1991). It is a link that interprets the physical environment in terms of its resource potential, land evaluation needs to assess the difference in productivity between existing and proposed futures uses of land (Young, 1978).

Data for different land uses must be presented in a form which allows for comparisons between uses based on some common measure of performance (Johnson et al., 1994). Comparison of land use scenarios is facilitated through fast computation of a large number of alternatives (Stomph et al., 1994).

2.2.2. Types of land evaluation

A. Physical and integral evaluation

Physical land evaluation is concerned principally with physical or ecological aspects of land and its use. It begins with basic surveys of land resources. Frequently, physical land evaluation has been applied to land use concerns which go beyond assessing the performance of alternative uses on particular types of land (Smith et al., 1986). According to FAO 1976, physical land evaluation identifies and compares potential land use alternatives, and thus it is preceded by the recognition of the need for some change in the use.

On the other hand, integral land evaluation is the synthesis of information obtained from physical land evaluation with pertinent socio-economic factors (Smith et al., 1986). It deals with information on goals and objectives for the use of land (Beek, 1980).

The purpose of integral land evaluation is not to predict one economically optimal pattern of land use, but rather to assess the range of options for production and land use that are feasible given the specified conditions, and to assess the effects of policies or changes in conditions upon these options (Smith et al., 1984).

B. Qualitative evaluation

Qualitative land evaluation indicates the suitability of land for particular use in qualitative terms (e.g. well suited, marginally suited). The principles have been outlined by the Food and Agricultural Organization of the United Nations (1976).

Qualitative land evaluation methods are based on simple procedures, i.e. the use of farmers' experience and expert knowledge. The availability of data and the possibility of collecting additional data determine which type of physical land evaluation is most appropriate. Qualitative physical land evaluation methods, usually represent less detailed technical approaches (Van Lanen et al., 1992). Qualitative ratings may be as simple as narrative statements of soil suitability for particular crops, or they may group soil subjectively into a small number of classes or grades of agricultural suitability (Huddleston, 1984).

Qualitative methods usually express the suitability in more than two classes (Van Lanen et al., 1992).

C. Quantitative evaluation

The quantitative procedure describes suitability in terms of potential crop yield and their variation which can be assessed (Van Lanen et al., 1992).

On the other hand, quantitative land evaluation combines the properties of crops, soils, and weather in such a way to estimate yield potentials. These estimates permit evaluation of the major constraints in any particular situation and of the requirements for eliminating these constraints.

The availability and quality of data are the principal limitations on accurate predictions of yield (Keulen et al., 1986).

Quantitative land evaluation methods combine the properties of crops, soils, and weather in away to estimate yield, such as kg dry matter per unit area, and associated inputs (e.g. m^3 water/ha, kg nutrients/ha) (Van Lanen et al., 1992).

The quantitative approach, as developed by FAO remains one of the best possible ways to achieve a quantification of the land evaluation system

(Sys, 1993). Quantified methods require more-or-less detailed models of land performance. These models, however, usually have high data requirements (Rossiter, 1996).

However quantitative evaluation methods require more input data, and more expensive than the qualitative ones.

D. Economic evaluation

Economic land evaluation is a method for predicting the micro-economic value of implementing a given land-use system on a given land area. This is more useful prediction of land performance than a purely physical evaluation, since many land-use decisions are made on the basis of economic value (Rossiter, 1995).

Economic evaluation is one which includes results given in terms of profit and loss for each specified enterprise on each kind of land.

Economic land evaluation is sensitive to a range of different assumptions which can vary every time (Johnson et al., 1994).

The variation of economic and biophysical variables identified in the physical suitability assessment and economic analysis can be characterized in terms of production and price risk. The best lands are determined not only by their ability to produce high yields at the lowest cost (Johnosn et al., 1994). The FAO promoted the use of economic land evaluations, either subsequent to the physical evaluation or in paralleled with it (FAO, 1989).

2.3. Systems of inventory

2.3.1. The land system approach

Land system is an area with a recurring pattern of topography, soils and vegetation and with a relatively uniform climate (Christian et al., 1953).

Land system approach is the best known landscape approach for providing a rapid inventory of land resources (Moss, 1983), (Davidson, 1992).

2.3.2. The source of information of land evaluation

A. Land

Knowledge of the physical characteristics of land is a fundemental source of land evaluation (Dumanisiki, 1979). The land resources are of different nature, such as physical resources, human resources and capital resources (Sys, 1985).

Land not only refers to soils but also includes the relevant features of geology, landforms, climate, and hydrology (Johnson et al., 1994).

B. Land cover

This refers to possible kind of use under consideration for the future (Christian and Stewart, 1968).

Effective public land use programs require accurate understanding of past and present land uses and their interrelationships (Gibson and Timmons, 1976). Data for different land uses must be presented in a form which allows for the comparison between uses, based on some common measure of performance (Johnson et al., 1994).

Many current land use systems are not sustainable as they contribute to the deterioration of the natural resources base, as a result of erosion, chemical exhaustion salinization, contamination with toxic chemicals. (Stomph et al., 1994)

Inappropriate land use leads to inefficient exploitation of natural resources, destruction of the land resource, poverty and other social problems (Rossiter, 1996). A better integration of biophsical and socio-economic data was achieved by georeferencing part of the land use and farming systems data (Funnpheng et al., 1994).

Current land use have evolved through processes involving decisions and actions in both the market place and the political arena (James et al., 1976).

C. Cost of inputs and outputs

The general economic information include present prices for outputs, forecast based on expected demand and supply, present costs for inputs as well as expected future price movements, depreciation rates, availability of local and export markets, present infrastructure, size of farm or production unit and effective agricultural area accessibility and location, influence of government policy (Johnson et al., 1994). The economic situation of a crop on the world market is very important (Sys, 1985). This includes results given in terms of profit and loss, for each kind of land. Obtaining the cost of inputs, cost of conservation, reclamation, management practices, and value of production (Purnell, 1977).

Land capability and suitability are related to particular inputs and outputs which have economic value. There is a need explicity to incorporate economic as well as biophysical data in the process of land evaluation (Johnson et al., 1991).

2.4. Evaluation methods

2.4.1. USDA system of land capability classification

This is the earliest known land capability system. This system is based on permanent physical land characteristics that limit land use or imposes risks of erosion or other damage that easily can be identified (Beek, 1980).

The system groups soil mapping units in eight capability classes on the basis of their capability to produce common cultivated crops and pasture plants over a long period of time (Beek, 1980) .The system is one of a general appraisal and not related to a specific land utilization type. However, the preferential utilization type and land use is reflected in the classes (Sys, 1985)

The classification is subjective insofar as the only criteria guiding classification are verbal descriptions for each classes (Ive et al., 1985). The main aim of land capability classification method is to assess the degree of limitation to land use or potential imposed by land characteristics on the basis of permanent properties (Davidson, 1992).

The USDA land capability classification rates land from class 1 (best) to 8 (Worst) according to the intensity of land use it can support and the degree of management that would be necessary to support that intensity. Implicit in this ranking is the assumption that a wider choice of land uses should allow the farmer more opportunities for income, and less stringent management requirements should result in lower cost of production (Rossiter, 1995).

Singer (1978) stated that systems indicating land capability for agriculture were developed to group soils with similar management problems for interpretive purposes, not to define which lands should be reserved for agriculture.

Despite its lack of explicit criteria, the USDA classification has been internationally accepted and modified to suit particular environments or special agricultural activities.

2.4.2. The FAO system of land evaluation

The system is based on basic concepts, principles, and procedures for land evaluation that are applicable in any part of the world (FAO, 1976).

The central concept of the FAO framework for land evaluation is the use of land qualities-complex attributes of land that act in a distinct manner on a specified LUT (FAO, 1976, 1983). Land utilization types defined according to the FAO (1976) as "a specific subdivision of a major kind of land use which should be defined in terms of produce or management".

Land qualities cannot be measured directly. Instead several measurable land characteristics that directly influence the chosen land qualities are used (Chinene, 1992).

The most typical feature of the framework procedures is the comparison of present or future land conditions with the most preferred conditions through an iterative adjustment process called "matching" (Diepen, 1991).

The FAO suitability classification system was employed at the levels of order, class, and sub-class (Shankarnarayan et al., 1984).

Immediate problems for the land evaluator are to choose relevant land qualities and land characteristics of predictive value and to combine the ratings of land qualities into an overall evaluation of land suitability (Chineue, 1992).

Application of the FAO framework for land evaluation can identify the most limiting land qualities, and provide a good basis for advising farmers on appropriate management practices (Chinene, 1992).

The FAO framework does allow the use of land characteristics directly to assess suitability, but it is generally clearer to use land qualities as an intermediate level of evaluation (Rossiter, 1994).

2.4.2.1. Land suitability order

The classification approach of the FAO framework for land evaluation (FAO, 1976) was adopted in terms of two suitability orders (S for suitable and N for unsuitable) (Theocharopoulos et al., 1995).

The purpose of classification, at the order level, is to minimize the risk of misunderstanding by establishing the basis meaning of more detailed interpretation (Sys, 1985). The order should always be quoted in the classification symbol, therefore, even when only one order of land is represented in the survey area (Sys, 1985)

2.4. 2. 2. Land suitability class

The following five land suitability classes where used: class S1-highly suitable, class S2-moderately suitable, class S3-marginally suitable NS not suitable (Theocharopoulos et al., 1995)

However, it has been recommended to use only 3 classes within order S and 2 classes within order N (Sys, 1985). The suitability class may be made equivalent to the rating of the most limiting land quality (Chinene, 1992).

The class will be indicated by an Arabic number in sequence of decreasing suitability within the order, and therefore, reflects degree of suitability within the orders (Sys, 1985).

The overall suitability assessment of mapping units has to be based on a weighting of the relevant properties or the principle of limiting factors (Dean, 1994).

Soils with the most favourable physical suitability class do not necessarily have the highest net return, and vice versa. Generally mapping units with the most favourable physical suitability class obtained the highest net returns (Johnson et al., 1994).

2.4.2. 3. Land suitability sub-classes

These are divisions of suitability classes which indicate not only the degree of suitability (as in the suitability class) but also the nature of the limitations that make the land less suitable (So, suitability class S1 has no Subclasses) (Rossiter, 1994).

The subclasses reflect the kinds of limitations or main kinds of improvement measures required, within classes, (Sys, 1985).

2.4.3. Land utilization types (LUT)

Rossiter (1996) defined the land utilization types as a specific land-use system with specified management methods in a defined technical and socio-economic setting, and with a specific duration or planning horizon.

The characterization of land utilization types may include a variety of factors according to the detail and purpose of the land evaluation study (Beek, 1980). The concept of land utilization type (LUT) proposed by the FAO explicity includes the social and economic context in which the land use system is to be applied (Rossiter, 1995).

The land use requirements are the most fundamental aspects of the land utilization types for purposes of land evaluation. The land use requirements of a LUT determine to a great extent which land resources data need to be studied and in how much detail (Beek, 1980).

The suitability of a given type of land can be defined only be satisfying the question "suitability for what" (Rondal, 1985).

Constraints on production factor such as labour and capital affect the feasibility of the LUT (Rossiter, 1995). Determining appropriate LUTs for rainfed areas could help improve overall productivity (Rondal, 1985).

2.4.4. Land quality

A land quality is considered as a complex attribute of the land that acts in a distinct manner in its influence on the suitability of land for specific kind of use (Sys, 1993).

A land quality is an asset of the land for a specific use. This concept is opposed to the land limitation concept used in land capability classification. A land limitation is a liability of the land (FAO, 1977).

Rossiter (1996) defined land quality as a complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use. The land qualities of the land mapping unit must meet the requirements of the LUT for that suitability class (Chinene, 1992).

Land qualities are described in terms of measurable land characteristics derived from the land mapping units. Within each land quality a number of constituent single or minor compound land characteristics would have to be distinguished for rating the land qualities to which they belong (Beek, 1980).

Land qualities which directly affect land suitability in a more or less independent manner, and which usually can not be directly or routinely measured (Rossiter, 1995). Land qualities must be estimated or inferrred from a set of diagnostic land characteristics (Rossiter, 1995).

Land quality is related to only one or two characteristics, the matching exercise is easy and the determination of optimal and marginal situation will remain feasible.

It is important for the choice is the fact that to be valuable for use in land evaluation selected diagnostic criteria (characteristics and /or qualities) should offer the possibility to define in clear comprehensive terms to optimal and marginal situation for the different land utilization types (Sys, 1993).

2.4.5. Land characteristics

A land characteristic is an attribute of the land which can be measured or estimated and which can be used for distiguishing between land units of differing suitabilities for use and employed as a means of describing land qualities (FAO, 1983).

The land characteristics are measured or estimated in rotuine survey (Rossiter, 1995).

The effects of a land characteristics on suitability are not direct, but through their effect on land qualities. This is because a single land characteristics may affect several qualities often in contradictory ways (Rossiter, 1994).

Land characteristics are directly available in land resources inventory. Their use may be easier for land evaluation. However those who prefer to elaborate the required matching exercise to transfer characteristics into qualities may also achieve good evaluation results (Smith et al., 1984).

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 for each quality there is a level of suitability as S1 (very suitable), an S2 (moderately suitable), an S3 (marginally suitable), NS (not suitable). According to this procedure suitability classes should be defined in a function of the evaluation procedure therefore three methods have been compared (Sys et al., 1990).

2.5.1. Simple limitation method

The simple limitation method defines land classes on the basis of the most severe limitation.

This method consider as the most simple method for qualitative land evaluation (Sys, 1993), and the types of limitations that is responsible for lowering the suitability classes are the basis for defining subclasses (Dent and Young, 1981).

The land characteristics are compared with the crop requirements and the land class in attributed according to the less favorable characteristics (Sys, 1985).

This simple evaluation method has the advantage that interactions between characteristics do not intefere as such. Greater number of characteristics can be used with out influencing the evaluation (Sys, 1985).

2.5.2. Limitation method

The limitation method defines land classes with respect to the number and intensity of limitations (Sys, 1993). Limitations are deviation from the optimal conditions of a land qualities which adversely affect the kind of land use (Sys et al., 1990).

This method requires great attention for interactions between characteristics/qualities (Sys, 1993).

The limitation method provides somewhat more information on the land conditions. To avoid interactions between the characteristics a minimum set of diagnostic criteria should be used (Sys, 1993).

2.5.3. Parametric method

The parametric approach in the evaluation of land characteristics consists in attributing numerical rating to the different limitation levels of the land characteristics in a numerical scale from a maximum (normally 100) to a minimum value (Sys, 1993).

The parametric method is useful in research because they express the value of the land as a numerical index which is easily to correlated with yield (Purnell, 1977).

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 (Huddleston, 1984).

In the parametric method a natural rating is attributed to the limitation levels. Classes are arbitrary defined according to the value of the land index (Sys, 1985). The calculation of a corrected land index from each calculated parameter value has been suggested.

2.5.4. Parametric approaches

2.5.4.1. Additive method

Additive method has been used in Germany since 1920s. It was mainly used for land taxation purposes (Diepen et al., 1991). The additive method assumes that all the influences of the different factors add together without interference, even this doesn't represent the nature (Purnell, 1977). Several soil properties where assigned numerical values according to their impact on plant growth. These numbers must be summed or subtracted from a maximum rating of 100 to derive the final rating (Diepen et al., 1991).

2.5.4.2 Multiplicative index

A. Land index

The storie index considered as an example of multiplicative parametric system. The factors are rated on a scale from 0 to 100 (Sys, 1985).

The system depends on the choice of determinates, their weighing, and the validity of the assumed multiplicative interaction between the factors. The number of factors should be kept at a minimum to avoid very low index values. Land indices are the final result of land evaluation (Diepen et al., 1991).

B. Productivity index

Productivity ratings derived from objective, as indicators of the relative quality of soil resources for crop productions. Crop yield is a prefer method of expressing productivity, if crop yield data where available for all crop soil combinations encountered. Therefore, empirical ratings derived from soil properties are widely preferred (Huddleston, 1984). The individual land or soil characteristics are assessed individually and then arithmetically combined (Young, 1976).

The major advantage of combined systems is the ability to incorporate information from several soil factors without minimizing the impact of one or two major limitations (Huddleston, 1984). While the disadvantages of systems of this type are their rigidity and restricted applicability. All of those cited are able to demonstrate good conrrelations between the productivity index and yields of a particular crop within the area for which the index was developed. As soon as one system is transferred to a substantially different climate the ratings require substantial alteration (Young, 1976).

2.6. Land Use planning

Land use planning is a decision support system for land use planning, to assist decision makers in the assessment and evaluation of alternative strategies for the tactical and operational land use plan (Sharifi et al., 1994). In order to plan effectively for the use of land, there is a need to develop an ability to assess land resources with respect to alternative sets of conditions and goals (Flaherty and Smith., 1982).

This means addressing fundamental conflicts between the demands of individuals for use of the land now and the needs of community for productive use of the land in the longer term (Dent, 1988).

Land use planning was introduced (to follow land evaluation) in the expectation that this would produce results more directly relevant for planners (Putte, 1989). Land evaluation creates an interface between land-related information and the integrated information requirements of land use planning (Smit et al., 1986).

Without adequate data rating to biophysical and economic factors that influence resources use, land use planning will not necessarily promote societal goals (Smith and Estes, 1987). If land use planning, based on proper land evaluation is considered as the ultimate practical use of soil science, a considerable effort is still required to sort out and to quantify the criteria to be used for the desired land use purposes (FAO, 1977).

The presence of an improved information base can have a positive impact on land use planning activities (Johnson et al., 1994). Part of the solution of the land-use problem is land evaluation in support of rational land-use planning and appropriate and sustainable use of natural and human resources (Rossiter, 1996).

Any land use planning system requires an information system which serve land resource programs have direct bearing upon the effectiveness of identifying and satisfying land use policy, planning, and program objectives (James et al., 1976).

To facilitate the decision-making process, data for different land uses must be presented in a form which allows for the comparison between uses, based on some common measure of performance (Johnson et al., 1994).

Evaluation of land suitability and potential is a major step forward in land use planning (Zhu et al., 1996). Land use planning is a cyclic rather than a finite procedure, and land evaluation techniques need to be able to accommodate changing conditions and alternative scenarios for the future (Smit et al., 1984).

2.7. GIS as a tool for land evaluation

A GIS is an integrated suite of computer based tools which facilitates the inputs, processing, display, and output of spatially referenced data (Theocharopoulos et al., 1995).

One outstanding merit of GIS is the ability to apply filter or sieve mapping to find points, lines, or areas that meet defined conditions (Theocharopoulos et al., 1995).

Geographic information system (GIS) principles are applied to facilitate information management, analysis of spatial data in relation to thematic data and finaly transfer and present the results in a manageable, communicable and easy understandable format. GIS technology is also applied as flexible method for solving multiple objective problem that could not have been easily addressed (Sharifi and Vankeulen, 1994).

The use of a GIS meant that land suitability maps could be combined in order to predict potential land-use patterns (Theocharopoulos et al., 1995). The advent of geographic information system (GISs) has created the capability of combine information from many different sources and relate them on a common spatial basis (Sharifi et al., 1994). The use of a GIS is a considerable help in saving time and thus cost in data management and presentation. It must also be noted that corrections and update to the data and maps are more easily achieved (Theocharopoulos et al., 1995).

A GIS may be viewed as a data base system in which most of the data are spatially indexed, and upon which a set of procedures operates in order to answer queries about spatial entities in the data (Smith et al., 1987).

The user can also structure his or her own land-use problems and build land-use models by empolying the existing GIS (Zhu et al., 1996). GIS principles are applied to facilitate information management, analysis of spatial data in relation to thematic data, and finally transfer and present the results in a manageable, communicable and easy understandable format (Sharifi et al., 1994).

3. Materials and Methods

3.1. Study area

The study area is located East of Jiza, 40 km South East of Amman (Figure 1). It covers an area of 131 square kilometers. It is located within latitudes (495,000-515,000) North, and longitudes (400,000-415,000) East using UTM system.

The study area is located within the arid to semi-arid regime in Jordan (Figure 2). It is located within Jordan highland plateau consisting of a series of undulating plains and rounded hills formed mainly in rocks of Belqa formation (Bender, 1974). Very finely dissected limestone and chert plateau.

The population density is low in the area except in Qnatra village located at the border of the catchment with the population number of about 1200 person. The total area planted with winter cereals especially barley and it is estimated at 50700 dunums. The irrigated and rainfed land produce 300 and 7000 tons, respectively. The number of vegetable-planted green house is 175 and produce about 580 tons (Personal Communication).

Figure (1): Map of Jordan, showing the location of Um Al-Rasas study area

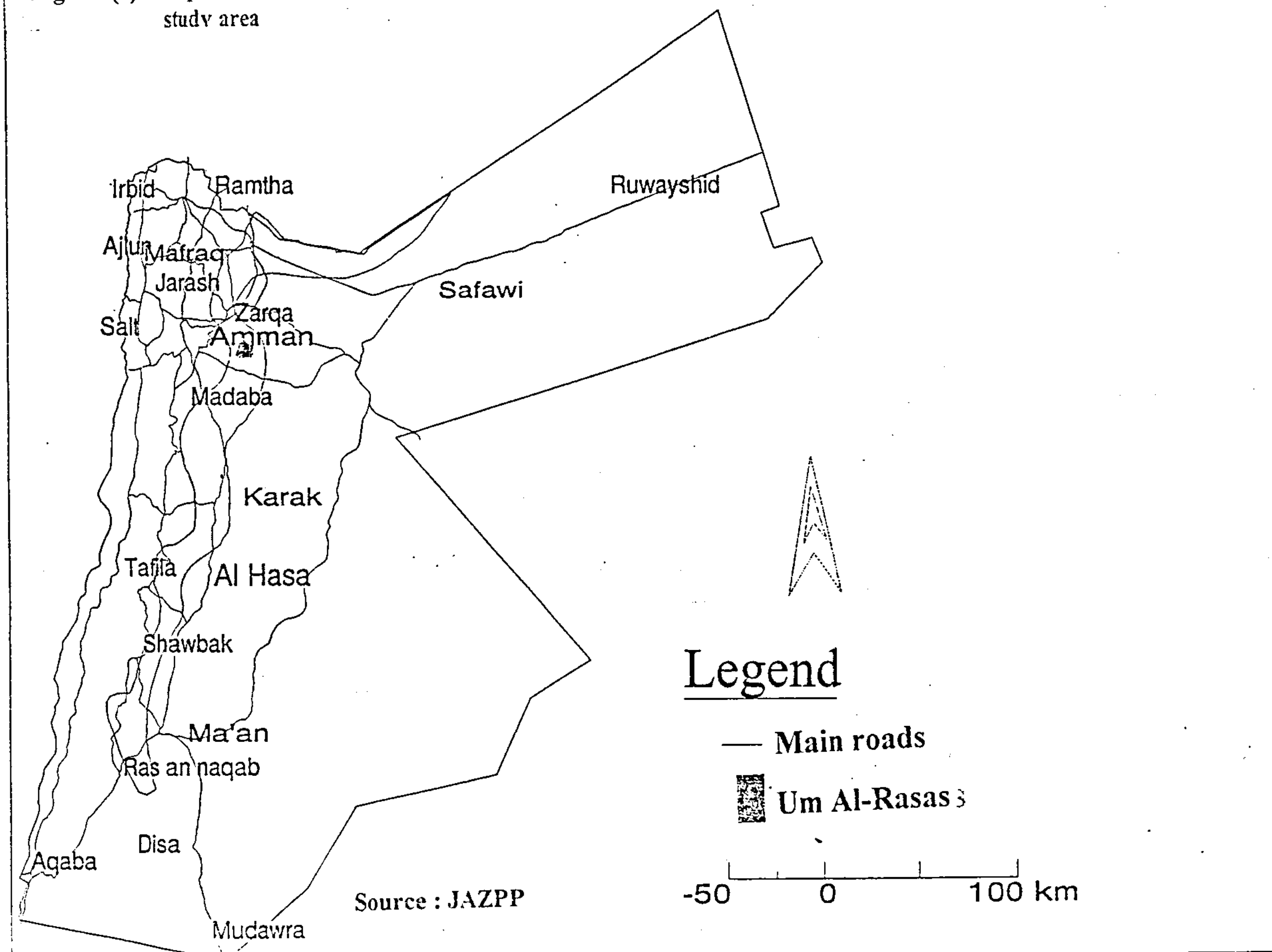
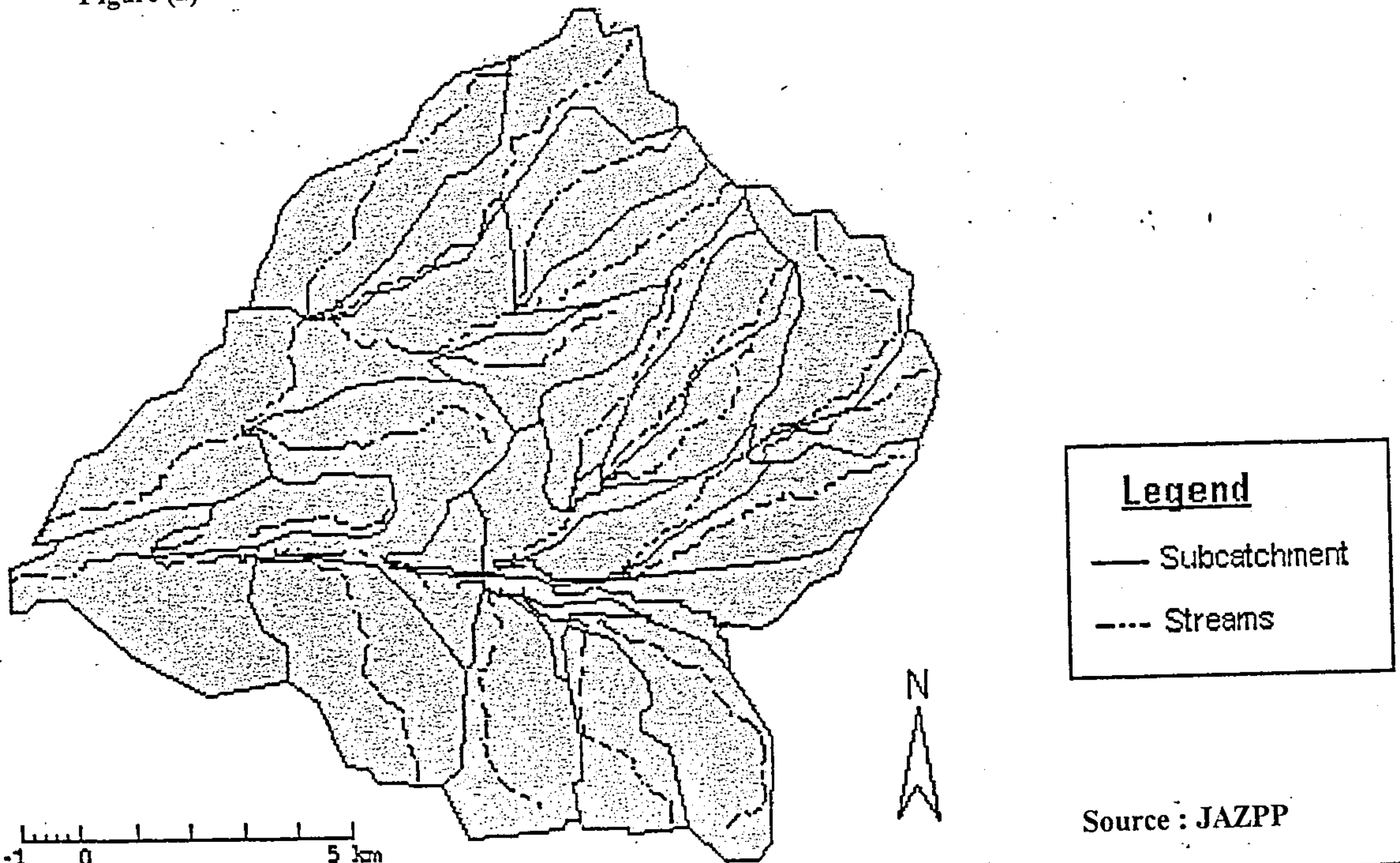


Figure (2): Subcatchment and streams



Source : JAZPP

The area planted with fruit trees, both irrigated and rainfed, is estimated at 5800dunums primarily apple, peaches. The area planted with olive trees is estimated at 200 dunums (NSMP, 1995).

The area lies within the xeric-aridic transitional moisture zone. The annual of precipitation varies from 175 to 200 mm.

The slope varies from 3-10 %. General steeper slope occupies the Western portions. The region varies in altitude from a minimum of 550 m a.s.l. in the North, to nearly 900 m a.s.l. in the extreme South.

The natural vegetation cover is weak and scattered. The main vegetative cover consist of small shrubs and grasses. Rainfed agriculture is practiced with some scattered farms of irrigated orchard and vegetable crops.

The main factors causing degradation of the soil of the study area are climate and improper cultivation practices such as rainfed agriculture in the areas with no potential.

Overgrazing is a major problem regarding the use of rangeland and had resulted in the invasion of less desirable plant species and increased soil erosion especially in the steppe lands.

Increasingly, the lower and middle hill slopes are being ploughed every year for barley production. Rainfall is rarely adequate to produce reasonable crop. Failure, or, at best, limited vegetative growth is common.

3.2. Geographic information system (GIS) technique

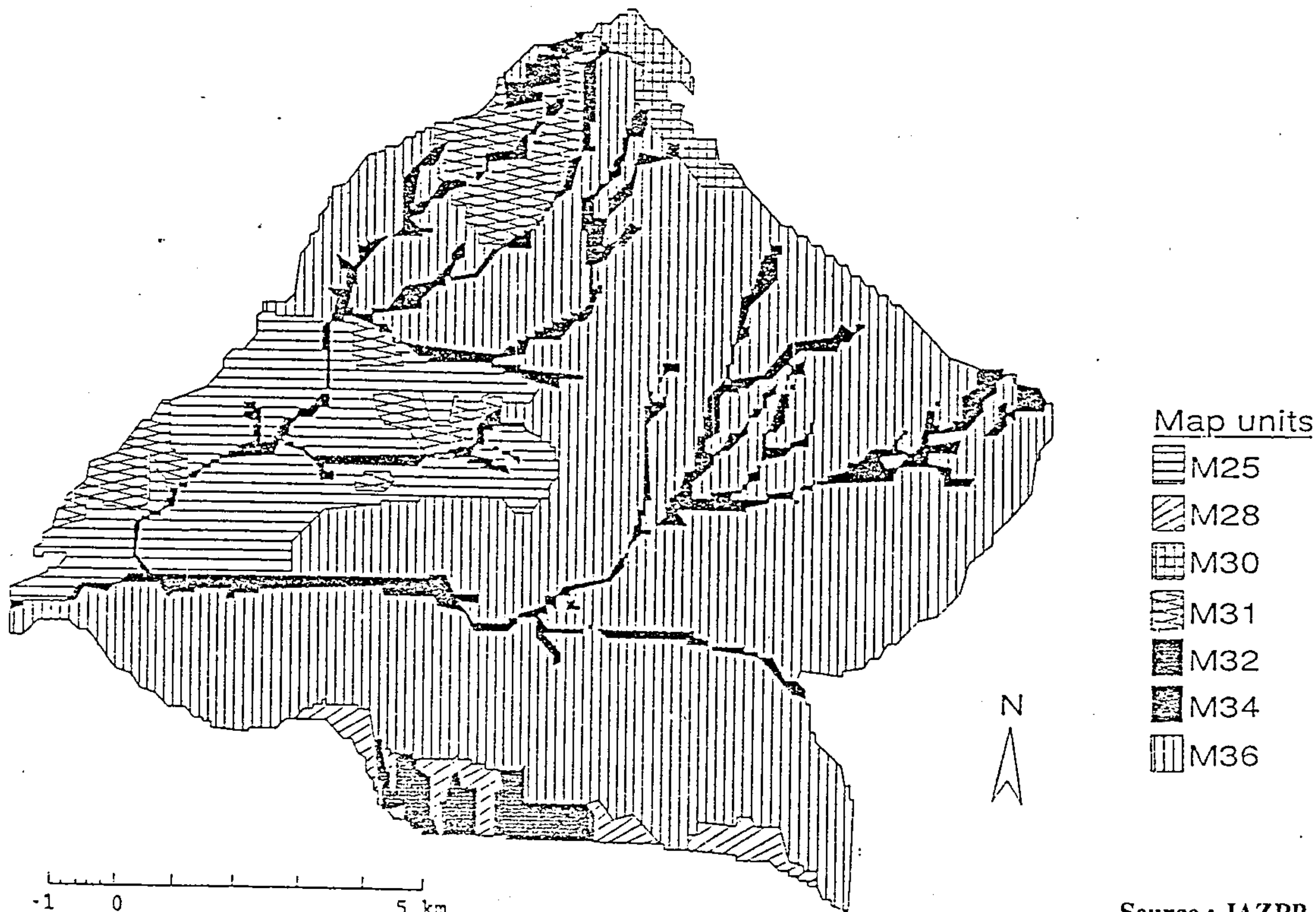
A geographic Information technique was used to construct suitability maps for the study area using international systems.

The GIS works include the following steps:

3.2.1. Digitizing

Data available from National Soil Map Project, (level2) semi-detailed level at a scale 1:50,000 was used. The boundary of the study area was digitized beside the mapping units to convert the map into digital form as shown in (Figure 3). Each mapping unit consist of soils association classified at the subgroups level (Appendix A). The procedure use to delineate the varies mapping units is given in national soil map project. The description of the soil including color, depth, texture, reaction, salinity, gradient and topographic position.

Figure (3): Soil mapping units



Source : JAZPP

Detailed interpretation for current land cover was carried using 1:50,000 landsat image. The detailed land cover map was digitized.

3.2.2 Socio-economic data

Socio-economic attributes such as population density, demographic characteristics, current land use, land tenure represent an important reference for the selection of pertinent land utilization types. They constitute the context of physical land evaluation whereas the physical land conditions are the main object in land evaluation. Current land use was selected and was georeferenced as a factor that could be related to the evaluation output.

3.2.3. Current land use

This current land use is georeferenced and can use GIS technique. Landsat image at a scale of 1:50,000 was used to make detailed interpretation for land cover in the study area. The developed FAO land cover legend was used as a guide for land cover interpretation, (Jordan Arid Zone Productivity Project under supervision of land use component A, Awni Taimeh, 1998).Then the detailed map was digitized and saved in digital format.

The FAO legend divides land cover into seven main elements. These elements has been divided as appropriate into sub-elements.

The main elements are:

1. Urban land use and associated non-agricultural land.

2.Horticultural crops, unirrigated and irrigated.

3. Open field crops and fallow land.

4. Orchard crops.

5. Rangeland, high intensity range >30% percentage ground cover.

Low intensity range >30% percentage ground cover.

6. Forest and other wooded land.

7. Unvegetated land.

After land cover interpretation was done in the GIS lab using satellite image, then problematic areas were denoted on the imagery by small remark, and traverses were planned to investigate these areas. Start and finish points on there traverses were marked on the overlays, and in the vehicle decimal km points and land cover units to the left and the right of the road were dictated by observations being spaced at intervals averaging 0.3 km. Data were then transferred from the record sheets to the overlays on the imagery, and from this data boundary lines were drawn between different individual units or complexes of units. Then the detailed map was digitized and saved in digital format.

Rangeland is divided into two categories on the basis of percentage ground cover. In general rangeland does not show regular, small, rectangular field boundaries, but has a tonal pattern entirely dictated by natural features.

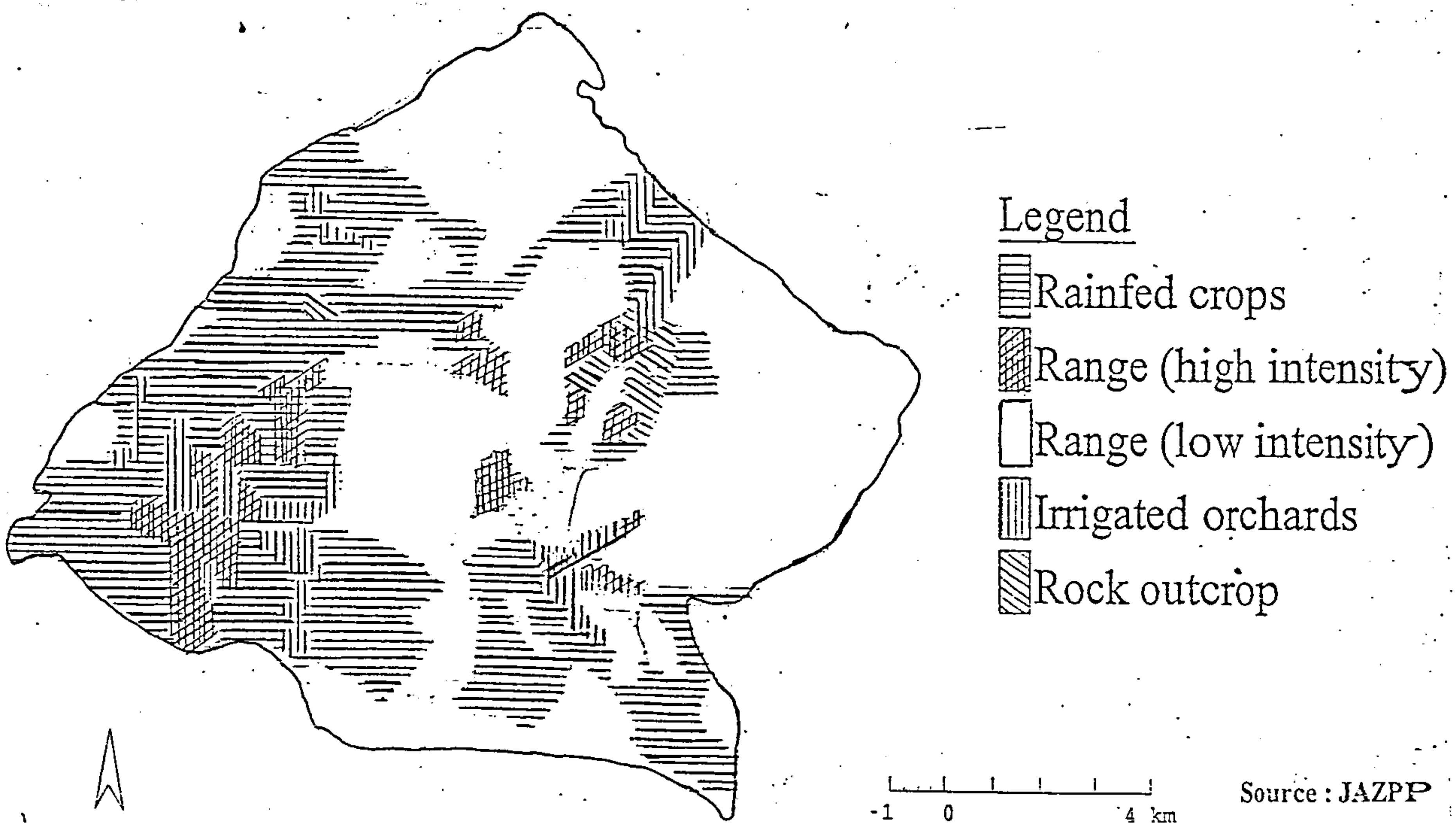
High percentage ground cover >30% can be recognize on the map with tones darker and redder than 5 YR 5/6. In the field 1 square meter was located and estimate the percentage of range cover per 1 square meter.

Low intensity range cover <30% generally areas corresponded to tones lighter than 5 YR 5/6, and in the field the range cover density is less than 30% per area of 1 square meter.

The land cover in the study area shows four kinds of uses as shown in Figure (4) as follows:

- Low intensity range cover <30% about 44.22% (56188 dunums) of the total area .
- High intensity range cover >30% about 8.18% (10394 dunums) of the total area.
- Rainfed agriculture cover 39.9% (50700 dunums) of the total area.
- Irrigated orchards cover 6.09 % (7734 dunums) of the total area.

Figure 4: Land cover of Um Al-Rasas



3.2.4. Data retrieval and collection

A. Missing data

The study area comprise seven mapping units, one site had been chosen for measuring infiltration rate in each mapping unit using the sprinkler infiltrometer method (Hatten, 1996).

Representative rectangular area of 0.75x1 meter was selected. The corners of the rectangle were marked with small sticks. On the downward side of the slope, the soil is cut away from the lower edge for a depth of 10cm. The face being angled into the slope, and a collector tray is placed so that it can collect any run-off from the plot.

Four catch-cans are placed within the rectangle in order to record depths of the distilled water applied to reduce the affect of salts on infiltrometer rate.

The process is repeated several times for a duration of 1 hour. The cumulative water levels in the cans being recorded each time as shown in Appendix C.

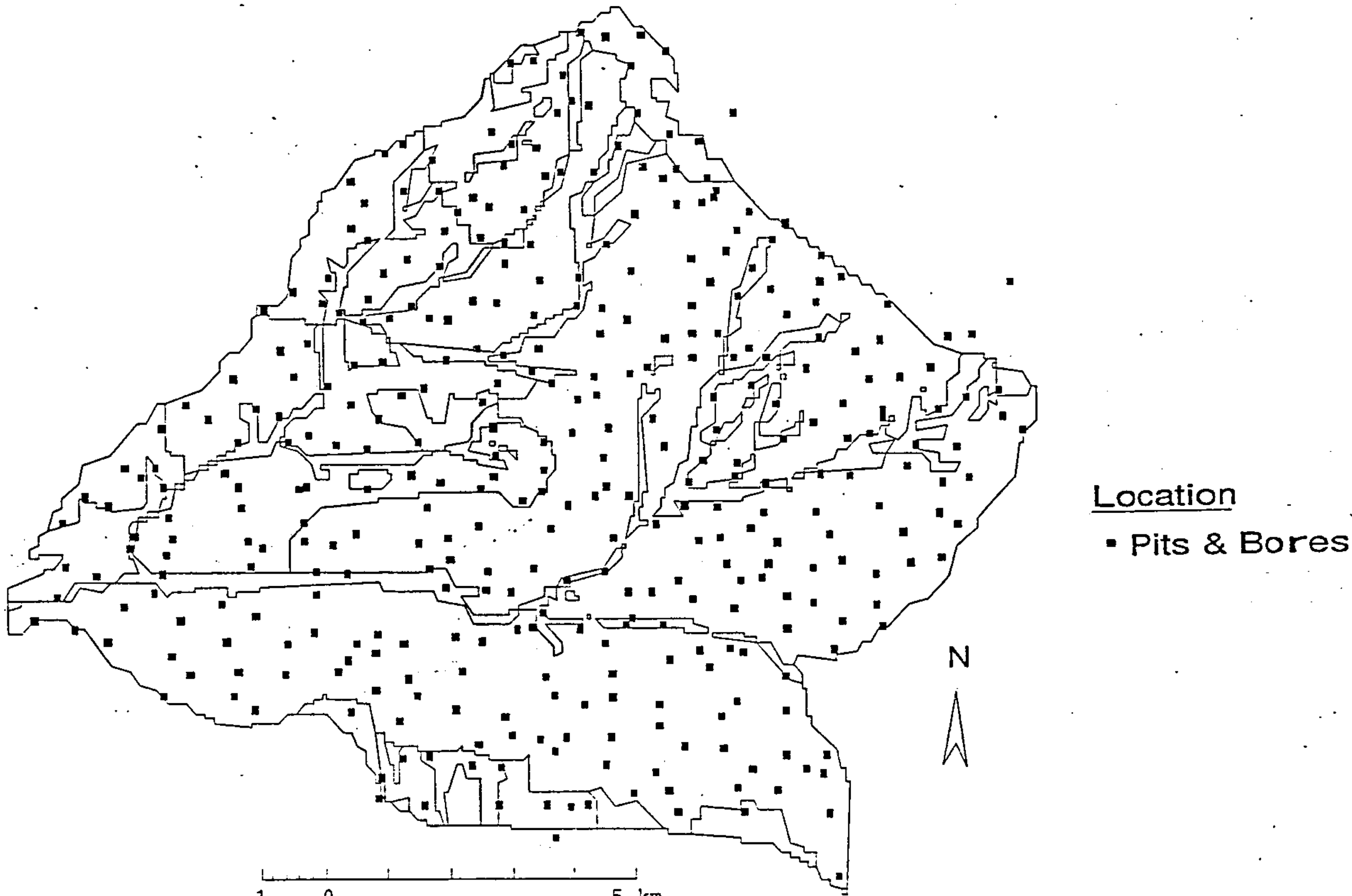
Salinity, alkalinity, and calcium carbonate content were measured in the laboratory for each mapping unit within the study area. Soil salinity of (ds/m) was measured on 1:1 soil to water. Exchangeable Sodium Percentage (ESP) and Sodium Absorption Ratio (SAR), was calculated from Ca, Mg using titration method (ICARDA, 1996) and Na measured by using flame photometer (Chapman and Part, 1961).Calcium carbonate was measured using Calcimeter (ICARDA, 1996).

B. Types of available data

The data was obtained from National Soil Map and Land Use Project for Jordan. The project was carried by Ministry of Agriculture in cooperation with commission of the European Communities. The established database was given a title of Jordan soils and climate information systems (JOSCIS) and have the following data: rainfall, temperature, soil properties, available water holding capacity, elevation, slope, surface cover types percentage, erosion, drainage classes, chemical and physical analysis.

Attributes relevant to the mapping units occuring with the study were imported from the National Soil Map Project database. These attributes were geographically referenced. The locations of representing pits and bores were imported among other attributes. The number bore holes and pits located within the study area were 32 and 34, respectively. The location of these sites are shown in Figure (5).

Figure 5: Location of pits and bores



Profiles representing the mapping unit as follows:

Map unit	Representative profile
M25	PM300, PM 302, PM304, PS111, PH150
M28	PG109, PM213, PM221, PM225, PS53, PS 63, PS110
M30	PB93, PB100, PB107, PH184, PH186
M31	PM286, PM 316, PM317, PM322
M32	PM324, PS77, PG200, PG171
M34	PB105, PG2, PB110, PD65
M36	PM312, PM314, PM305, PB97, PG6

Imported attributes were stored in the GIS as point files. Then single file was created containing the required fields using SPAN-Map. The output file to be used in the suitability analysis contains all mapping units in the study area with their relevant attributes.

3.2.5 Average and modal calculation

For the purpose of suitability analysis, each mapping unit should have a representative value for each parameter used in the evaluation.

The calculations of average were done for each parameter that represent a numerical value of measured property. While the modal value were those that are described as a class or type. Average and modal calculation is shown in table (1).

Table (1) :Average and modal values for the different mapping units (JOSCIS, 1995)

Map Unit	* Rainfall mm	* WGPT Deg.day>8C°	* AWHC mm/100cm	* Soil Depth cm	*$CaCO_3$ %	* EC mmhos/cm	* ESP %	**Erosion Type	**Erosion class	**Surface cover Type	*Surface cover %	*Slope %	*Stoniness	* Infiltration Rate mm/hr
M25	216	415	131.4	86.2	18.5	0.3	0.9	5	2	4	6.0	3.3	8.4	18.1
M28	182	398	107.3	65.0	18.0	0.4	6.3	1	1	3	3.6	6.0	6.7	17.3
M30	181	368	50.0	47.6	19.0	0.4	0.1	1	2	3	17.0	5.0	15.2	10.1
M31	225	413	102.7	66.4	22.5	0.4	8.0	1	1	4	5.6	2.9	9.0	15.2
M32	175	397	94.8	73.2	22.2	1.5	3.8	2	2	5	18.5	5.8	16.3	11.8
M34	195	401	141.2	90.5	21.5	0.3	9.0	5	2	5	3.4	2.3	6.0	22.1
M36	188	399	132.9	84.7	18.5	0.5	0.4	2	2	3	4.7	2.4	9.0	20.6

* Average Values
** Modal Values
Erosion type
1. sheet erosion
2. rill erosion
3. undifferentiated

Erosion class
1. slight
2. moderate

surface cover type
1. gravels
2. stones
3. boulders

The parameters with average values were: rainfall, temperature, slope, $CaCO_3$, Salinity of surface horizon, alkalinity of surface horizon, soil depth within 0-120cm, surface cover percentage, stoniness, and available water holding capacity within 0-100cm. Modal values were estimated for three types of erosion (sheet, rill, undifferentiated) and class, surface cover type (rock, stones, gravels), and drainage class.

3.3. Steps of land evaluation

FAO guidelines had been used for land evaluation because the FAO framework is a dynamic system and aims to predict the effect of changes in land use through understanding of the relationships of both physical and socio-economic.

FAO framework can be used at any scale and at any level of precision and provide practical guidelines to assist in carrying land evaluation for rainfed agriculture.

This system is based on the following principles:

1. Land suitability is assessed and classified with respect to specific kinds of use.
2. Evaluation requires a comparison of the outputs obtained and the inputs needed on different types of land.
3. A multi-disciplinary approach is required.

4. Evaluation is made in terms relevant to the physical economic and social context of the area concerned.

5. Suitability refers to use on a sustainable basis.

6. Evaluation involves comparisons of more than one kind of use.

A fundamental procedure in land evaluation refers basically to the matching of land-use requirements with attributes of land mapping units. These requirements are grouped into land qualities with their relevant characteristics in which they are matched with the proposed land utilization types (LUT's).

3.3.1. Land utilization types

According to the principles of the FAO (1976) framework land suitability is assessed and classified with respect to specified kinds of use.

Land suitability analyses have been conducted to assess the suitability of the area for the following types of utilizations:

1. Rainfed
2. Barley
3. Range

These land utilization types were selected because they are the main types dominant in the study area under existing land use.

The bases of the land evaluation is based on the potential suitability of the land to avoid soil degradation and at the same time to sustain productivity.

3.3.2. Criteria for each land utilization type

A. The general criteria use for FAO as follows:

1. Moisture availability :	Mean annual rainfall
	Available water holding capacity (AWHC).
2. Temperature regime:	Winter growth potential (WGPT)
3. Rooting conditions:	Soil depth
4. Soil toxicity:	$CaCO_3$
5. Erosion hazard:	Erosion type
	Erosion severity
6. Topography:	Slope
7. Salinity hazard:	Salinity
8. Alkalinity hazard:	Sodicity

Land qualities have been classified into five main groups, denoted by a code letter as follows:

c: climate.

s: soil.

e: erosion.

r: rockiness/stoniness.

t: topography (slope).

n: salinity/alkalinity.

i: infiltration rate.

Table (2) shows the criteria and their relevant characteristics and units followed by FAO.

Table (2): Required land qualities and their relevant characteristics for land evaluation for rainfed agriculture.

Land Quality	Land characteristics	Unit	Grouping criteria
1. Moisture availability	Mean annual rainfall	mm	Climate (c)
2. Temperature regime	winter growth Potential	deg.day over 8 C^{o}	
3. Moisture availability	Available water holding capacity (AWHC)	mm/m	Soil (s)
4. Rooting conditions	Soil depth	cm	
5. Soil toxicity	$CaCO_3$	%	
6. Erosion hazard	Erosion type Erosion severity	type class	Erosion (e)
7. Terrain	Slope	%	Topography (t)
8. Rooting. conditions	Rockiness Boulders and stones Stoniness of surface Horizon	% % % %	Rockiness (r)
9. Salinity hazard 10. Alkalinity hazard	Electrical conductivity ESP	mmhos/cm %	Salinity/ Alkalinity (n)

B. Criteria used for FAO, rainfed agriculture:

1. Mean annual rainfall: the optimum requirement not less than 250mm.
2. Winter growth potential: the requirement more than 250 degree.day over 8°C.
3. Total available holding capacity (AWHC): the requirement more than 150mm/100cm.
4. Soil depth: more than 90cm.
5. Calcium Carbonate: the best requirement varies from 0-30 %.
6. Slope: the requirement less than 4%.
7. Salinity: the requirement must be less than 2ds/m.
8. Sodicity: the requirement must be less than 15%. The land suitability criteria for rainfed agriculture is shown in Table (3)

Table (3): Land suitability criteria for rainfed agriculture

Land Quality/Land Characteristics	Unit	S1	S2	S3	ns
Climate (c)					
Mean Annual Rainfall	mm	>250	200-250	150-200	<150
Winter Growth Potential (WGPT)	deg.day>8C°	>250			
Soil (s)					
Total Available Water Holding Capacity (AWHC)	mm/100cm	>150	110-150	75-110	<75
Soil Depth	cm	>90	60-90	30-60	<30
Total Calcium Carbonate	%	0-30	30-40	40-60	>60
Erosion (e)					
Erosion Hazard 2= Rill or 3= Gully *	Type	1	2	3	4
Erosion Hazard 1=Sheet 4 = Wind 5 = undifferentiated**	Class	2	3	4	
Topography (t)					
Slope	%	<4	4-8	8-16	>16
Rockiness (r)					
Rock Outcrop (SF-COV=2)	%	<5	5-10	10-20	>20
Stone at the surface (SF-COV= 3, 4, 5)	%	<20	20-40	40-60	>60
Stone Content of surface horizon (stoniness)	%	<10	10-20	20-30	>30
Salinity/Alkalinity (n)					
EC	ds/m	0-2	2-4	4-8	>8
ESP	%	0-15	15-25	25-35	>35

(Jordan Arid Zone Productivity Project under supervision of land use component A, Awni Taimeh, 1998)

* 1- nil 2- slight 3- moderate 4- severe

** 2- slight 3- moderate 4- severe

C. Criteria use for barley

1. Mean annual rainfall: requirement more than 250mm.
2. Winter growth potential: the requirement more than 250 degree.day over 8°C.
3. Total available holding capacity (AWHC):more than 150mm/100cm.
4. Soil depth: more than 50cm.
5. Calcium Carbonate: less than 20%.
6. Slope: less than 2%.
7. Salinity: the requirement must be less than 12ds/m.
8. Sodicity: less than 25%.
9. Infiltration rate: the best criteria is more than 16mm/hr.

The land suitability for barley is shown in Table (4)

D. Criteria used for range

1. Mean annual rainfall: the requirement more than 100mm.
2. Winter growth potential: more than 400 degree.day over 8°C.
3. Total available holding capacity (AWHC):more than 90mm/100cm.
4. Soil depth: more than 50cm.
5. Calcium Carbonate: more than 30%.
6. Slope: less than 20%.
7. Salinity: less than 8ds/m.
8. Sodicity: less than 15%.
9. Infiltration rate: more than 10mm/hr.

The land suitability criteria for range is shown in Table (5)

Table (4): Land suitability criteria for barley

Land Quality/Land Characteristics	Unit	S1	S2	S3	NS
Climate (c)					
Mean Annual Rainfall	mm	>250	200-250	150-200	<150
Winter Growth Potential (Deg. days over 8 °C)	°C	>250			
Soil (s)					
Total Available Water Holding Capacity (AWHC)	mm/100cm	>150	110-150	75-110	<75
Rootable Depth	cm	>50	20-50	10-20	<10
Salinity EC	ds/m	0-12	12-16	16-20	>20
Alkalinity ESP	%	0-25	25-35	35-45	>45
Calcium Carbonate	%	0-20	20-40	40-60	>60
Erosion (Erosion hazard for 2 rill or 3 gully *	type	1	2	3	4
(Erosion hazard for 1 sheet 4 wind or 5 undif ** (1= Nil, 2 = slight, 3 = moderate, 4= severe)	Class	2	3	4	
Topography (slope %) max. value	%	<2	2-4	4-6	>6
Rockiness Rockoutcrop	%	<5	5-10	10-20	>20
Stone % at surface	%	<15	15-35	35-55	>55
Stone content of surface horizon %	%	<10	10-20	20-30	>30
Drainage	class	well	moderately well	imperfectly	poorly/V. poor
Infiltration rate	mm/hr	>16	8-16	4-8	<4

(Jordan Arid Zone Productivity Project under supervision of land use component A, Awni Taimeh, 1998)

* 1- nil 2- slight 3- moderate 4- severe

** 2- slight 3- moderate 4- severe

Table (5): Land suitability criteria for range

Land Quality/Land Characteristics	Unit	S1	S2	S3	NS
Climate (c)					
Mean Annual Rainfall	mm	100-200	50-100	<50	
Winter growth potential (Deg. days over 8 °C)	°C	400	250		
Soil (s)					
Total Available Water Holding Capacity (AWHC)	mm/100cm	>90	60-90	30-60	<30
Soil depth	cm	>50	35-50	10-35	<10
Salinity EC	ds/m	0-8	8-12	12-16	>16
Alkalinity ESP	%	0-15	15-25	25-35	>35
Calcium Carbonate	%	0-30	30-40	40-60	>60
Erosion (e) (Erosion hazard for 2= Rill or 3= Gully *	Type	1	2	3	4
Erosion Hazard 1= sheet 4= wind 5= undifferentiated **	Class	2	3	4	
Topography (slope %) max. value	%	<20	20-40	40-80	>80
Rockiness Rockoutcrop	%	<20	20-50	50-100	
Stone % at surface	%	<30	30-60	60-100	
Stone content of surface horizon %	%	<20	20-50	50-100	
Infiltration rate	mm/hr	>10	8-10	6-8	<6

(Jordan Arid Zone Productivity Project under supervision of land use component A, Awni Taimeh, 1998)

* 1- nil 2- slight 3- moderate 4- severe

** 2- slight 3- moderate 4- severe

E. Criteria used for water spreading for range

1. Mean annual rainfall: the requirement more than 200mm.
2. Winter growth potential: more than 250 degree.day over 8°C.
3. Total available holding capacity (AWHC):more than 150mm/100cm.
4. Soil depth: more than 130cm.
5. Slope: less than 1%.
6. Salinity: less than 4ds/m.
7. Sodicity: less than 15%.
8. Infiltration rate: less than 4mm/hr.

The land suitability criteria for water spreading for range is shown in Table (6)

F. Criteria used for con tour furrows for forage shrubs

1. Mean annual rainfall: the requirement more than 200mm.
2. Winter growth potential: more than 400 degree.day over 8°C.
3. Total available holding capacity (AWHC):more than 110mm/100cm.
4. Soil depth: more than 100cm.
5. Slope: less than 7%.
6. Salinity: less than 4ds/m.
7. Sodicity: less than 35%.
8. Infiltration rate: less than 4mm/hr.

The land suitability criteria for water harvesting as contour furrows for forage shrubs is shown in Table (7).

Table (6): Land suitability criteria for water spreading for range

Land Quality/Land characteristics	Unit	S1	S2	S3	NS
Climate (c)					
Mean Annual Rainfall	mm	>200	150-200	100-150	<100
Winter growth potential (WGPT)	Deg.Day>8c	>250			
Soil (s)					
Total Available water holding capacity (AWHC)	mm/100cm	>150	110-150	75-110	<75
Soil Depth	cm	>130	95-130	65-95	<65
Erosion (e)					
Erosion Hazard 2 = Rill or 3=Gully *	Type	1	2	3	4
Erosion Hazard 1 =sheet 4=wind 5=undifferentiated **	class	2	3	4	
Topography (t)					
Slope	%	<1	1-2	2-3	>3
Rockiness (r)					
Rock Outcrop (SF-Cov = 2)	%	<10	10-20	20-35	>35
Stone at the surface (SF-cov=3, 4, 5)	%	<20	20-40	40-60	>60
Stone content of surface horizon (stoniness)	%	<10	10-20	20-35	>35
Salinity /Alkalinity (n)					
EC	ds/m	<4	4-8	8-16	>16
ESP	%	0-15	15-25	25-35	>35
Infiltration Rate (Terminal IR)	mm/hr	<4	4-8	>8	

(Jordan Arid Zone Productivity Project under supervision of land use component A, Awni Taimeh, 1998)

* 1- nil 2- slight 3- moderate 4- severe

** 2- slight 3- moderate 4- severe

Table (7): Land suitability criteria for water harvesting as contour furrows for forage shrubs.

Land Quality/Land Characteristics	Unit	S1	S2	S3	ns
Climate (c)					
Mean Annual Rainfall	mm	>200	150-200	100-150	<100
Winter Growth Potential (WGPT)	deg.day >8 C	>400	250-400		
Soil (s)					
Total Available Water Holding Capacity (AWHC)	mm/100 cm	>110	75-110	50-75	<50
Soil depth	cm	>100	70-100	40-70	<40
Erosion (e)					
Erosion Hazard 2=Rill or 3=Gully *	Type	1	2	3	4
Erosion hazard 1=sheet 4=wind 5=undifferentiated **	Class	2	3	4	
Topography (t)					
Slope	%	<7	7-12	12-20	>20
Rockiness (r)					
Rock Outcrop (SF-Cov=2)	%	<10	10-20	20-35	>35
Stone at the surface (SF-Cov=3, 4, 5)	%	<20	20-40	40-60	>60
Stone content of surface horizon (Stoniness)	%	<10	10-20	20-35	>35
Salinity /Alkalinity (n)					
EC	ds/m	<4	4-8	8-16	>16
ESP	%	<35	35-50	NL	
Infiltration Rate (Terminal IR)	mm/hr	<4	4-8	>8	

(Jordan Arid Zone Productivity Project under supervision of land use component A, Awni Taimeh, 1998)

* 1- nil 2- slight 3- moderate 4- severe

** 2- slight 3- moderate 4- severe

3.3.3 Land qualities:

The main groups was aggregated into five components:

1. Climate

Two parameters were determined: mean annual rainfall and winter growth potential degree.day above 8°C.

Rainfall was determined for sites within mapping units using daily precipitation data that were stored for the period of early 1950-1992 for many stations and for more than 50 raingauge.

Computer program was used to calculate actual values or average calculated with there mean and standard deviation and expected precipitation at reliability level of 50%. Then the average annual rainfall was determined for each site with regarding to its position based on coordinates.

Winter growth potential (WGPT) defined as the number of degree. days above 8°C for the three coldest months of the year (December, January, February). This is calculated from each month's mean monthly temperature of climate stations, and the assumption that day time mean temperature are some 3 degree. above the monthly means.

Computer program was used to calculate the annual air temperature for sites based on regression equations of altitude, latitude, and longitude (NSMP, 1995).

2. Soil

Available water holding capacity (AWHC) was used to define the moisture reserve for a depth of 100 cm. Depth of soil is used as a criterion because it indicates rootable depth and present of impenetrable layers. It is calculated based on texture, depth, bulk density, mineral fragments. Total $CaCO_3$ was considered.

Limits of salinity for each land utilization type have been selected on the criteria of yield depression of the crops/land covers involved at the respective salinity levels.

Exchangeable sodium percentage (ESP), was measured because sodium make dispersion for soil and reduce the infiltration rate of the soil.

3. Erosion hazards

Erosion type, and degree of hazard were used because of their effect on seedbed preparation and soil losses. Types of erosion in the study area are: sheet, rill, and undifferentiated erosion with slight hazard. These type of erosion depend on slope, moisture status, texture.

4. Topography

This parameter is expressed as slope percentage. It was calculated by taking the average value of slopes for sites in each mapping unit. The variation of slope in the study area from 2-6%.

5. Rockiness/stoniness

Three parameters are important here: store content of the surface horizon, stone, rock or boulder percentage on the surface, and the dominant size of t he surface course material.

Rockiness can be defined by two components: rock outcrop, and stone at the surface, while stoniness defined by stone contents of the surface horizon.

3.3.4. Matching processes

Individual land use requirement are matched with land characteristics to obtain land suitability rating.

Statistical data obtained from average and modal values were used as a basis for land evaluation.

The process of matching leads determination of qualities of land that satisfy the requirements of a specific land use.

3.3.5. Suitability ratings

Suitability ratings are sets of values which indicate how well each land use requirement is satisfied by particular conditions of the corresponding land quality (FAO, 1983).

According to the FAO framework the evaluation procedure is based on the translation of the criterion limitation levels into land classes:

S1 (Highly suitable): Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity.

S2 (Moderately suitable): Land having limitations which in aggregate are moderately severe for sustained application, but which is physically and economically suitable for the defined use.

S3 (Marginally suitable): Land having limitations which in aggregate are severe for sustained application, it is economically marginal for the defined use, and it has different criteria comparing with moderately suitable.

NS (Not suitable): Land unit with severe limitation, potentially suitable but economically not suitable.

The modeling language was used in the suitability analysis to create a new table containing the overall suitability rating for each mapping unit to assess the land suitability of each land utilization type.

The system dopt simple limitation method or Leibig's law uses to reach an overall suitability taken the least favorable quality as a limiting. The combination of individual land suitability rating followed by identifying the limitations that cause lowering of the preliminary land suitability class and regarding utilization for barley or range, then suggest land optimum utilization.

4. Results and Discussion

4.1. Potential suitability for rainfed agriculture

The rating of different mapping units versus the criteria of rainfed arable is presented in (Table 8) which shows the overall suitability and their. The table indicates the relevant subclasses of limitations that cause lowering of the overall suitability ratings.

Table (8) indicates that 86 % of the total area is marginally suitable, 12 % is classified as moderately suitable, and 1.5 % of the total area classified not suitable for rainfed agriculture such as arable crops.

Most of the area (82%) is classified as marginally suitable because of rainfall limitations.

The results indicated that climate is the most limiting factor. While the suitability of 11 % of the total area is restricted by soil depth Table (8).

The most limiting factor for M28, M30, M32 is slope (6 %) which restrict mechanized cultivation operations.

The soils of the study area have no salinity or alkalinity problems. Figure (6) shows the suitability map for rainfed agriculture.

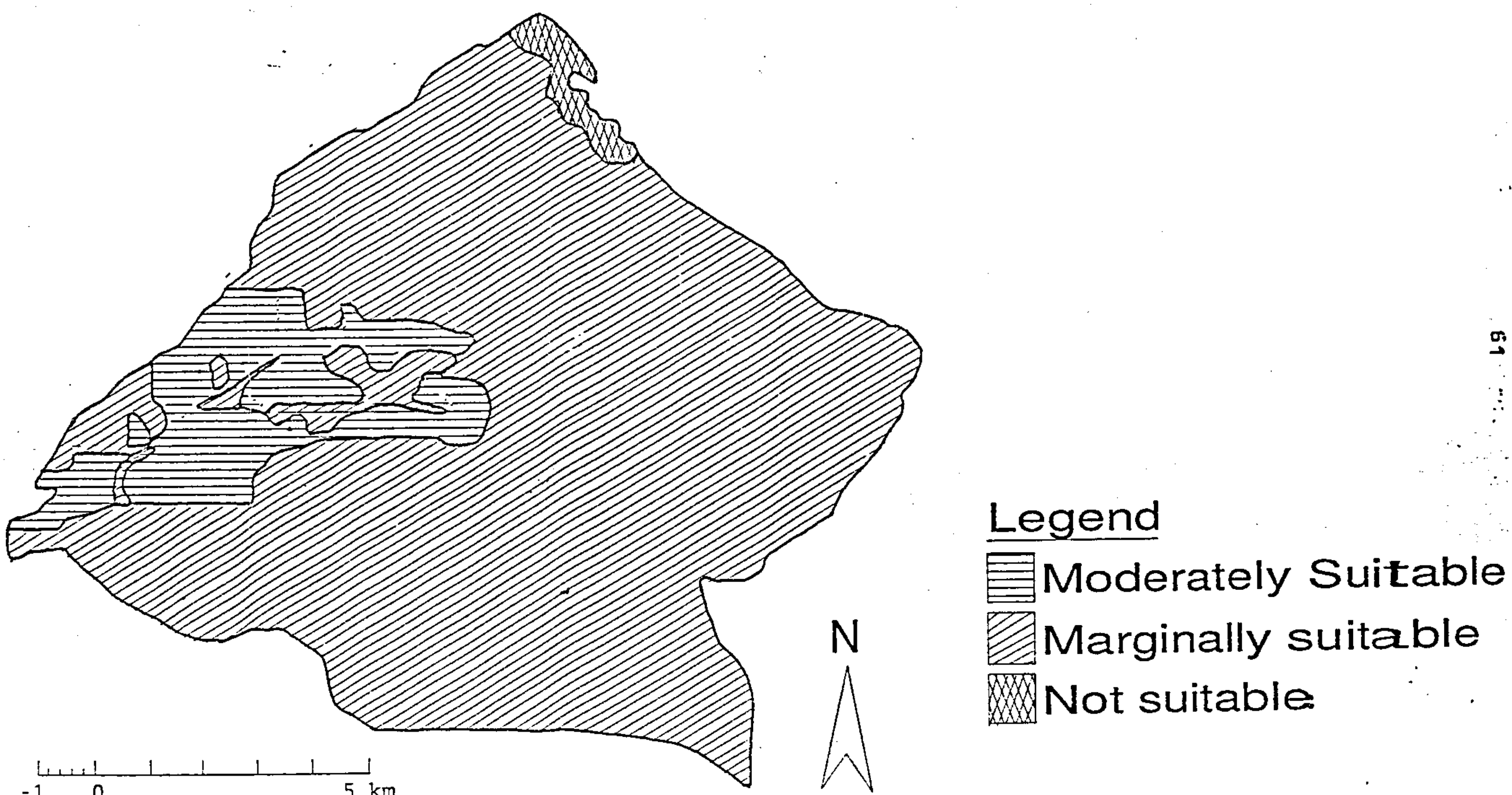
Table (8): Suitability rating of different mapping units for rainfed agriculture

Map Unit	Rainfall (mm)	WGPT deg.day	Soil Depth	AWHC mm/100cm	Salinity/ Alkalinity	Slope	Overall Suitability	Area %	Area Dunums
M25	S2	S1	S2	S2	S1	S1	S2	12.29	14394
M28	S3	S1	S2	S3	S1	S2	S3cs	2.22	2601
M30	S3	S1	S3	NS	S1	S2	NSs	1.55	1810
M31	S2	S1	S2	S3	S1	S1	S3s	5.81	6809
M32	S3	S1	S2	S3	S1	S2	S3cs	1.86	2181
M34	S3	S1	S1	S2	S1	S1	S3c	10.19	11932
M36	S3	S1	S2	S2	S1	S1	S3c	66.08	77402

c: climate/rainfall limitation.

s: soil limitation

Figure (6): Potential suitability for rainfed arable.



4.1.1. Potential suitability for range production

Table 9 shows that 28 % of the total area is suitable for natural range, while 70 % is classified as moderately suitable, and 2 % considered marginally suitable. Map units M25, M31, and M34 are classified very suitable for range and they represent 28. 29% (33135dunums) and these units represent the best units for range production.

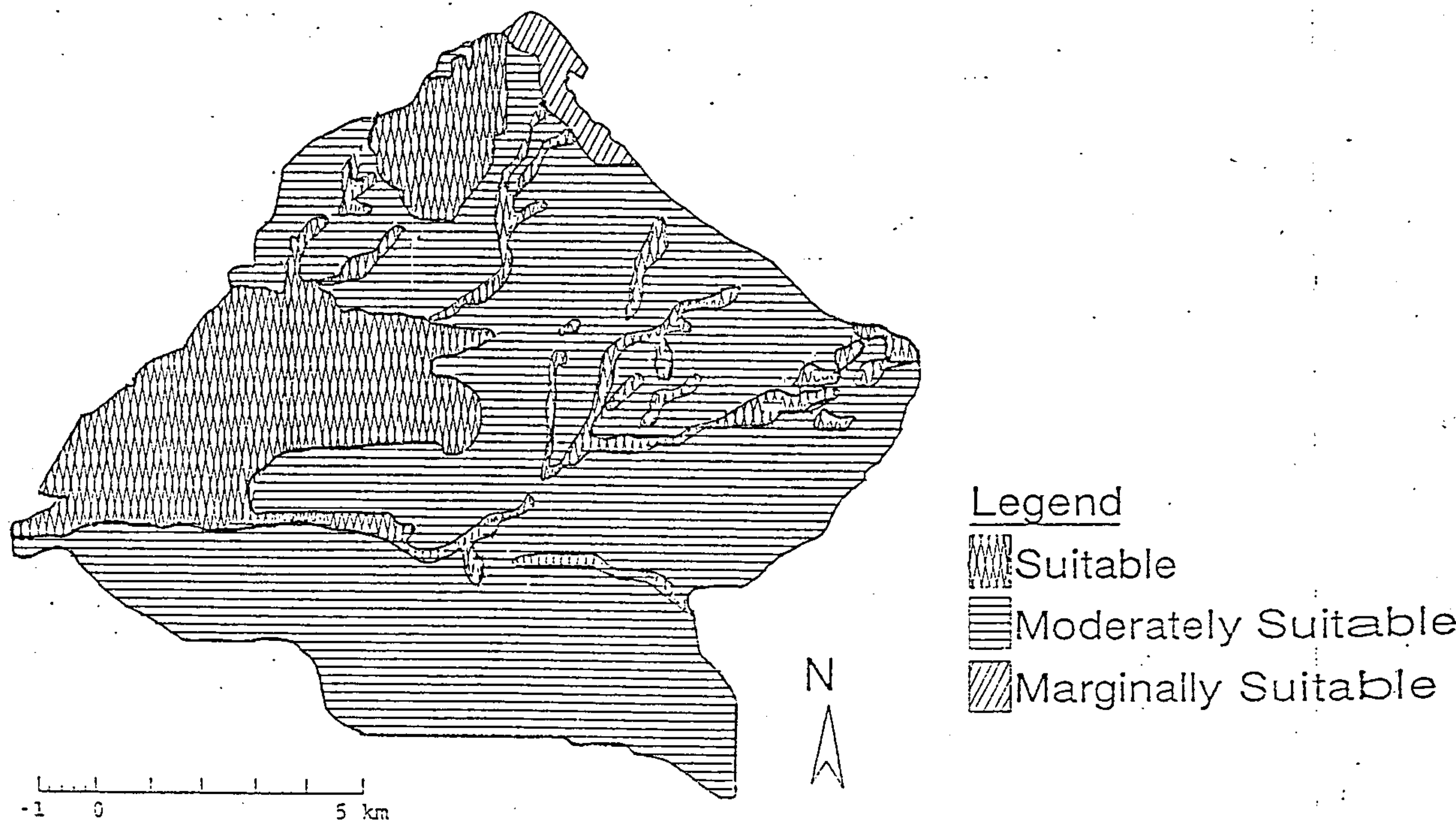
Map units M28, M32, and M36 are classified moderately suitable for range due to low winter growth potential due to land suitability criteria for range which is shows that less than 400 degree.days over 8°C classified as moderately suitable for range. This mean that about 70% of the area suffer from low winter growth potential which limit and restrict the expansion of natural rangeland. Unit M30 (1810 dunums) is classified as marginally suitable due to shallow soil which is less than 40 cm. From the analysis it can be concluded from the above results that 98% of the study area varies from suitable to moderately suitable for range production. The potential suitability for range is shown in Figure (7).

Table (9): Suitability rating for Range

Map Unit	Rainfall (mm)	WGPT deg.day	Soil Depth	AWHC mm/100cm	Salinity/ Alkalinity	Erosion hazard	Slope	Rockiness/ stoniness	Infiltration rate	Overall Suitability	Area - %	Area dunum
M25	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	12.29	14394
M28	S1	S2	S1	S1	S1	S1	S1	S1	S1	S2	2.22	2601
M30	S1	S2	S2	S2	S1	S1	S1	S1	S1	S3s	1.55	1810
M31	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	5.81	6809
M32	S1	S2	S1	S1	S1	S1	S1	S1	S1	S2	1.86	2181
M34	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	10.19	11942
M36	S1	S2	S1	S1	S1	S1	S1	S1	S1	S2	66.08	77402

s: soil limitation

Figure (7): Potential suitability for range.



A comparison is made between current land use and potential suitability for range as shown in Figure (8).

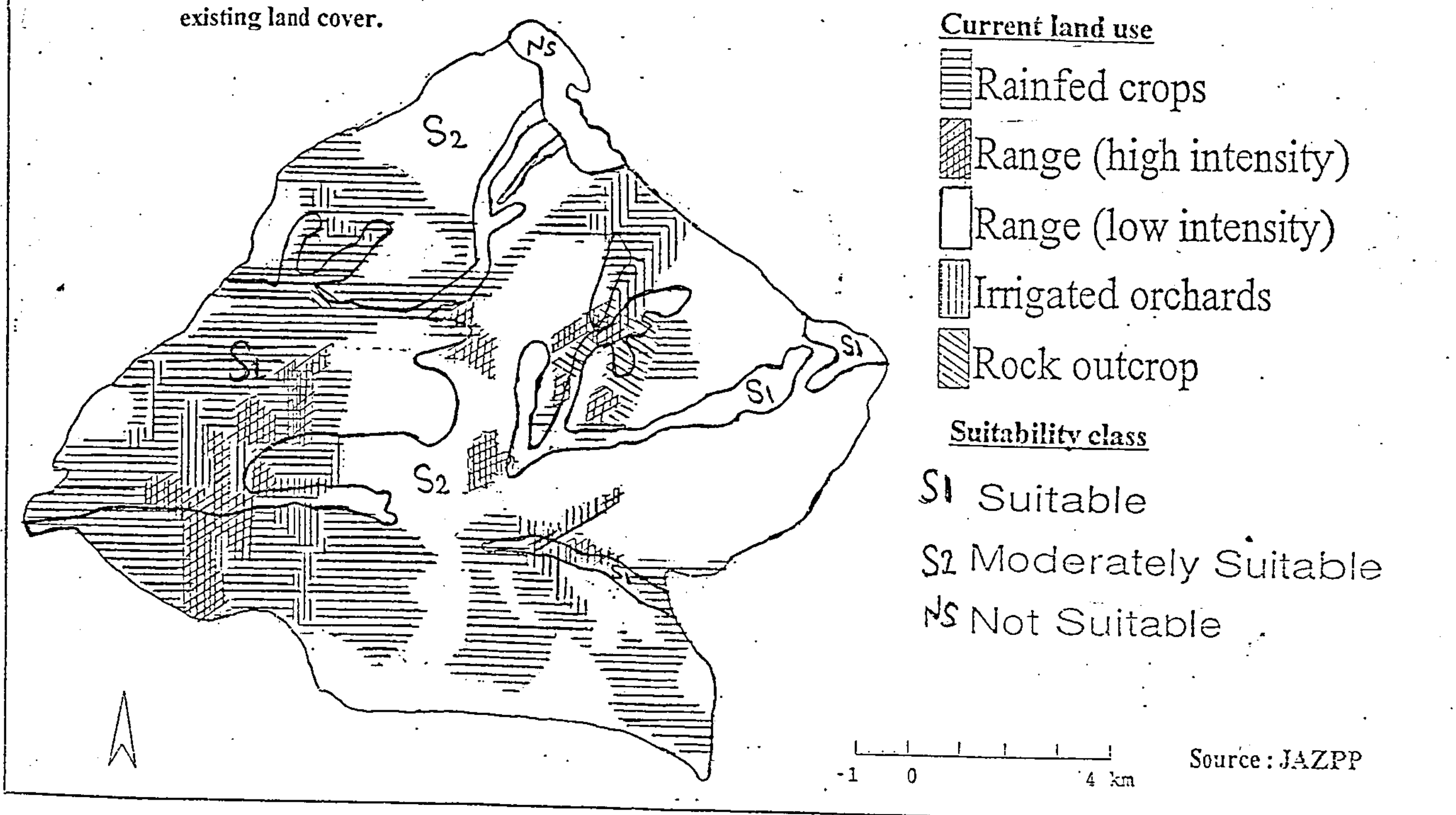
Units M25, M31 (21203 dunums) are classified as highly suitable for range.

The current land use in units M25, M31 are mixed of rainfed crops, range, and irrigated orchards.

The comparisons shows that part of units are matched with the potential assessment of range, and the rest of the units are not a proper use especially for rainfed crops. Unit M25, M31 are proposed for range and existing use is not matched with them.

Main units M28,, M32, M36 (82184 dunums) are potential classified as moderately suitable for range while the current land use for these units is mixed of rainfed arable, irrigated orchard and range. The comparison show that the part of these units used for range and they goes with the potential assessment for range and the rest of the area in these units are not used for range as proposed so it is not a proper use when the compared them with potential suitability for range. Map unit M30 (1810 dunums) is not suitable for range and it is covered by low intensity range under existing cover, so there is no match. It is advised to use it for non agricultural purposes like urban.

Figure 8: Comparison of range production with existing land cover.



4.1.2. Potential suitability for barley production

The analyses indicated in Table (10) shows that only unit M25 (14394 dumuns) is classified moderately suitable for barely production and the other units ranging from marginally suitable to not suitable. Map units M28, M32 M34, M36 were classified marginally suitable due to low rainfall which is less than 200mm annually, and M28, M32, suffer from low available holding capacity which is less than 100mm/100cm regarding the criteria for barely production. Map units M28, M32 have a slope of about 6% and they are classified marginally suitable for range according to the criteria.

Unit M30 is not suitable for barely production because of low available water holding capacity which is 50mm/100cm and according to the criteria for barely production the value of available water holding capacity less than 75mm/100cm is not suitable.

From these analyses it is concluded that about 12% of the area is moderately suitable for barley production and representing by unit M25, so it is recommended to use this unit for barely production.

Analysis indicated from Table (10) shows that 86% (100000 dunums) is marginally suitable for barley production representing by units M28, M32, M34, and M36 while comparing with the analysis indicated before for range shows that it is bitter to use unit M34 for range rather than to use it for barley because it is classified very suitable for range and marginally suitable for barely.

Also it is better to use M28, M32, M36 for range because the analysis shows that these units are moderately suitable for range while the analysis shows that these units are marginally suitable for barely.

Analysis shows that M30 is not suitable for barley but according to the analysis done for range shows that M30 is marginally suitable for range and it is recommended to use it for range.

Figure (9) shows the potential suitability for barley production.

From the assessment process, it can be concluded that the area is restricted for barley production due to rainfall, low winter growth potential and available water holding capacity.

Table (10): Suitability rating for barley production

Map Unit	Rainfall (mm)	WGPT deg.day	Soil Depth	AWHC mm/100cm	Salinity/ Alkalinity	Erosion hazard	Slope	Rockiness/ stoniness	Infiltration rate	Overall Suitability	Area - %	Area donum
M25	S2	S1	S2	S1	S1	S1	S2	S1	S1	S2	12.29	14394
M28	S3	S1	S3	S1	S1	S1	S3	S1	S1	S3cst	2.22	2601
M30	S3	S1	NS	S2	S1	S1	S3	S2	S2	NSs	1.55	1810
M31	S2	S1	S3	S1	S1	S1	S2	S1	S2	S3s	5.81	6809
M32	S3	S1	S3	S1	S1	S1	S3	S2	S2	S3cst	1.86	2181
M34	S3	S1	S2	S1	S1	S1	S2	S1	S1	S3c	10.19	11932
M36	S3	S1	S2	S1	S1	S1	S2	S1	S1	S3c	66.08	77102

c: climate/ rainfall limitation.
s: Soil limitation
t: topography (slope) limitation

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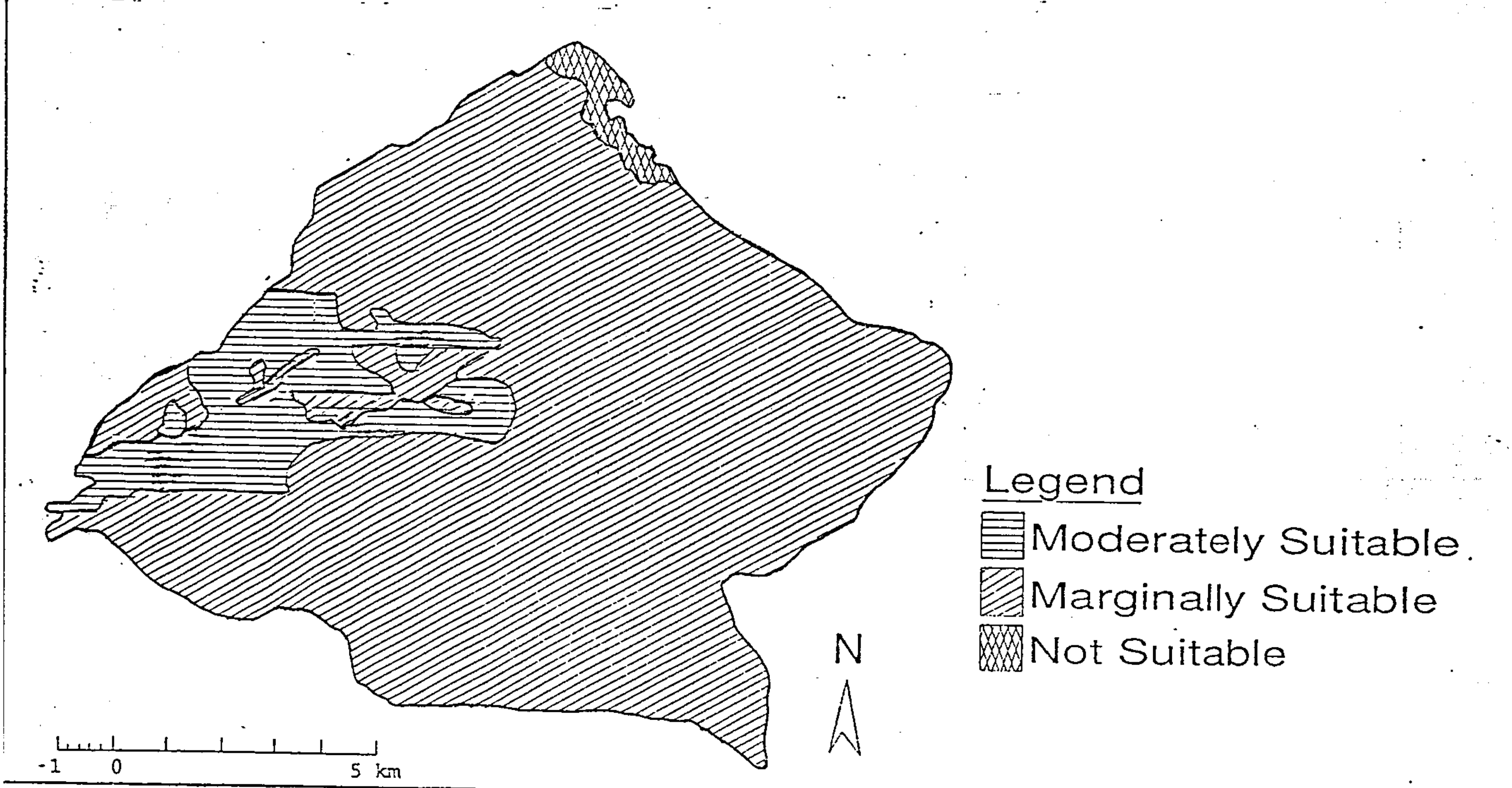
Figure 9: **Potential suitability for barley production**



A comparison was applied between potential suitability of barley production and current land use as shown in Figure (10). It is concluded that unit M25 (14394 dunums) is classified as moderately suitable for barely production while it is used for range. This unit can be proposed for barley production rather than to use it for range so it has potential to produce barley.

Main units M28, M31, M32, M34, M36 (100925 dunums) are potentially classified as marginally suitable for barley production while under current land use these units are mixed of rainfed crops, range, and irrigated orchards.

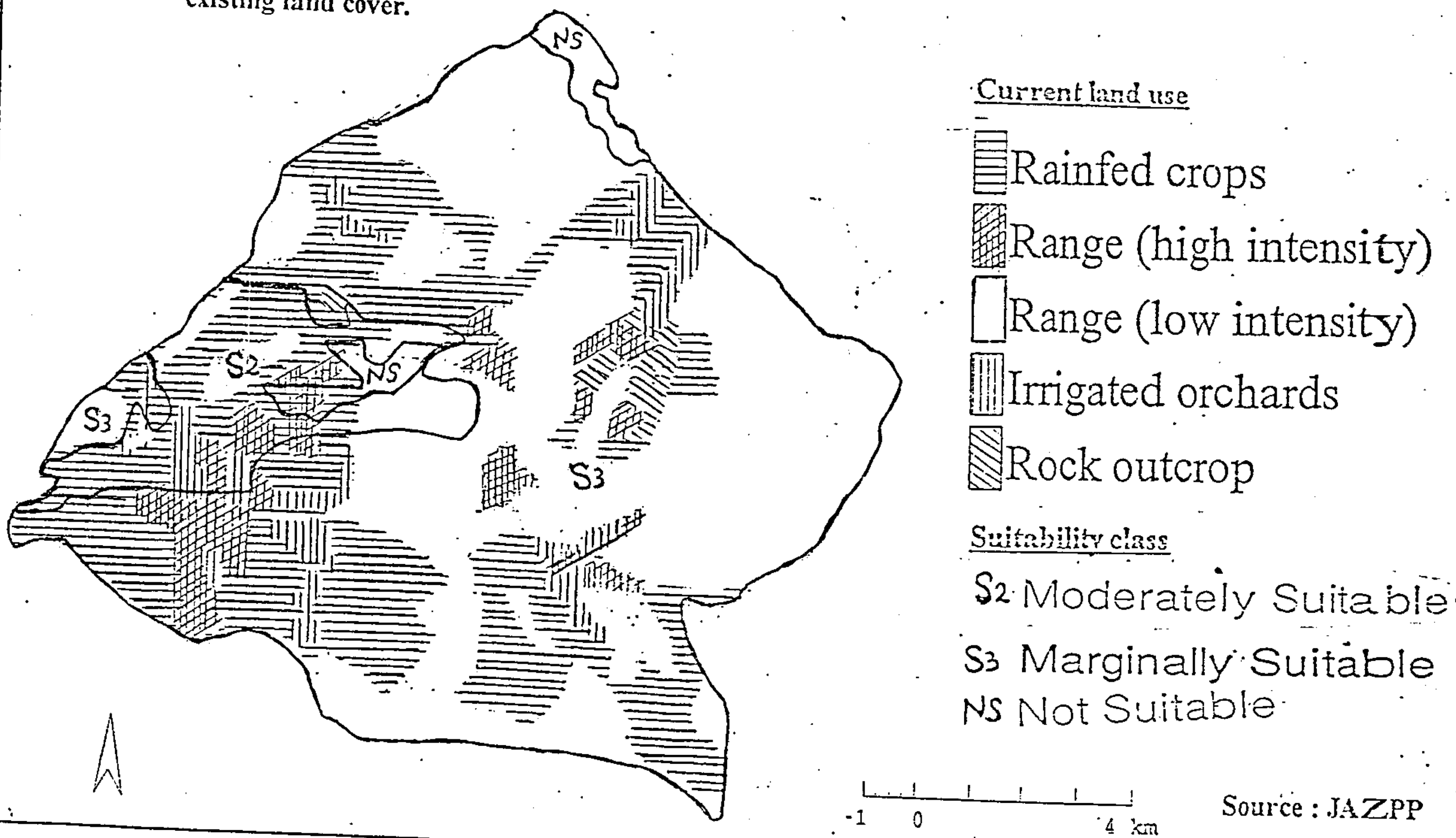
There is some matching between potential suitability of barley and part of these units, the other parts used for irrigated orchard and it needs other criteria for irrigated orchards and it is not the aim of this investigation. Map unit M30 is not suitable for barely production due to shallow soil while under existing land use covered by low intensity range. It is concluded that unit M30 is used only for range and it is better to leave it as it is.

4.2. Application of water harvesting

Precipitation is the main constraint to land utilization in this area. 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.

The nature of the rainfall distribution and intensity in the area can't support a crop growth and establishment under present conditions, and high rainfall intensity and the high runoff favor the introduction of different water harvesting techniques which is considered the most practical option available to increase the effective precipitation to meet the demand of intended crops.

Figure 10: Comparison of barley production with existing land cover.



1. Potential suitability of land for range using water spreading

Table (11) shows that 76 % of the total area is marginally suitable for using water spreading and 23 % of the total area is not suitable. Two mapping units (M34, M36) can be used for water spreading and M36 represent 66 % of the total area. Accordingly water spreading make 76% of the area as marginally suitable for implementing water harvesting (improved range).

Table (11) indicates that the main limitation that decrease the suitability of the area for water spreading is slope. The slopes of the overall area exceed 1%, while the optimum requirement for applying water spreading should be less than 1%.

The slope lowered the suitability class of 23 % of the total area to not

suitable. While soil depth is responsible for classifying of 98% of the total area as marginally suitable Figure (11) shows the suitability map for water spreading for range.

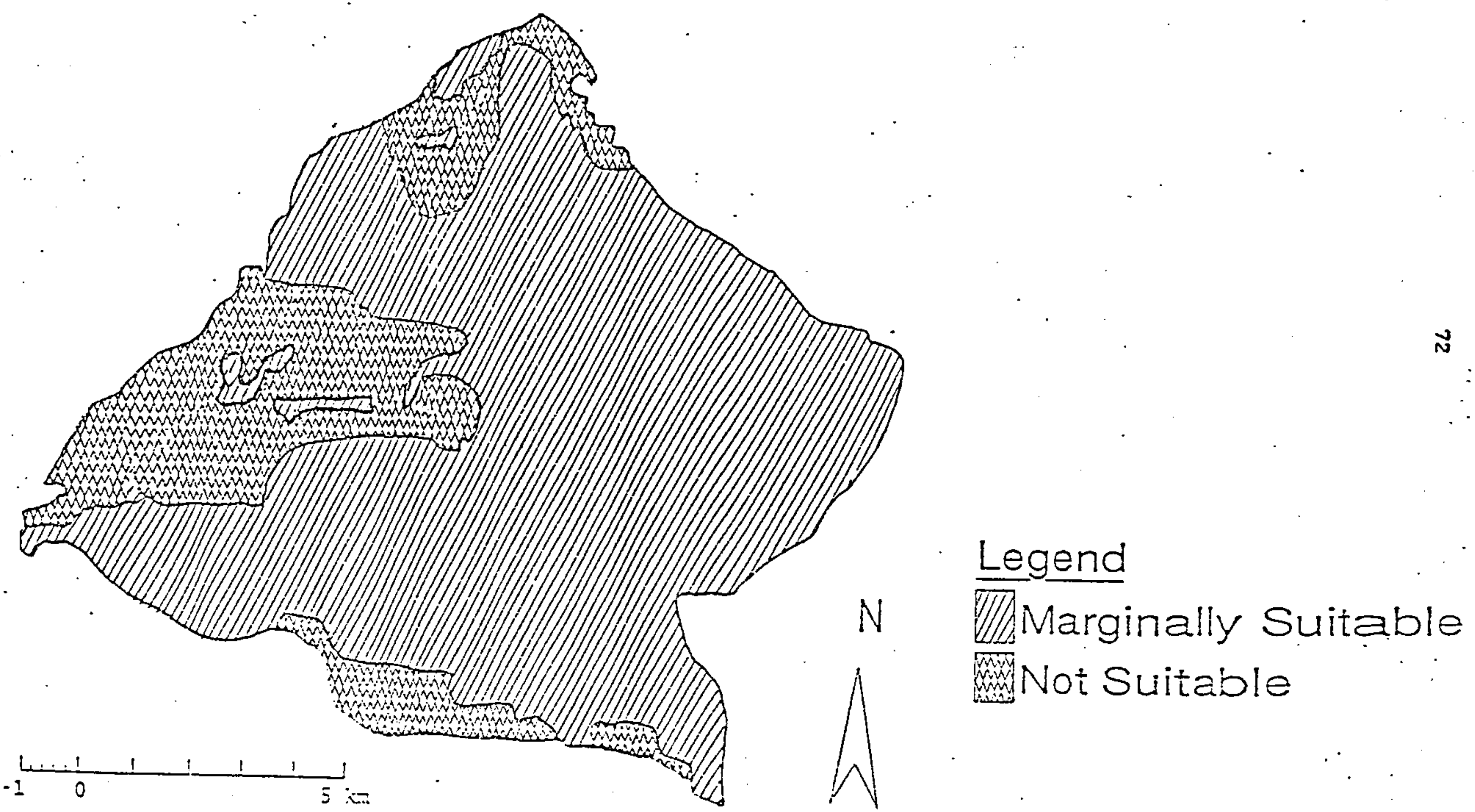
Table (11): Suitability rating for range using water spreading

Map Unit	Rainfall (mm)	WGPT deg.day	Soil Depth	AWHC mm/100cm	Salinity/ Alkalinity	Erosion hazard	Slope	Rockiness/ stoniness	Infiltration rate	Overall Suitability	Area - %	Area dunum
M25	S1	S1	S3	S2	S1	S1	NS	S1	S1	NSt	12 29	14394
M28	S2	S1	S3	S3	S1	S1	NS	S1	S2	NSt	2 22	2601
M30	S2	S1	NS	NS	S1	S1	NS	S1	S2	NSt	1 55	1810
M31	S1	S1	S3	S3	S1	S1	NS	S1	S1	NSt	5 81	6809
M32	S2	S1	S3	S3	S1	S1	NS	S1	S2	NSt	1 86	2181
M34	S2	S1	S3	S2	S1	S1	S3	S1	S1	S3st	10 19	11932
M36	S2	S1	S3	S2	S1	S1	S3	S1	S1	S3st	66 08	77402

s: soil limitation

t: topography (slope) limitation

Figure 11: Suitability rating for water spreading for range



A comparison of using water spreading with existing land cover is shown in Figure (12).

Two units M34, M36 are marginally suitable for water spreading for range while the existing land use in these two units are mixed of rainfed irrigated orchard and range.

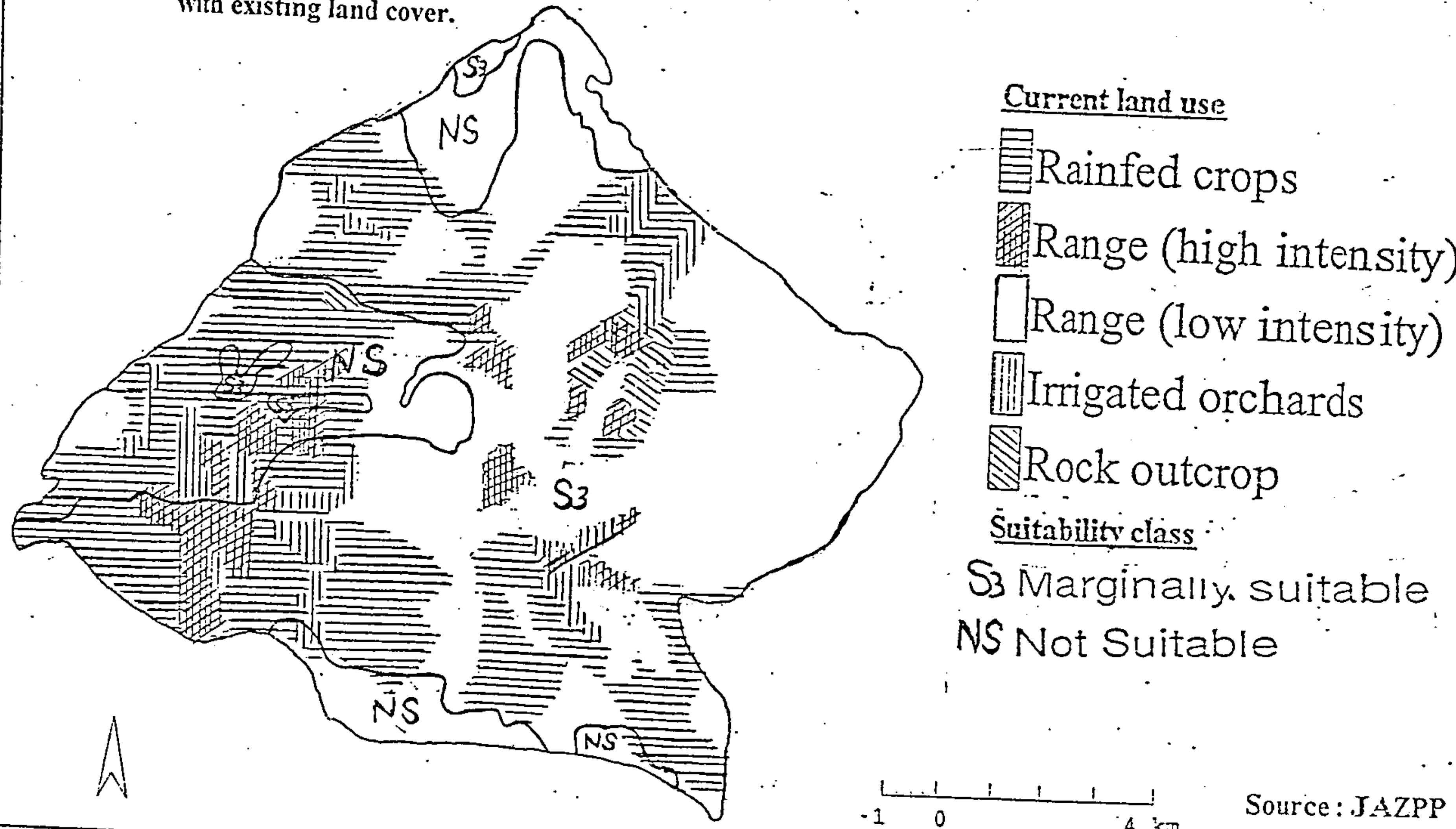
It is concluded that no need to introduce water spreading in these two units.

The analysis shows that M34, M36 are classified very suitable for range production without any type of water harvesting technique.

Units M25, M28, M30, M31, and M32 are classified not suitable for water spreading because of slope restrictions more than 2% and according to the criteria it is not suitable for water spreading.

It is concluded that using water spreading for range is not suitable to use it in this area.

Figure 12: Comparison of water spreading for range with existing land cover.



Source: JAZPP

2. Potential suitability of land for improved rangeland using contour furrows

Table 12 shows that 98% of the total area is marginally suitable, and about 2 % of the total area is classified not suitable represented by mapping unit (M30) due to shallow soil depth less than 50cm, and this unit represent

about 1800 dunum and the main limiting restriction due to the shallow soil and low value of water holding capacity.

The analyses of table 12 shows that the suitability of 98 % of the total area was classified as marginally suitable due to the infiltration rate restriction, 8 % of the total area is marginally suitable because of soil depth limitation.

Figure (13) shows the suitability rating for forage shrubs using contour fourrows.

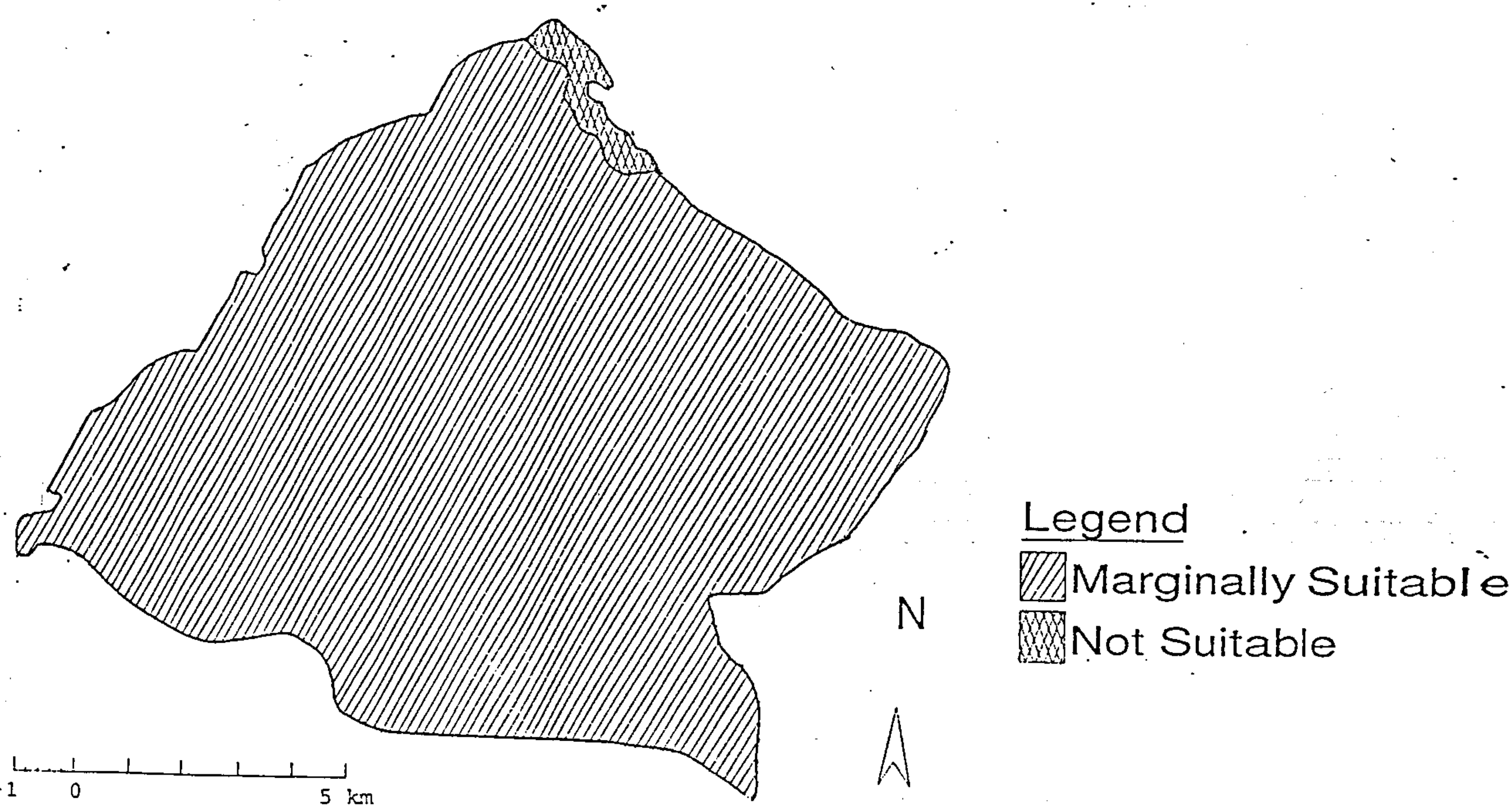
Table (12): Suitability rating for forage shrubs using contour furrows

Map Unit	Rainfall (mm)	WGPT deg.day	Soil Depth	AWHC mm/100cm	Salinity/ Alkalinity	Erosion hazard	Slope	Rockiness/ stoniness	Infiltration rate	Overall Suitability	Area - %	Area dunum
M25	S1	S1	S2	S1	S1	S1	S1	S1	S3	S3i	12 29	14394
M28	S2	S2	S3	S2	S1	S1	S1	S1	S3	S3si	2 22	2601
M30	S2	S2	NS	S3	S1	S1	S1	S1	S3	NSs	1 55	1810
M31	S1	S1	S3	S2	S1	S1	S1	S1	S3	S3si	5.81	6809
M32	S2	S1	S2	S2	S1	S1	S1	S1	S3	S3i	1 86	2181
M34	S2	S2	S2	S1	S1	S1	S1	S1	S3	Ssi	10 19	11932
M36	S2	S2	S2	S1	S1	S1	S1	S1	S3	S3i	66 08	77402

s: soil limitation

i: infiltration rate limitation.

Figure 13: Suitability rating for forage shrubs using contour furrows.



The analyses indicated that 81 % of the total area suffers from low rainfall. It can be noticed from the analyses that applying contour furrows is not a suitable way to improve rangelands Table (12).

A comparison of using contour furrows for forage shrubs with existing land cover is shown in Figure (14).

Two units M28, M32 (4782 dunums) were improved from moderately suitable to suitable for range as a result of using contour furrows. This mean that (4782 dunums) can be improved by using contour furrows, while the existing land cover is low intensity range. The improved area (4782 dunums) increase the area used by a range. The improved area added to the area used for range (21203 dunums) and the total area become (25985 dunums) used for range. Units M25, M31, M34 are classified marginally suitable using contour furrows for forage shrubs while these units are very suitable for ranges without improvement, so no need to apply contour furrows in these units.

Unit M30 is not suitable for contour furrows for range improvement while the existing cover in this unit is low intensity range and it is recommended to leave it under existing land cover.

Table (13) give information regarding the comparison potential suitability for land utilization types with current land use.

Figure 14: Comparison of using contour furrows for forage shrubs with existing land cover

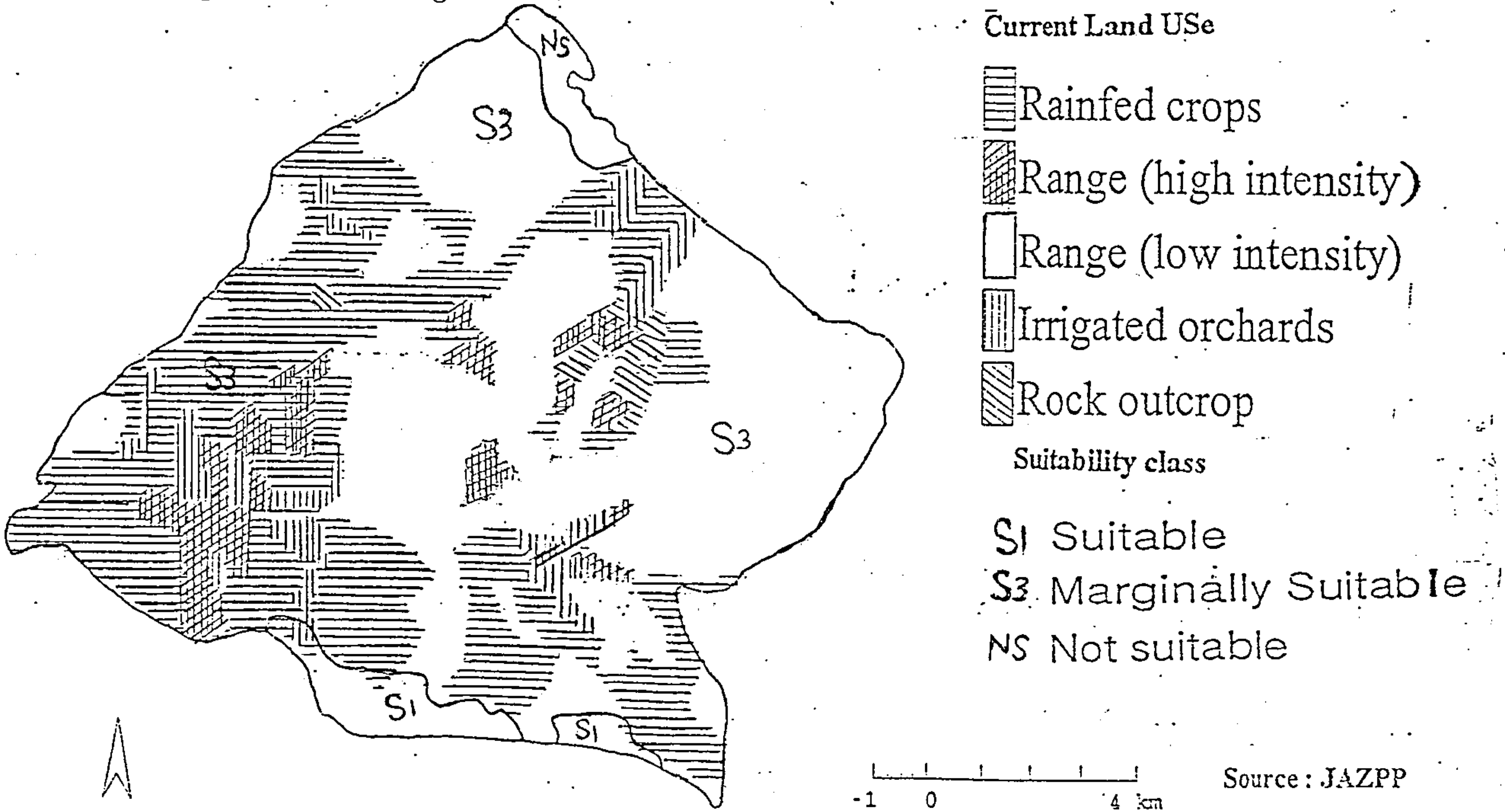


Table 13: Potential Suitability for Land utilization Types VS Current land use

	Overall suitability rating	Area %	Area dunum	Current land use %	Area dunum
Potential suitability for rainfed arable	S2 S3 NS	12.29 86.16 1.55	14394 100925 1810	44.22	56188
Potential Suitability for range	S1 S2 S3	28.29 70.16 1.55	33135 82184 1810	48.00	61094
Potential suitability for range using water spreading (W.S)	S3 NS	76.27 23.73	89334 27795	48.00	61094
Potential suitability for range using (W.S) with treated soil surface	S3 NS	66.08 33.92	77402 39727	48.00	61094
Potential suitability for range using contour furrows	S3 NS	98.45 1.55	115319 1810	48.00	61094
Potential suitability for range using contour furrows with treated soil surface	S2 S3 NS	90.42 8.03 1.55	105909 9410 1810	48.00	61094

4.3. Possibility of land improvement

Improvement of land was proposed by improved land qualities relevant to each mapping unit and compared them with existing conditions to get better match with the requirements of the proposed use. This improvement raise the suitability ratings of the mapping units.

Land evaluation is carried out for all mapping units under different assumptions to check if this improvement was implemented or not.

Different alternative assumptions were used. This is done by changing the constraints to examine the ability to improve suitability of the land.

4.3.1. Applying different assumptions

The following assumptions were suggested:

1. Assumption 1

The basic of this assumption depend on the compensation of limited rainfall by water harvesting. This assumption has changed the suitability of units M28, M32 from moderate suitable to highly suitable as shown in Table (14).

2. Assumption 2

This assumption proposed that the effect of soil infiltration rate is modified by chemicals application which affect the suitability of land for water harvesting.

Suitability process was applied assuming that the infiltration rate is optimum.

The potential suitability of (105,909dunums) become moderately suitable for range shrubs under introducing water harvesting technique as contour furrows.

4.4. Land use scenarios for alternative land utilization

Based on the previous suitability assessment for study area for possible land utilization types, with or without improvement, two land use alternative plans are proposed as scenarios related to the study area.

The proposed scenarios selected the best land utilization types, either highly suitable or moderately suitable under different assumption discussed before. These scenarios were used the data obtained from Table (14).

Table (14): potential suitability of land and areas of best suitability for different land utilization types under different assumptions

Land utilization Types	Suitability Class												
	Mapping Units												
	M25	M28	M30	M31	M32	M34	M36	S1 %	S1 Dunum	S2 %	S2 dunum	Total S1+S2 %	Total S1+S2 dunum
Arable (potential)	S2	S3	S3	NS	S3	S3	S3	-	-	12.29	14394	12.29	14394
Arable Assumption 2	S2	S3	S3	NS	S3	S3	S3	-	-	12.29	14394	12.29	14394
Range (potential)	S1	S2	S3	S1	S2	S1	S2	28.29	33135	70.16	82184	98.45	115319
Range Assumption 1	S1	S1	S3	S1	S1	S1	S2	32.37	37917	66.08	77402	98.45	115319
Range Assumption 2	S1	S2	S3	S1	S2	S1	S2	28.29	33135	70.16	82184	98.45	115319
Barley (potential)	S2	S3	NS	S3	S3	S3	S3	-	-	12.29	14394	12.29	14394
Barely Assumption 2	S2	S3	NS	S3	S3	S3	S3	-	-	12.29	14394	12.29	14394
W. Spreading for range (potential)	NS	NS	NS	NS	NS	S3	S3	-	-	-	-	-	-
W. Spreading for range assumption 2	NS	NS	NS	NS	NS	NS	S3	-	-	-	-	-	-
WH-range/shrubs (potential)	S3	S3	NS	S3	S3	S3	S3	-	-	-	-	-	-
WH-range/shrubs assumption 2	S2	S3	NS	S3	S2	S2	S2	-	-	90.42	105909	90.42	105909

4.4.1. Scenario A

The alternative plan assume that the shortage of water is compensated by water harvesting and the possible of cultivated area for crops is possible.

The analysis Table (14) suggested that units M25 (14394 dunums) is the most promising land. This unit could be cultivated for field crops or barley because it is highly suitable under the first assumption, while unit M30, is the worst unit and it's suitability ranging from marginally suitable to not suitable and there is no possible improvement due to restriction of soil depth. This suggest that 12.29 % (14394 dunums) of the total area can be suitable to produce crops or barley, and that 86.16% (100,925 dunums) of the land is suitable for natural rangeland development. The remaining 1.55% (1810 dunums) of the land are not suitable (or marginally suitable) for crop production, barley or range even if water is provided.

4. 4. 2. Scenario B

This alternative plan assumes that water and soil conserved by introducing contour furrows for range so as to reach the best or optimum utilization of limited amount of rainfall through the increasing of the availability of water and preventing or controlling soil erosion.

This could be achieved through introducing water harvesting and land management guarantees sustainable production should be considered.

Analysis given in Table (14) suggest that unit M25, M32, M34, M36 could be suitable for rangeland improvement if water harvesting is implemented after the reduction of the infiltration rate of the harvested area.

This alternative land use plan indicates that 90.42% (105,909dunums) could be suitable for rangeland improvement if coupled with water harvesting techniques and appropriate management practices such as contour furrows to promote plant cover and prevent erosion hazard.

Combining all scenarios under suggested assumption indicate that 1.55% (1810 dunums) of the study area is marginally suitable to not suitable for any use. This area is represented by unit M30 which is not cultivable and could be used for urban uses.

5. Conclusions and Recommendations

5.1 Conclusions

1. Most of the study area is potentially suitable for natural rangeland.
2. The most limiting factors restricting application of water spreading technique aimed at improving range production are soil depth and slope.
3. Applying water harvesting techniques through contour furrows for forage shrubs could be implemented if soil surface is treated by chemicals application.
4. Treated soil surface will modify the infiltration rate and this will improve the potential suitability of different land utilization types using contour furrows.
5. Under (scenario A) 12.29% (14394 dunums) of the total area is suitable for barley.
6. Under (scenario B) 90.42% (105,909 dunums) is suitable for range land improvement if coupled with water harvesting technique and appropriate management practices such as contour furrows.
7. Under all suggested assumptions indicate that 1.55% (1810 dunums) of the study area is marginally to not suitable for any use.

5.2 Recommendations

1. It is recommended to collect water behind earth dams construction with applying good conservation management practices, such as furrows planting.
2. The best use for study area is recommended for rangeland which offers high social acceptance, most water utilization method and low cost.

3. Using contour furrows is a practical method in areas of high infiltration rate and erosion problems.
4. It is recommended to follow this study by socio-economic studies to help decision makers to improve land use by reducing the current use problems.

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Appendix A: Map Unit description (JOSCIS, 1994)

Map Unit	Geomorphology Parent Material	Vegetation Cov./ Land use	Moisture Regime	Stones/max. Rock outcrop	USDA CODE/SERIES/ DEPTH	(USDA subgroup & Particle size class)	(% Dominance)
M25	Flat to V. gently undulating plain with V. deep aeolian/colluvial mantle	Rainfed arable with much fallow; irrigated treecrops	Transitional (wetter areas)	V. few stones. No boulders or rock outcrops	FBEL FEL 11d FBFU FFU 19 d FBFU FFU 17d FBEL FEL 10d FBEL FEL 15 d (5% shallow)	Xerochreptic calaciorthid (Hz) Xerochreptic Camborthid (Hz) Xerochreptic Camborthid (F) Xerochreptic Calciorthid (F) Xerochreptic Calciorthid (Mh) (103cm average depth)	(30%) (20 %) (15 %) (15%) (10 %)
M28	Colluvial fans and gentle to moderate slopes between low limestone hills & plains. Mod. Deep colluv.	Rainfed arable with v. much fallow	Transitional (wetter areas)	Few stones; few boulders or rock outcrops	FBEL FEL 11 d/md FBFU FFU 19 d/md FBEL FEL 10 d/md FBFU FFU 15 d/md (22% shallow)	Xerochreptic calaciorthid (Hz) Xerochreptic Camborthid (Hz) Xerochreptic Calaciorthid (F) Xerochreptic Camborthid (F) Xerochreptic Calciorthid (79 cm average depth)	(25 %) (20%) (10%) (10%)
M30	Gently undulating plain with variable but mod. Deep aeolian/colluvial mantle over mid and lower slopes	Poor brush range & some low yield rainfed arable	Transitional (wetter areas)	F. common stones; 10% boulders & rock outcrops	FBFU FFU 19 md/d FBEL FEL 11d FBFX FBX 6 s FBFX FBX 5 s (26 % shallow)	Xerochreptic Camborthid (Hz) Xerochreptic Calciorthid (Hz) Lithic Xeroch. Camborthid (Mh) Lithic Xeroch. Camborthid (Qmh) (69 cm average depth)	(50 %) (25 %) (8 %) (7 %)
M31	Rolling terrain: dissected rocky limestone plateau & convex upper slopes; mod, colluvial mantle in places	Low-yield rainfed arable & poor brush range	Transitional (wetter areas)	Common stones; occasional boulders & rock outcrops	FBEL FEL 11 md FBFU FFU 15 md FBFU FFU 19 md FBFX FBX 6 s (32 % shallow)	Xerochreptic Calciorthid (Hz) Xerochreptic Camborthid (Hz) Xerochreptic Camborthid (Hz) Lithic Xeroch. Camborthid (Qmh) (67 Cm average depth)	(30 %) (20 %) (20 %) (!5 %)

Cont.

Map Unit	Geomorphology parent Material	Vegetation Cov./ Land use	Moisture Regime	Stones/max. Rock outcrop	USDA CODE/SERIES /DEPTH	(USDA subgroup & Particle size class)	(% Dominance)
M32	Rolling to hilly: dissected plateau edges & convex upper slopes	Brush rangeland: generally poor cover	Transitional (gen.Wetter parts)	Abundant stones & boulders: 25 % rock outcrop	FBEL FEL 11 md FBFU FFU 19 md/s FBFX (nd) s KEBE KBE 5 s (48 % shallow)	Xerochreptic Calciorthid (Hz) Xerochreptic Camborthid (Hz) Lithic Xeroch. Camborthid (nd) Lithic Xeric Torriorthent (Qmhv) (55 cm average depth)	(30 %) (25 %) (20 %) (15 %)
M34	Flat to slightly sloping alluvial toeslopes crossing "upland" areas	Brush rangeland (good cover) & much rainfed arable & fallow	Transitional (Influx of water)	Few stones, few boulders or rock outcrps	FBFU FFU 15 d FBEL FEL 11 d FBFU FFU 14 d FBEL FEL 15 d (12 % shallow)	Xerochreptic Camborthid (Hz) Xerochreptic Calciorthid (Hz) Xerochreptic Camborthid (M) Xerochreptic Calciorthid (Mh) (96 cm average depth)	(45 %) (20 %) (15 %) (10 %)
M36	Gently undulating to flat fluventlle plains with high stream frequency; deep alluv. / colluvial mantle	Poor brush rangeland; much low-yield rainfed arable & fallow	Transitional	Few stones; occasional boulders & rock outcrop	FBEL FEL 11d FBFU FFU 15 m/md FBEL FEL 15 d FBFU FFU 19 d/md (9% shallow)	Xerochreptic calciorthid (Hz) Xerochreptic Camborthid (Hz) Xerochreptic Calciorthid (Mh) Xerochreptic Camborthid (Hz) (93 cm average depth)	(30 %) (30 %) (20 %) (15 %)

Appendix B: Mapping units areas and percentage

Map Units	Area %	Cumulative Area %	Area (Km^2)
M25	12.29	12.29	14.394
M28	2.22	14.51	2.601
M30	1.55	16.06	1.810
M31	5.81	21.87	6.809
M32	1.86	23.73	2.181
M34	10.19	33.92	11.932
M36	66.08	100.00	77.402

Appendix C: Chemical analysis and basic infiltration rates for mapping units

Map Units	ESP %	EC ds/m	$CaCO_3$ %	IR mm/hr
M25	0.9	0.35	18.5	18.1
M28	6.3	0.41	18.0	17.3
M30	0.1	0.43	19.0	10.1
M31	8.0	0.39	22.5	15.2
M32	3.8	1.5	22.2	11.8
M34	9.0	0.33	21.5	22.1
M36	0.4	0.52	18.5	20.6

Appendix D: Current land cover and their areas

Land Use Type	Area %	Area (dunum)
Rainfed crops	44.22	56188
Range (high intensity)	8.18	10394
Range (low intensity)	39.90	50700
Irrigated orchards	6.09	7734
Rock outcrops	1.61	2042

Appendix E : Potential suitability for land utilization Types

	Highly suitable S1		Moderately suitable S2		Marginally suitable S3		Not Suitable NS	
	Map unit	S1 %	Map unit	S2 %	Map unit	S3 %	Map unit	NS %
Potential suitability for rainfed arable	-	-	M25	12.29	M28	2.22	M30	1.55
	-	-	-	-	M31	5.81	-	-
	-	-	-	-	M32	1.86	-	-
	-	-	-	-	M34	10.19	-	-
	-	-	-	-	M36	66.8	-	-
Total				**12.29**		**86.16**		**1.55**
Potential suitability for range	M25	12.29	M28	2.22	M30	1.55	-	-
	M31	5.81	M32	1.86	-	-	-	-
	M34	10.19	M36	66.08	-	-	-	-
Total		**28.29**		**70.16**		**1.55**		
Potential suitability for barley	-	-	M25	12.29	M28	2.22	M30	1.55
	-	-	-	-	M31	5.81	-	-
	-	-	-	-	M32	1.86	-	-
	-	-	-	-	M34	1.19	-	-
	-	-	-	-	M36	66.08	-	-
Total				**12.29**		**86.16**		**1.55**
Suitability rating for range using water spreading	-	-	-	-	M34	10.19	M25	12.29
	-	-	-	-	M36	66.08	M28	2.22
	-	-	-	-	-	-	M30	1.55
	-	-	-	-	-	-	M31	5.81
	-	-	-	-	-	-	M32	1.86
Total						**76.27**		**23.73**
Suitability rating for shrubs using contour furrows	-	-	-	-	M25	12.29	M30	1.55
	-	-	-	-	M28	2.22	-	-
	-	-	-	-	M31	5.81	-	-
	-	-	-	-	M32	1.86	-	-
	-	-	-	-	M34	10.19	-	-
	-	-	-	-	M36	66.08	-	-
Total						**98.45**		**1.55**

Appendix F: List of Abbreviations

- WGPT	Winter Growth Potential Temperature
- W.H	Water Harvesting
- AWHC	Available Water Holding Capacity
- JOSCIS	Jordan Soil and Climate Information Systems
- JAZPP	Jordan Arid Zone Productivity Project
- EC	Electrical Conductivity
- ESP	Exchangeable Sodium Percentage
- IR	Infiltration Rate
- NSMP	National Soil Map Project
- MOH	Ministry of Agriculture

الملـــخص

الإستخدام الأمثل للأراضي المستغلة بالشعير والمراعي في المناطق الجافة وشبه الجافة في الأردن

إعداد

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إشراف

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مشرف مشارك

أ.د. عوني طعيمة

تغطي هذه الدراسة مساحة ١٣١٠كم٢، وتقع على بعد ٤٠ كم الى الجنوب الشرقي مـــن عمان وهي تمثل المناطق الجافة وشبه الجافة في الأردن.

تهدف هذه الدراسة الى تحقيق الأهداف التالية:

١. تقييم القدرة الإنتاجية للأراضي موضع الدراسة.

٢. اقتراح احسن البدائل من اجل استعمال افضل لهذه المنطقة.

تم استخدام نظم المعلومات الجغرافية كأداة متطورة لانجاز هذه الدراسة، وتم اســـتخدام معادلات برمجية في بناء نظام متكامل لتحقيق اهداف الدراسة.

استخدمت مبادئ ومنهجية منظمة الأغذية والزراعة (فاو) لتقييم موائمــــة الأراضـــي، وتمتاز هذه المنهجية بالمفهوم الفاعل والمتكامل والذي يواكب معرفـــة تـــأثير التغيـــيرات فـــي

استعمالات الأراضي من خلال فهم العلاقات التي تربط العوامل الفيزيائية والإجتماعية والإقتصادية بعضها مع بعض.

تم تقييم ملائمة الأراضي على مستوى شبه تفصيلي بمقياس رسم ١:٥٠٠٠٠.

بينت الدراسة أن تقييم درجة الملائمة تعتمد على مقارنة احتياجات الإستعمالات المختلفة للأراضي مع الخصائص المتوفرة لأنواع الترب الموجودة والتي تعكس مستويات مختلفة من درجات الملائمة. تم تقييم ملائمة الأراضي بالنسبة لأربعة انواع من الإستعمالات المفترضة مع الأخذ بعين الإعتبار مشاكل التربة وتوفر الماء إلى جانب الظروف الإجتماعية والإقتصادية.

ويمكن آن تكون أراضي المنطقة ملائمة لاستعمالات مختلفة من خلال تطبيق طرق ادارة مناسبة. لذلك اقترحت عدة سيناريوهات لتطوير الأراضي في هذه المنطقة تستهدف هذه السيناريوهات الى تطوير افضل منطقة مناسبة لأفضل استخدام والذي يمكن امكانية عالية لإنتاج.

يعتمد السيناريو الأول على افتراض آن الأراضي ليست تحت آي ادارة، ويرشح هذا السيناريو حوالي ١٢ في المائة من المنطقة تستخدم لانتاج الشعير. وكذلك استخدام اخر ٩٨ في المائة في المنطقة لتكون مراعي طبيعية.

يقترح السيناريو الثاني تطوير المراعي باستخدام تقنيات الأتلام الكنتورية وهذا يعطي فرضية تطوير ٩٠ في المائة من المنطقة.

تجميع ونثر المياه ليست بالطريقة المناسبة في هذه المنطقة لوجود عوائق منها الانحدار وعدم وجود عمق للتربة في بعض المناطق.