Agricultural Land Use in Wadi el-Far'a

Ahmad Abu Hammad and Brian Blankespoor

Abstract

This sector uses GIS analysis to synthesize agricultural data in order to make recommendations on the agricultural land use of the Wadi el-Far'a. Land units are delineated in hierarchical sensitivity in relation to agricultural parameters of climate, temperature, to determine different degrees of value for land use and protection. The most sensitive land units are recommended for protection. Also, ecological significant areas and water sensitive recharge areas are delineated. This work is part of an ongoing investigation of the Wadi el-Far'a that contributes baseline data and makes recommendations for future research.

I. Purpose

Wadi el-Far'a,one of the most prominent wadis in the West Bank, is a significant agricultural resource. It has ecological as well as landscape diversity from source to mouth. It provides significant amounts of water to the inhabitants of the region, who use it both for household needs and agricultural irrigation. It is important to consider land use, since it describes and documents the human-environmental dynamics and relationships. This can make sense of the past, analyze the present, and project for future planning and protection.

This sector aims to make recommendations on planning and protection on Wadi el-Far'a with an emphasis on agriculture. The study will concentrate on the following topics: land use, crop water requirements, crop production, land unit description and final analysis while integrating information of geology, soil, and climate outlined in the Natural Environment sector.

II. Methology

In accordance with GIS, two main categories of methods are outlined: non-spatial and spatial. The first method obtains data by field measurements, data collection from different sources and the utilization of these data into formulae to develop further derivations of innovative relationships and recommendations for future developmental activities. Second, the spatial methods apply the Geographic Information System (GIS) by the creation of compiled data layers. The spatial data are mainly obtained from secondary sources, i.e. Ministry of Planning (M OPIC), ARIJ, PCBS and Israeli surveys of soil as well as geology. We hope this information will be adopted into the planning and development of the area to achieve the highest degree of conservation and sustainability.

A. Non-Spatial Data

Described in respective order, the non-spatial data include: water balance and crop water requirement. The Thornthwaite method is used to calculate the potential Evapotranspiration (ETp). ETp is defined as the evapotranspiration from a reference healthy and fully cover crop (Alfalfa) with a uniform height and with enough water supply to prevent water stress. Potential evaporation is defined as the evaporation from free water surfaces under the prevailing circumstances of the climatic parameters. Soil descriptions are based on regional field checks utilizing USDA standards for profile description. Water Balance is defined in this report as the measured difference between rainfall and evapotranspiration.

Crop water requirement (ETc) is defined as the depth of water needed to meet the

water loss through evapotranspiration of a non-diseased crop which is growing in a large field under non-restricting soil conditions (soil water and fertility status), and achieving potential production under the given soil, water and environment circumstances.

The calculation of ETc depends on the following equation:

ETc = Kc * ETp ----------(1)

Where

ETc : evapotranspiration from a specific crop

ETp : evapotranspiration from a reference crop

Kc : crop coefficient

ETp can be calculated using the modified Penman-Monteith equation which depends on available climatic parameters (Solar radiation, wind speed, soil heat flux, temperature and relative humidity). This equation has been programmed through a software called CROPWAT by FAO and one can calculate ETp using the available climatic data. Kc values are provided according to the different growth stages and crops by FAO. Depending on the available climatic data for Wadi el-Far'a provided by the Palestinian weather station, ETp has been calculated for each month of the year.

B. Spatial Data

A Geographic Information System stored all the data. The geographic extent of the project and the study area delineation are defined in the IT sector (See IT Sector Report). Land Unit description regions and area calculation are demarcated by the GIS. First, the Land Unit description is determined by the following GIS data layers: climate zone and soil type (See Natural Environment Sector). Second, the area is calculated in the GIS by the calculation area function to analyze the land use.

C. Spatial Analysis

There are four main subjects where spatial analysis is applied: land unit description, agriculture (MOPIC, 1998a), ecological significant areas (MOPIC, 1998b), and water sensitive recharge areas (MOPIC, 1998c). They are discussed in respective order.

The Land Unit descriptions give a more detailed description of the wadi. It emphasizes the parameters of the landform patterns, the parent material, slope, relative elevation, temperature, and moisture regimes of soils (USDA deifintion). The classification of the land units, "*Factors affecting management practices and plant life"* are also mentioned specially for the larger land units into the area.

Agriculture

The main objective of this study is to identify areas of different degrees of value for agricultural future land use and protection. The study concentrated on two major issues for achieving the land value classification in accordance to agricultural land use. They are the following:

- Potential of the land for agricultural uses or suitability for cultivation (cultivable land)
- Current cultivation or agricultural land use status (cultivated versus not cultivated).

Each main parameter has been given a ranking according to its weight and

importance. The suitability analysis of the land depends on criteria for assigning the different land categories with regard to its potential for agricultural land use, whereas the value of the land with regard to the status of cultivation depends only on whether the land is currently cultivated or not, the latter has been given a lower weight of importance. The synthesis resulted in categorization of the two main parameters in terms of values or importance for agricultural land use and necessity for protection, which is important for future development of the agricultural sector. This constitutes the basis for the final classification where a two-field matrix describing the sensitivity of each field is applied. Also, the assessment will differentiate between two types of land uses (bare and cultivated), giving more attention to the currently cultivated areas.

Most of the data used in the classification of different criteria for the suitability to agriculture is descriptive in genre and was collected from different sources. Agricultural data was gathered and refined in cooperation with the Departments of Agriculture in the West Bank.

Classes for cultivable land (land suitability for agricultural purposes) are identified according to broad and multiple criteria utilizing a framework of international standards. These criteria include:

- Soil type,
- Soil depth,
- Soil texture,
- Infiltration rate,
- Topography (slope aspect and ratio),
- Rainfall,
- Potential Evaporation,
- Availability of water resources for development,

From a practical point of view, and in order to facilitate the classification of different soil associations to different types with regard to different limitations and soil textures for the agricultural purposes, the term *Suitability Class* will be used.

For example, a soil class, in general, can be defined as the order of an object (in this context it is the soil) to a particular use (agricultural purposes) with accordance to certain criteria specified (in this situation these are the limitations found in the soil and the soil texture).

Consequently, Soil Class I corresponds to that type of soil which has the least limitation and the best soil texture, whereas Soil Class III is related to the type of soil which has highest limitation and bad soil texture.

The same method will be applied for the previously mentioned parameters for final assessment of the classification.

The overall classification of the value of the land for agriculture and the degree of necessity for protection result in three major classes which are:

- Grade 1 is the areas that corresponds roughly to valuable agricultural areas with minimum limitations. These are the areas that should be assigned for future conservation and protection for sustainable agricultural land use. The necessity of laws and regulation for the protection of such lands are vital.

- Grade 2 is the areas with moderate value to agriculture. For such areas, two major things have to be done, the first is sound and well management plan for future development, in this regard, an Environmental Impact Assessment or at least an Environmental Check would be very important, and secondly, more detailed studies for assigning the sensitive elements that restrict these areas in this category.
- Grade 3 is those areas with minimum value to agricultural purposes due to severe restrictions. In such areas, developmental projects can be done provided that a Quick Environmental Check should be developed for such areas.

Ecologically Significant Areas

This study synthesizes a combination of literature review and field survey information. In cooperation with Hebron University and An Najah National University (1999), the study determined areas of ecological importance to be protected from development based on the identification of endangered species of fauna and flora. It is notable that all the areas that have been declared by the Israelis as nature reserves and forested areas have been put under a certain degree of protection.

Water Sensitive Recharge Areas

For the purpose of classifying groundwater recharge areas in the West Bank, a series of selection criteria are identified (See below). These criteria are mainly related to the surface features which have direct influence on water percolation from the surface into the subsurface and the sources of water recharge such as precipitation. It was assumed that precipitation (diffuse recharge) is the major source of groundwater recharge. Therefore, it was considered one of the determining factors in the current classification.

The second determining factor was the lithology of the surface deposits, i.e. the composition (materials) of the surface deposits and their porosity status (primary and secondary) which controls water infiltration from both precipitation and other water bodies as well as infiltration of pollutants (See Geology Sector).

Other factors like hydrogeological characteristics of the formation, depth of water table and water quality are also important in the context of protecting important recharge areas. The classification of recharge areas were based on a number of criteria. These are the following:

The area has been divided into a number of recharge sub-areas which have been classified as:

- Highly Sensitive
- Locally Highly Sensitive
- Sensitive
- Moderately Sensitive
- Not Sensitive Areas

Furthermore, other areas were defined as areas that need to be protected such as Dead Sea Coast and the Alluvial Aquifer in the Jordan Valley. The recharge areas are classified in accordance with the selection criteria mentioned earlier. The level of sensitivity is determined by evaluating each area according to the different criteria.

III. Data Results

A. General Background

Water resources for this wadi is coming mainly from rainfall as well as several springs adjacent to the area. The annual discharge rate is varying from 8.7 MCM in dry years to about 30 MCM in rainy years with a mean annual discharge of about 16 MCM. Wadi el-Far'a is an area that comprises the richest part of what's called the Eastern height region. Wadi el-Far'a constitutes the most striking feature of the Eastern Height region; this is due to the tectonic feature of Wadi el-Far'a, a trough varying in width between 50 and 1000m; its floor lies at sea level at a distance of 20 km from its exit into the Jordan Valley, whereas the flanking mountains reach heights of 750 m above sea level at a horizontal distance of 2.5 km from the valley bottom.

Its plentiful and available resources (Water, Land, geological as well as landscape features) qualified Wadi el-Far'a to be an area for future Palestinian developmental planning, in terms of conservation, sustainability as well as development. Semi-arid and arid climatic zones are prevailing in most of Wadi el-Far'a.

The rainfall decreases from approximately 600 mm along the Northwestern part and more elevated part (600 m above sea level) to about 200 mm along the Jordan Valley (350 m below sea level). The winter rain season is between the months of October to April.

B. Land Use

The diversity of the land use in the Wadi el-Far'a is related to the diversity of the climate, land and water resources, topography, and human activities. This section discusses the dominant landuse categories, concentrating specifically on the agricultural application, which is considered the most important human as well as economic activities of Wadi el-Far'a area.

In order to understand land use, the built-up areas are described in their current spatial context in the area of Wadi el-Far'a. There are 20 Palestinian villages and hamlets (khirba) with a total builtup area of about 9.5 km². These areas include one Palestinian Refugee camp which is el-Far'a Camp located in the north eastern part of the area. Six agglomerates of the Jewish colonies are occupying a siginificant portion of the study area with about 3.45 km², in addition, five other agglomerates are classified as militarily bases in the central northeastern as well as southern part of the area with a total area of about 1.7 km² (see Holly Byker, *The Settlements*). The total area of the Israeli built-up areas is thus about 5.1 km² that's comprising about 54% of that of the Palestinians (**Figure 10**). (For more in depth analysis and data, See **Built-up Areas** sector).

The remaining land use is primarily agriculture. The different landuse of the area shows a heterogeneity that reflects the diversity of land, topography and climatic parameters. Rainfed annual crops like wheat and barley represent an important land use and dominate the undulating plains of Tubas, Tammoun and Tayasir. The main land use of summit surfaces is non-irrigated annual field crops like wheat and barley. El-Far'a valley is partially cultivated with cereals, especially the upper part, and irrigated vegetables and citrus in the plains of the central as well as the nothern part.

The area is intensively cultivated with irrigated vegetables as well as fruit trees (mainly citrus plantation), especially in northern and central part of the area (Tubas and el-Far'a valley). Whereas the surrounding hills are mainly used for rainfed cultivation, especially wheat and barley during the Winter period, most of this rainfed area is used for the production of Summer crops (Okra, cucumber and tomato) after harvesting the Winter ones. In addition to the different cropping patterns that are prevailing in this area, one can find nature reserves as well as forested areas specially in the hilly areas (**Figure 11**).

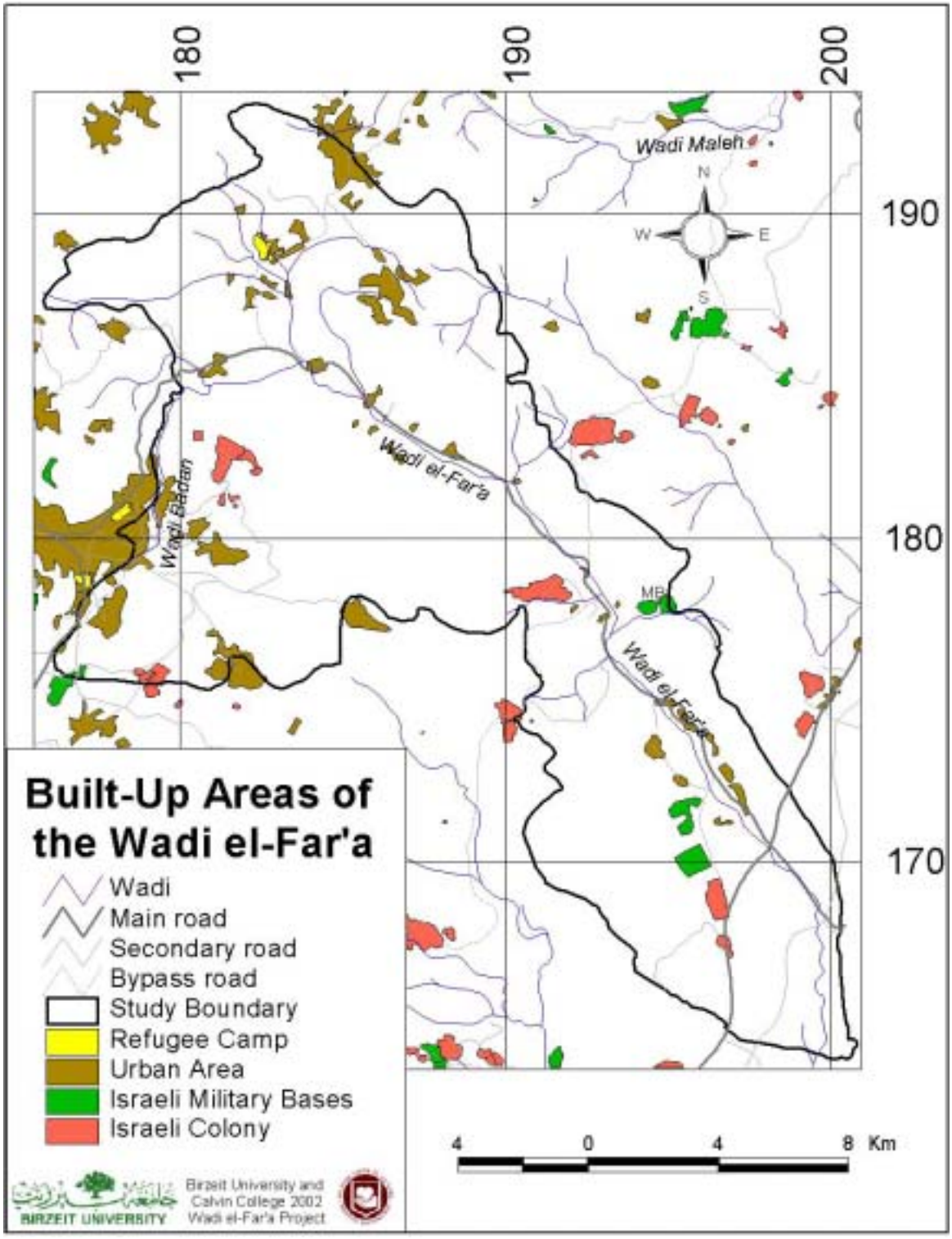

Figure 10: Built-up Agglomerates in the Wadi el-Far'a

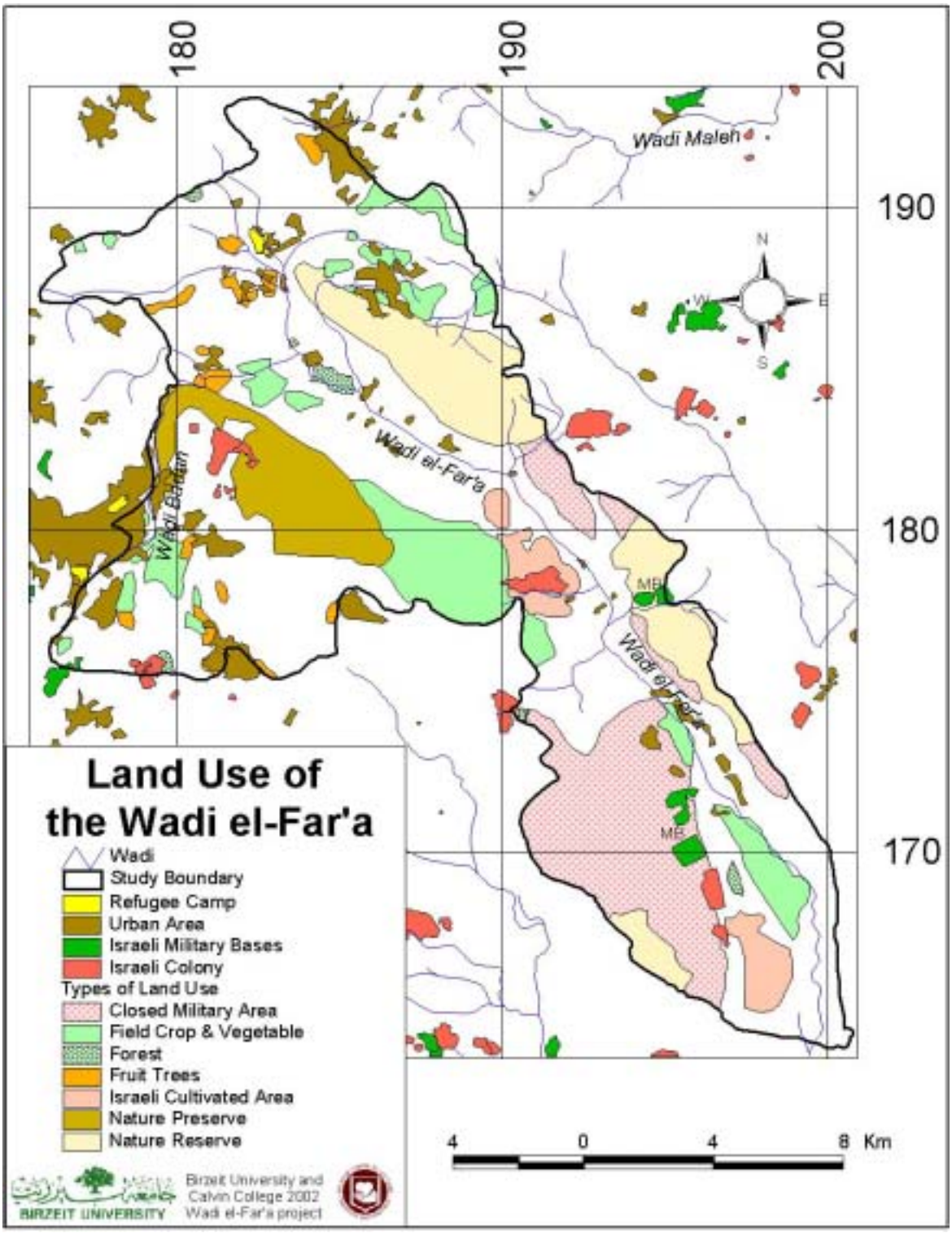

Figure 11: Prevailing Land Use in Wadi el-Far'a

The total irrigated area in Wadi el-Far'a is approximately 9 km². This is divided into 1.7 km² for irrigated fruit trees (citrus and banana), 3 km² open field irrigated vegetables (tomato, potato, eggplants, cauliflowers, cucumbers and onions) and 4 km² irrigated field crops (mainly wheat and barley). About 20 km² is designated as non irrigated field crops and vegetables (**Figure 11, Table 5**).

TABLE 5: Designated land use for both Palestinians & Israelis in Wadi el-Far'a

Use	**Area (km²)**	**% of total area (282 km²)**
Irrigated fruit trees	1.7	0.6
Open field irrig. Vegetables	3.0	1.1
Irrigated field crops	4.0	1.4
Rainfed field crops & veget.	20.0	7.1
Palestinian builtup areas	9.5	3.4
Total Palestinian use	***38.2***	***13.5***
Article I. Forested areas	1.5	0.5
Nature reserves	43.3	15.4
Closed military area	37.6	13.3
Jewish cultivated area	7.9	2.8
Military bases	1.7	0.6
Jewish colonies builtup area	3.4	1.2
Total Israeli use	***95.4***	***33.8***

Table 6 describes the prevailing cropping pattern for the vegetables, fruit trees and field crops associated with the production for Wadi el-Far'a area.
The irrigated agriculture techniques varied between modern ones (sprinkler and drip) to old traditional surface irrigation methods (furrows and basins). The new techniques are adopted extensively in the area, specially drip irrigation for the production of the irrigated vegetables, however surface irrigation is mostly used for the fruit trees and citrus plantation. Sprinkler irrigation is also used for field crop plantation as well as vegetable production (some types of vegetables like potato).

TABLE 6: Irrigated crops production and cropping pattern in Wadi el-Far'a

Irrigated vegetables			**Irrigated fruit trees**			**Irrigated field crops & forages**		
Crop	***Area*** (Dunums)	***Production*** (Tons)	Crop	***Area*** (Dunums)	***Production*** (Tons)	Crop	***Area*** (Dunums)	Production (Tons)
Tomato	261	756	Citrus	1470	4166	Field crops	4135	11225
Potato	459	1101	Olives	200	68			
Cucumber	228	228	Avocado	30	24			
Cauliflower	205	799						
Eggplant	89	329						
Pepper	109	239						
Onion	433	1559						
Beans	180	63						
Cabbage	144	428						
Snake cucumber	355	284						
Other	537	------						

Source: MoA, ARIJ and PCBS data bases.

Crop Water Requirements and Evapotranspiration

Crop water requirments (ETc) have been discussed previously. It's important to estimate ETc for efficient use of available water resources, besides any deviation from this amount of water needed by the plant will result either in water losses (if applied water > ETc), or in a significant decrease of crop production due to stress on the plant itself (if water <ETc).

Table 7 reveals that citrus plantations consumed the largest amount of water throughout the year in comparison with other type of plantation.

TABLE 7: Mean potential evapotranspiration ETp and ETc for some crops in different months of the year in Wadi el-Far'a

Month	**ETp mm/ day**	**Crop water requirments (ETc) - mm/ month**								
		Tomato	**Potato**	**Cucumber**	**Cauliflower**	**Eggplant**	**Onion**	**Barley**	**Wheat**	**Citrus**
Jan.	1.8	58	55	32	52	58	52	58	31	41
Feb.	2.3	68	19	--	67	75	67	74	52	53
March	3.4	--	--	--	93	106	96	66	92	74
Apr.	4.2	--	--	--	--	133	120	--	132	89
May	5.3	--	--	--	--	149	140	--	144	105
June	6.2	--	--	--	--	--	--	--	--	122
July	7.5	--	--	--	--	--	--	--	--	145
Aug.	6.9	--	--	--	--	--	--	--	--	133
Sep.	5.6	66	--	--	--	66	--	--	--	107
Oct.	3.4	65	43	44	41	62	--	--	--	69
Nov.	2.3	72	56	57	46	69	30	22	21	49
Dec.	1.6	51	51	46	46	51	38	38	19	36
Total/ year	1540	380	224	179	345	769	542	258	491	1024

Crop Production and Water Use Efficiencies (WUE)

Water use efficiency is defined as the amount of water needed to be applied to a certain crop to produce one kilogram of the fruit of that crop. This measurement is important to quantify the efficiency of the current use of the available water and to check the profitability of a certain crop. **Table 8** shows some of the figures for the production and the water use efficiencies for some crops planted in Wadi el-Far'a area.

TABLE 8: Production and water use efficiency under different techniques applied in Wadi el-Far'a

Technique used	**Production (Tons)**	**WUE (kg fruit/ m^3 water)**
Open field vegetables	34736	4.5
Fruit trees (citrus)	5122	1.5
Field crops	3712	0.9
Low plastic tunnels	11994	6.1
Plastic houses	982	8.3
High plastic tunnels	89	3.4

TABLE 9: Production and water use efficiency under different techniques applied in Jericho

Technique used	**Production (Tons)**	**WUE (kg fruit/ m^3 water)**
Open field vegetables	40364	5.9
Fruit trees (citrus)	26780	1.1
Field crops	1051	0.7
Low plastic tunnels	6172	4.1
Plastic houses	309	10.6
High plastic tunnels	99	10.2

A quick comparison between different techniques used in both Jericho and Wadi el-Far'a reveals that some of these techniques are more adaptable and efficient in Wadi el-Far'a than in Jericho (fruit trees, field crops and vegetables under low plastic tunnels), whereas other techniques are more adaptable in Jericho than in Wadi el-Far'a (plastic houses and high plastic tunnels).

4. Potentials For Future Development

A. Land Units Description

Although one can observe a heterogeneity in the land of Wadi el-Far'a with regard to the land form, topography, and other criteria, the area of Wadi el-Far'a could be subdivided into eight land classes. In this section each of the land units delineated in the area of Wadi el-Far'a are summarized in Table 10 and then described in further detail. Also **Figure 14** represents the spatial distribution of these 8 land units.

TABLE 10: Land Units Summary

Land Unit	**Area (km^2)**	**Elevation Range (m asl)**	**Landform pattern**	**Main Land Use**	**Temperature and moisture soil regimes (USDA)**
Cultivated Undulated Plains	17	380 - 270	Gentle inclined foot-slopes, alluvial fans, valley floors.	Rain-fed annual crops.	*Thermic - Xeric*
Cultivated Level Plains	16	660 - 460	Level foot-slopes, alluvial fans, and plains.	Rain-fed annual crops.	*Thermic - Xeric*

Cultivated Summit Surfaces	35	810 - 550	Level and gently inclined summit surfaces, moderate inclined to moderate steep slopes	Rain-fed annual crops.	*Thermic - Xeric*
Al Far`a Valley	28	170 - -40	Gentle inclined foot-slopes, alluvial fans, valley floors.	Irrigated and rain-fed crops.	*Hyperthermic - Ustic*
Cultivated Undulated Low Plains	2	400 - -10	Gentle inclined foot-slopes, alluvial fans, valley floors.	Rain-fed annual crops.	*Hyperthermic - Ustic*
Permanent Cultivated Low Plains	3	-190 - -130	Level foot-slopes, valley floors.	Irrigated annual and perennial crops.	*Hyperthermic - Aridic*
Cultivated Rolling Hills	12	904 - 390	Moderately inclined to moderately steep slopes.	Olive groves, rain-fed crops.	*Thermic - Xeric*
Uncultivated Hills	168	700- -20	Moderately inclined to steep slope	Seasonal natural grassland.	*Thermic - Xeric Hyperthermic - Ustic*

B. Land Unit: el-Far'a Valley

The Wadi el–Far'a land unit has an area of about 28 km². A striking feature of the land unit is the presence of a permanent stream, which makes it possible to irrigate different crops. Areas included in this land unit consist of the upper and central part of the valley of Wadi el-Far'a. The land unit is Northwest to South - east oriented and its elevation ranges from 190 m above sea level to 130 m below sea level.

The parent material and substratum of the land unit consist of alluvial and colluvial deposits. Valley floors are mainly made of alluvial deposits transported by the wadi, while the foot-slopes and alluvial fans parent material mainly consists of alluvial-colluvial deposits from the adjacent hills.

(i.) The main landform elements are gentle inclined (inclination 3 - 8 %) foot-slopes and alluvial fans and level (inclination less than 3 %) valley floors. Level wide terraces cover a small portion of the upper part of the valley (Al Badhan). Moderately steep to steep (inclination-18 - 58 %) scarps surrounds those terraces. Valley floors, foot-slopes and alluvial fans are almost free of rock outcrops. Scarps and slopes, as well as hillcrests generally have from common to abundant rock outcrops.

The main land use of the valley floors is irrigated cultivation. Main crops are tomatos, eggplants, onions, potatoes and other vegetables (see table 6). Citrus and olive groves are both present, but the citrus plantation is dominant. The main land uses of the alluvial fans and foot-slopes are both irrigated and non-irrigated cultivation. Main crops are wheat and barley (non-irrigated) and onions, potatoes and other vegetables (irrigated). Terraces in the upper part of the valley (Al Badhan) are mainly cultivated with cereals which are mainly rainfed.

The average air temperature is 23.6º C. According to USDA soil temperature regime, it is *hyperthermic* and the soil moisture regime is *ustic*.

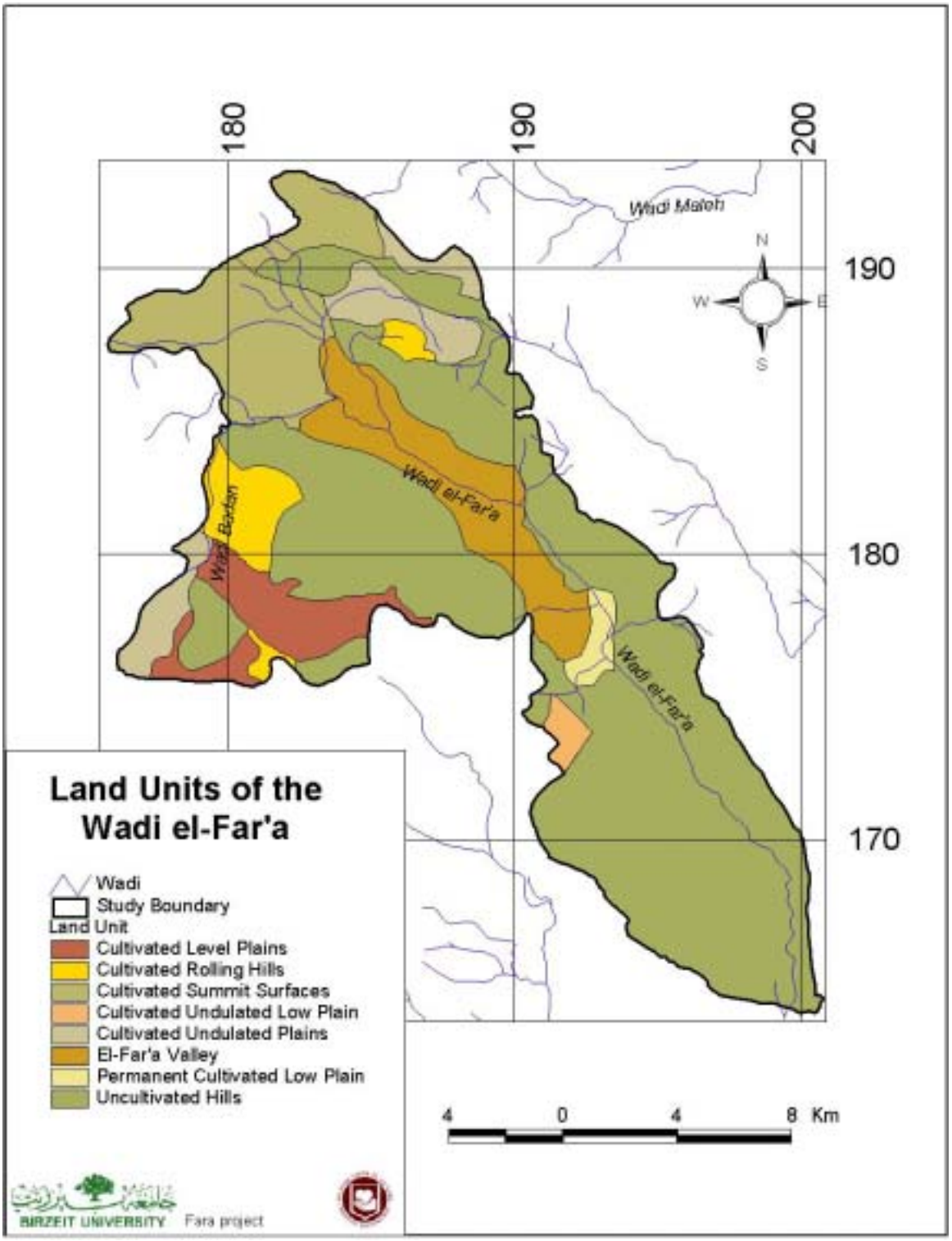

Figure 14: Land Unit Descriptions of the Wadi el-Far'a

Soils on the level valley floor and gentle inclined alluvial fans and foot-slopes are generally deep - very deep. Sometimes on foot- slopes soil is moderately deep. Soils are suitable for both annual and perennial crops. Presence of permanent stream and springs makes possible the cultivation of irrigated crops, both annual, (onions, potatoes, squashes, cornflower) and perennial (citrus and olive trees). Generally, irrigated crops are concentrated on level valley floors. It is observed that the soil contains many stones that may influence agricultural practices of irrigated crops. For Al-'Aqrabaniya and Al-Buqaya soil types, soil is well drained when having opened cracks. Drainage is moderately well when there are no cracks. An- Nassariya soil is generally well drained.

Regarding irrigation, due to the moderate permeability of soils and in order to avoid water stagnation on level surfaces and run-off on inclined ones, drip irrigation should be preferred to sprinkler use. Regarding water availability for rain-fed crops, the same considerations are valid for the land unit "Cultivated undulated low plain".

Figure 15: el-Far'a Valley near An Nassariya Village

C. Land Unit: Cultivated Undulated Low Plain

This land unit has an area of about 2 km². The land unit includes areas mainly located in the western part of Wadi el-Far'a. Its elevation ranges from 400 m above sea level to 10 m below sea level.

Apart from the Al Buqaya plain in the northern part of the land system, which is a gently inclined to level plain with foot-slopes and valley floors, the land unit includes mainly areas which have the shape of steps on the rift descending to the Jordan Valley. The parent material and substratum of the land unit consist of alluvial colluvial deposits.

The main land use of foot-slopes and valley floors is rainfed cultivation. Main crops are wheat and barley. Irrigated vineyard and vegetables can be found in the lower part of Al Buqaya plains. Slopes are not cultivated and the natural vegetation consists of bushes of *Sarcopoterium spinosum, Calycotome villosa* and short grasses. Natural vegetation is overgrazed where animals track the soil surface.

Soils on level plains and foot-slopes are deep to very deep, sometimes moderately deep, without physical limitations for root growth. They are suitable for both annual and perennial crops. Generally, stoniness does not influence agricultural practices. However, shallow soil depth represents a constraint for root growth. In addition, the presence of opened cracks during the dry season and important swelling and shrinking soil movements may affect root growth of permanent crops. The soil is well drained when there are open cracks, while the drainage is moderate when there are no cracks.

Total rainfall and length of the rainy season ensure sufficient water availability for

annual rain-fed crops only in some years. Satisfactory yields of wheat and barley cultivation strongly depend on the length of the rainy season and on the water stored in the soil. To this regard, the reduction of water losses by run-off and/or through evapotranspiration should be minimized. During fallow years, particular attention should be paid to agricultural practices aiming at restoring water soil storage. Thus, shallow ploughing in winter, to increase the permeability of soils when cracks are no longer opened, is of high utility. Regarding olive trees, which are sometimes cultivated in the plains, the presence of opened cracks during the dry season and important swelling and shrinking soil movements may affect root growth if soil is not irrigated.

As well as for annual rain-fed crops, water availability is not sufficient to ensure yearly satisfactory production without irrigation. The introduction of this crop should be taken into consideration only where water is available. Present erosion of the land unit ranges from slight to moderate according to the slope. Due to the presence of cracks at the beginning of the rain season, run-off and sheet erosion are likely to be higher during winter months and fallow years. In addition, rill erosion plays an important role in land degradation of *t*he plains, because the plains are in relative low position and surrounded by steep hills.

D**. Land Unit: Permanent Cultivated Low Plains**

The Permanent Cultivated Low Plains are located further south along the Wadi. This land unit has an area of about 3 km². The areas included in this land unit consist of the south - east part of the Wadi el-Far'a valley. The elevation ranges from 100 m below the sea level to 185 m below the sea level. The parent material of the land unit consists of alluvial deposits. The area is characterized by a level 1 km-wide valley floor with an average slope of less than 1 % and it is surrounded by steep hills.

Figure 16: Citrus groves and irrigated annual crops in Frush Beit Dajan Land Unit.

The main land uses of the valley floors are irrigated vegetables and citrus plantations. Main crops are citrus, onions, potatoes, squash and other vegetables.

Soils on level terraces and valley floor are generally deep to very deep. Soils are suitable for both annual (onions, potatoes, squashes, cornflower) and perennial (Citrus trees) crops. Generally, irrigated crops are concentrated on the lower and central part of the level valley floors. The presence of stoniness may influence agricultural practices of irrigated crops. Generally the soil dariange is good but it may be moderate due to high content of clay and presence of crust in some locations.

E. Land Unit: Cultivated Undulated Plains

Plains included in this land unit are the plains of Tayasir and Tubas, distributed in the northern part of the area; it has an area of about 17 km². The main land use of the plains is non-irrigated cultivation. The main crops are annual field crops like wheat and barley. Olive groves and green houses are present in Tubas plain. Soils are deep to very deep, sometimes moderately deep without physical limitations for root growth. They are suitable for both annual and perennial crops. Presence of open cracks during the dry season and important swelling and shrinking soil movements may affect root growth of permanent crops. Soil drainage depends strongly on presence of cracks. In autumn, at the beginning of the rainy season, cracks are opened and drainage is rapid. During the winter when soil is moist, due to high content of clay, drainage is moderate. Thus, erosion is likely to be more active during the winter months. In that period soil is saturated and has slower infiltration. But on the other hand, in February and March the crops have already covered the surface protecting the soil from erosion.

Due to the lack of vegetative cover and also to the inclination of slopes surrounding the plains, run-off flowing from the slopes and concentrating in the plains is important. Surface of plain is generally enough inclined (3 to 8 %) to keep the speed of water high enough to be erosive also in the plains. As a result of that, footslopes and alluvial fans of plains are often incised by both rills and gullies.

F. Land Unit: Cultivated Level Plains

Soils on level plains and foot-slopes are deep to very deep and sometimes moderately deep without physical limitations for root growth. They are suitable for both annual and perennial crops. Presence of opened cracks during the dry season and important swelling and shrinking soil movements may affect root growth of permanent crops.

As described for the land unit "Cultivated Undulated Plain" soil drainage, soil permeability and soil erodibility depend on the presence of cracks. As previously stated, soil is well drained when having opened cracks and drainage is moderate well when there are no cracks. It is observed that generally present sheet erosion is slight since plains are mainly level. Cultivated level plains benefit of the highest rainfall rate. Higher water availability and longer rainy season enhance the vertical characteristics of the soils. Marked swelling movements are likely to be common, resulting in the additional difficulties for the management of such soils. The rainy season is long enough to ensure, in most of the years, sufficient water availability for the growth of main rain-fed annual crops (wheat and barley). Nevertheless, the need of occasional irrigation is not excluded during drought years.

G. Land Unit: Cultivated Summit Surfaces

The main land use of summit surfaces is non-irrigated agriculture. This land unit has an area of about 35 km². The main crops are annual field crops like wheat and barley. Slopes are covered with overgrazed natural bushes mainly consisting of *Sarcopoterium spinosum* and grasses.

Soils on level to gently inclined summit surfaces are generally deep to very deep. As approaching to the edges, sometimes the soils are moderately deep. As described for land unit "Cultivated Undulated Plain" soil drainage, soil permeability and soil erodibility depend on the presence of cracks. External drainage of the summit surface increases water loss. In general, soil water erodibility is very low.

As a striking feature of "Cultivated Summit Surfaces" landform sheet erosion is moderate, because its elevated position in the landscape and to gentle to moderate inclination are present. Water erosion is particularly active as approaching to the edges of the

summit surface where surface is more inclined and soils are more shallow.

H. Land Unit: Cultivated Rolling Hills

Main landform elements of this land unit are moderately inclined to moderately steep slopes (inclination 8 - 32%) where the slopes are mainly terraced. The total area of this land unit is 12 km².

The main land use is non-irrigated olive groves, which dominate the landscape. Annual rainfed crops like wheat and barley are also cultivated. Shallow soil depth, surface stoniness and rock outcrops are the main constraints for agricultural practices. Soil depth, which ranges from very shallow to moderately deep, is among the main constraints for root growth. Generally, the soil is well drained but, sometimes, due to the shallow depth and to the inclination, it is somewhat excessively drained.

Regarding water availability, this land unit benefits from a high rainfall. Nevertheless, although total annual rainfall may appear sufficient for olive groves, its distribution is characterized by being concentrated during the winter months, leaving the summer season completely devoid of rain. Water deficiencies are common before the beginning of the rainy season during the final phases of the ripening process and affecting both quality and quantity of the production of olives. Then, the water deficit is amplified by a weak water storage capacity of shallow soils on terraced slopes and by significant losses due to run-off.

The productivity strongly depends on total rainfall and rainfall distribution and it is variable throughout the years. Periodic irrigation should be taken into consideration during the dry periods. The soil water erosion ranges from moderate to severe, erosion mainly depends on the inclination and on the maintenance status of terraces.

Figure 17: Cultivated Rolling with terraces for stabilizing the soil.

I. Land Unit: Uncultivated Hills

This land unit includes areas mainly located in the eastern part of the study region where it has a total approximate area of 168 km². The main landform elements are moderately inclined to steep slopes and hillcrests (inclination 8 - 58%) and level to gently inclined (inclination less than 8%) valley bottoms.

Due to rock outcrop, inclination and shallow soils, the land unit is not suitable for cultivation except in the valley bottoms. Therefore, the area is used as pastureland. Natural vegetation consists mainly of bushes of *Sarcopoterium spinosum, Calycotome villosa* and grasses in the upper part and *Soueda asphaltica* as descending to the Jordan Valley. Overgrazing is witnessed by the presence of plants as *Urginea maritima* and *Asphodelus microcarpus* and evident animal tracking. In addition, the almost complete degradation of the natural vegetation by overgrazing has been accelerating the soil erosion process. Shallow earth materials are still available between prevailing rock outcrop and just waiting to erode more and more.

Figure 18: Overgrazed slopes of the uncultivated hills land unit

5. ENVIROMENTAL PROTECTION

The following section briefly describes the delineated areas for protection with a

concise description of the criteria upon which the areas have been assigned. The protection of the different resources of Wadi el-Far'a area mainly concentrates on agricultural land, water, and areas of biodiversity or ecological significance. These studies have been done into the Ministry of Planning and International Cooperation between 1998 and 2000.

A. Agriculture

The main objective of this study is to identify areas of different degrees of value for agricultural future land use and protection. The study concentrated on two major issues for achieving the land value classification with accordance to agricultural landuse. These are the following:

- Potential of the land for agricultural uses or suitability for agricultural purposes (cultivable land)
- Current cultivation or agricultural land use status (cultivated versus not cultivated).

The overall results of the area delineation and its degree of protection is shown in **Figure 19**. The area assigned as highly to be protected should be prevented from random development and should be, as much as possible conserved only for agricultural use.

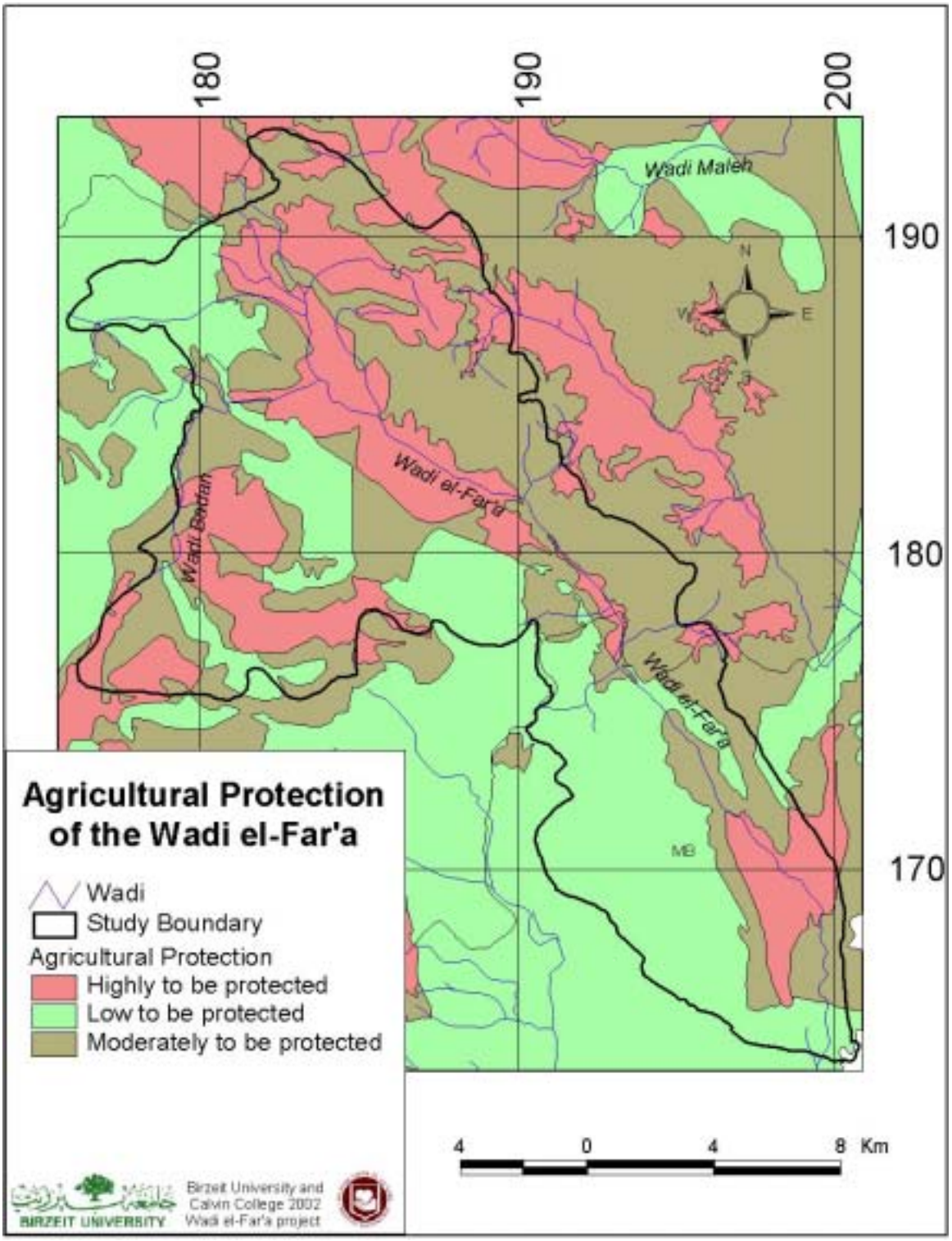

Figure 19: Protection needs for agricultural area in Wadi el-Far'a

Figure 19 also reveals that most of the area surrounding Wadi el-Far'a's tributaries, including the main one, is either highly or moderately needed to be protected from random and unplanned development. In this regard, we suggest that those areas with high degree to be protected should be conserved for agriculture use. For areas with moderate and low needs to be protected, we suggest well planned developmental activities in these areas. For this to be achieved, an Environmental Impact Assessment (EIA) or at least Environmental Quick Check (EQC) should be applied in areas where developmental activities are proposed.

B. Ecologically Significant Areas

As well as indicating the areas of ecological importance, this report also indicates generally the flora and fauna found in the area, their approximate range, those among them which are protected or endangered and the plants which are of social or economic importance. (See"Botany" in Natural Landscapes Sector Report). In this regard, such areas have to be protected from any development through a set of laws that must be implimented with tact and foresight. The guidelines for their future sustainable use are also important.

C. Water Sensetive Recharge Areas

Figure 21 reveals the degree of sensitivity of the ground water recharge areas. These areas range from highly sensitive to not sensitive. Again, the presence of regulations and laws that prevent certain developmental activities in areas of high sensitivity is important. Zoning can be useful to prevent industrial activities that are prohibited in these sensitive areas and regulated and planned in the non-sensitive areas to not impede development. Also, a general outline for an EIA parameters, standards and procedures to be followed up is essential.

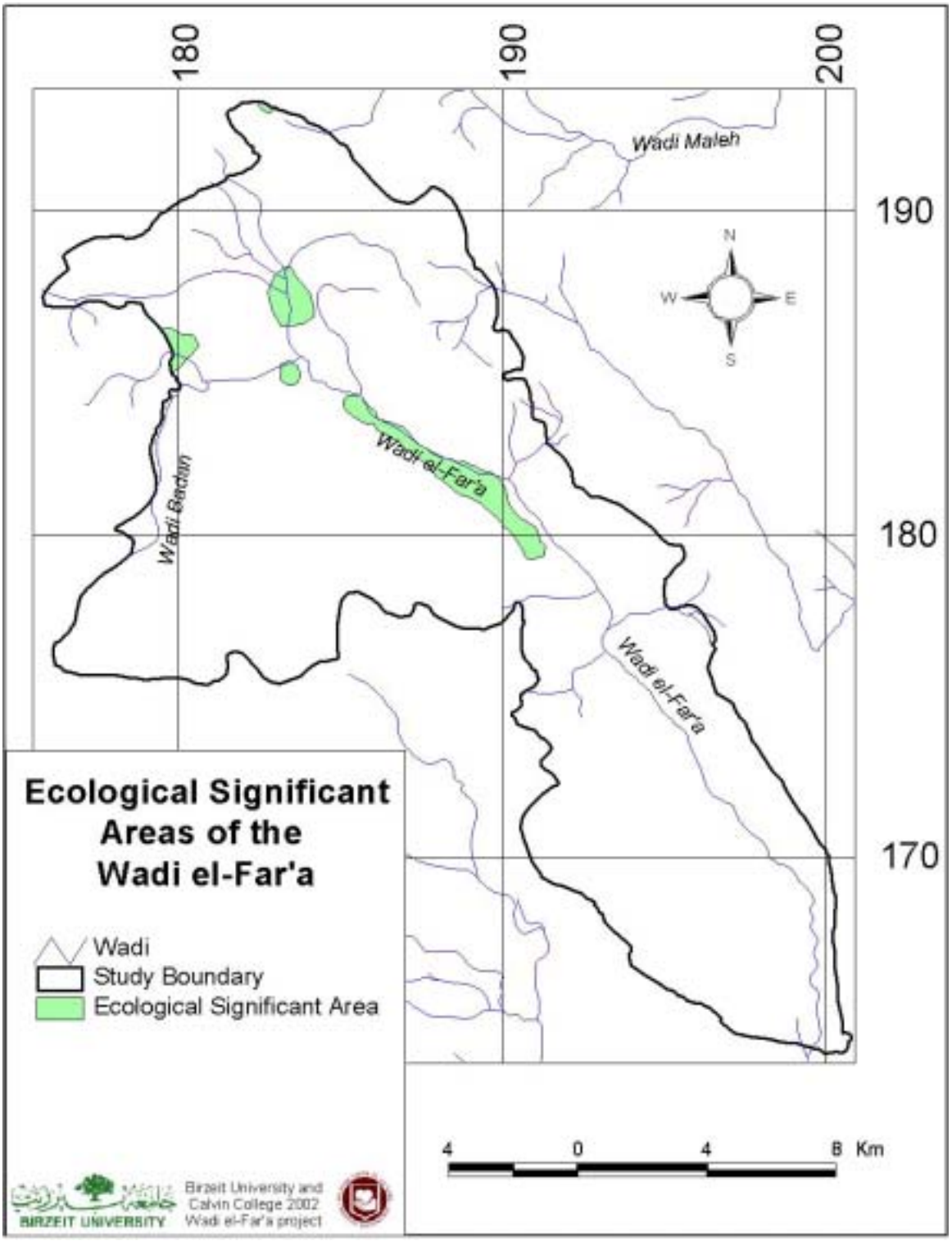

Figure 20: Ecological Significant Area

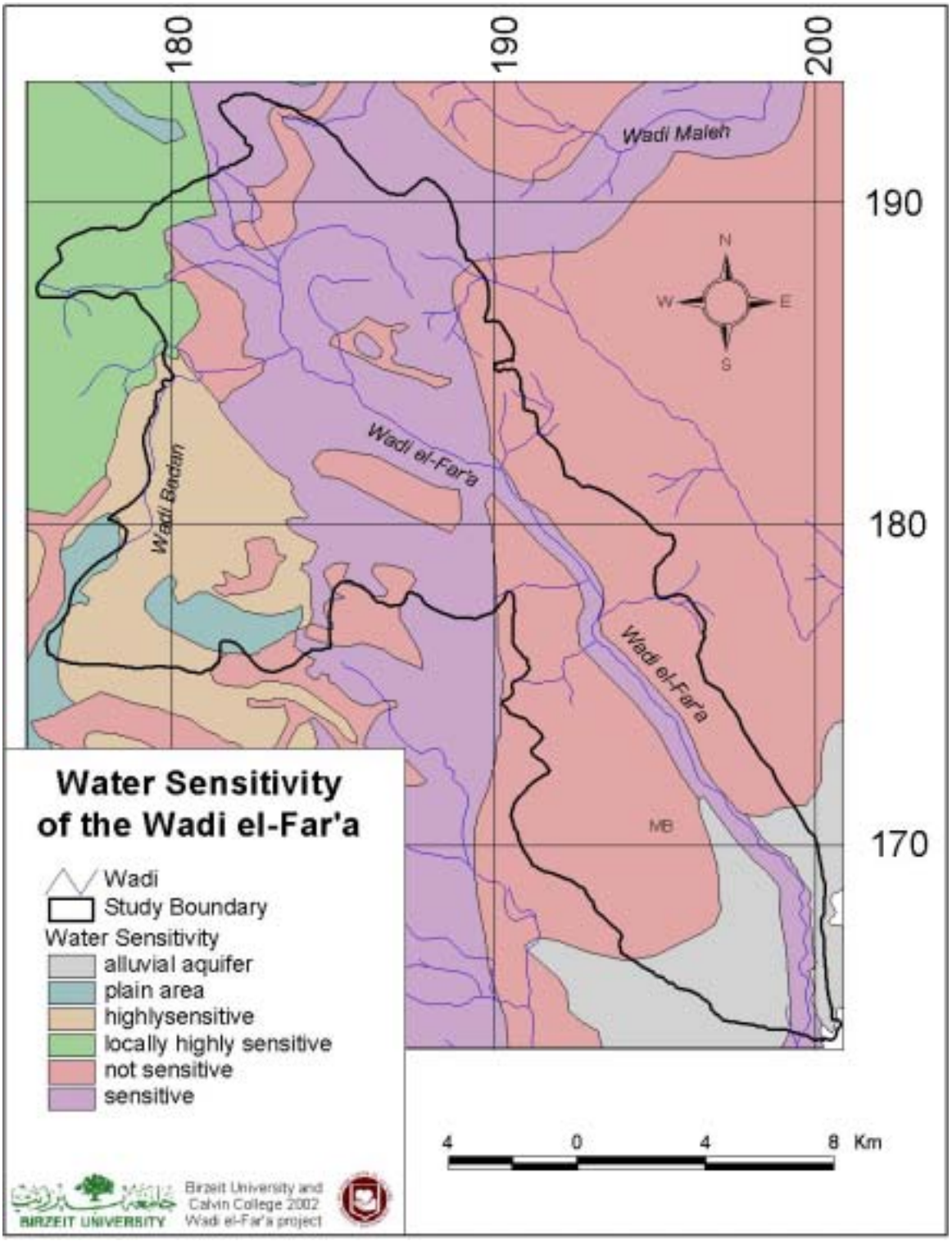

Figure 21: Senstive water recharge areas in Wadi el-Far'a

6. INTERPRETATION AND DISCUSSION

The land use, crop water requirements, crop production and water use efficiencies data are discussed and then synthesized in spatial analysis in three categories: agriculture, ecology, and water sensitive recharge areas.

The land use analyzed the built-up areas and then described eight land units in the Wadi el–Far'a.

A. Land Use

In the built-up areas the GIS portrays the spatial area distribution of land according to type and affiliation with Israeli or Palestinian populations. **Table 5** depicts that the Israelis are using more land in the study area. The Israeli land uses are various. For example: forested areas have been designated as nature reserves, but ultimately these lands are under Israeli control and the Palestinians are prevented from using or benefiting from such lands. The area controlled by the Israelis is almost three times that of the Palestinians as shown in the previous table.

The crop water requirements provide baseline data to compare the requirements and availability of water in the wadi. Although it does not need irrigation for the whole period of the year, it seems that farmers are consistent in tradition and are more apt to apply the maximum available amount of water to ensure high production. In some months of the year, especially those with rainfall, the farmers do not need to irrigate citrus, which will save water for other purposes. It is well known that the new techniques can save at least 30% of the irrigation water through the reduction of water losses by conveyance system as well as evaporation from soil surface. Besides, modern irrigation systems increase the productivity and quality of crops, because the improved scheduling of irrigation quantities and times result in better and more efficient use of available water.

To do so, extensive field research on crop water needs in different months associated with monthly available rainfall have to be done so that we can identify exactly the net amount of water needed for irrigation in each month for different crops, especially for those that are consuming a large amount of water (citrus, wheat, dates and melons). In addition, a cost benefit analysis and studies for different crops associated with the cost of water at different months should be achieved so that we can compare the results for the same crop at different locations of the West Bank. This will enable the identification of the most profitable, efficient and suitable cropping patterns for each area of the West Bank

. Because of the lack of specific local information on the type of crops, yield and productivity of each type of cultivation, the study was conducted on a district level and not a local one. Ambitious future detailed assessments will need type of crop, productivity of each specific location (El-Far'a, An Nassariya, al Aqrabaniya and Frush Beit Dajan); furthermore, it will need some other criteria to be incorporated into the classification, i.e. amount and type of fertilizer as well as water used, land preparation needs, pesticides and other chemicals used.

The assessment depends to a large extent on soil, which is considered one of the major resources for the agricultural production since it constitutes the nutrient reservoir for providing proper plant growth. The soil is also working as the main support and fixing agent to the plants body. The cultivation of annual leguminous crops (ex. *Hedysarum ssp*.) may have a positive effect on soil protection during fallow years and its feasibility should be subjected to experimentation.

The Water Use Efficiency (WUE) is spatial data that acknowledges the crops, climate, soil, and geology diversity in the Wadi el-Far'a. The WUE can give beginning background data to specific spatial recommendations for farmers in developing the crop pattern for the

wadi.

In the Land Unit descriptions, it is notable to consider the local physical characteristics in determining land use. First of all, the following three land unit descriptions are the most important irrigated areas within close proximity of the Wadi el-Far'a: Cultivated Undulated Plains, El-Far'a Valley, and Permanent Cultivated Low Plains. Second, the other land units give spatial location and insight into their relative responses to various characteristics pertitent to development. In the Cultivated Summit Surfaces land unit, conservative agricultural techniques are highly recommended in order to reduce run-off and to improve water infiltration. Among suggestions which can be applied by farmers without external support are ploughing along contour lines and ploughing the surface during fallow years in order to improve the rate of infiltration. Terracing the edges of the summit surfaces where the surface is more inclined should be taken into consideration. In the Cultivated Rolling Hills land unit, it is notable that terraces are responsible not only for stability and the productivity of the slopes but also for the security of the downstream reducing the run-off and preventing flooding in the more valuable lands located in the downstream. Based on these considerations, maintenance of terraces can not be left only to the initiative of farmers but it should be the object of regional and watershed level land conservation programs. In the Uncultivated Hills land unit, reclamation of slopes for agricultural purposes is definitively not feasible nor under technical neither economical point of view. Reducing grazing pressure to sustainable level, in order to give the nature the chance to reestablish a more diversified and continuous natural cover, is a condition for any attempts of ecological rehabilitation of the area. Finally, the land unit descriptions depict useful information for planning agriculture, ecological sensitive areas and water sensitive recharge areas.

B. Agriculture

Valuable agricultural areas are delineated by a certain combination of land suitability and cultivation status. The highly valuable agricultural areas have a high suitability for agricultural uses and at the same time they are currently cultivated (Fig. 19). The area assigned with high value should be prevented from random developmet and should be as much as possible conserved only for agricultural use. For areas with moderate and low needs to be protected, we suggest well planned developmental activities in these areas. For this to be achieved, an Environmental Impact Assessment (EIA) or at least Environmental Quick Check (EQC) should be applied in areas where developmental activities is planned to be done.

A legislative approach of setting rules, laws and regulation to protect them, when coupled with public awareness, input, and support can be an affective method of protection.

C. Ecologically Significant Areas

While this project lays down the first layer of knowledge about the areas of ecological importance in Palestine, the process of evaluation should not stop at this point. In a land in which one can drive from the desert of the Jordan Valley to the fertile highlands in thirty minutes time, those areas which are ecologically sensitive need to be researched and and focused on an extensive scale that will enable their protection (**Figure 20**).
On this background, there is increasing concern for the immediate protection of Palestinian natural resources, of which the conservation of biological diversity (fauna and flora) must occupy a high priority. Consequently, the main objective of this task is to identify areas of ecological importance in el-Far'a area which should be protected through measures and regulations that will restrict random development.

In order to achieve this, a combination of literature review and field survey was applied. Many of the areas that were identified happen to coincide with forests or Israeli declared Nature Reserves (see **Figure 11**). Often these Nature Reserves cover a much larger area than warranted. In other cases, environmentally important areas are left out of current Israeli zones of protection. Nevertheless, all existing Nature Reserves and forests should be protected according to the Oslo II-agreement. In addition, the area seems to have an especially sensitive ecological equilibrium, since the greatest variation in soil types and vegetation units were found here at short distances.

We suggest that these guidelines compose the basics for efficient use of these area along with protection. As an example, the guideline can suggest the use of these areas as an OPEN ECO-EDUCATIONAL and RECREATIONAL CENTER, that will take into consideration both efficient use as well as conservation needs of such areas.

D. Water Sensetive Recharge Areas

The sensitive water recharge areas reveals different categories, they range from highly sensitive to not sensitive. The presence of regulations and laws that prevent certain developmental activities in areas of high sensitivity is important. A guideline can also be useful, especially when it includes a set of industrial activities that are prohibited in these sensitive areas. A general outline for EIA parameters, standards and procedures to be followed up is essential. In addition, alternatives for other non-sensitive areas for the application of certain industrial and developmental activities is also needed, so that the developmental process of the Wadi el-Far'a area can not stopped. A continuous process of ground water monitoring and analysis for quality control is important, so that any detection of water quality deterioration will be signaled, problems identified and their solutions implemented.

8. Recommendations

The following are a list of short recommendations:

Short term

- **a.** Presentation of report
- **b.** Increase awareness and local input to project ideas (institutions to gain support, and later to local people to connect data to application).
- **c.** Short list of quick needs as well as small projects in the area, which will help in freezing the existing situation or at least reducing it from further deterioration.

Long Term

- **a.** Study of irrigation techniques and their efficiencies
- **b.** Intensive studies for the prevailing cropping pattern (size, productivity, type, water efficiency (WUE), feasibility economically (ie. Input-output) study for each crop, and techniques of production – greenhouse, open, and mulched)
- **c.** Study of water losses under different irrigation techniques
- **d.** Study of water delivery system, because currently it is irrigated by open canals.
- **e.** Study of the production-consumption profile, marketing and location to market as well as the possibility for having small agro-industrial sites that can serve the area as well as the surrounding ones.
- **f.** Studies on the use of waste water for irrigation in agriculture. The

study should also concentrate on which stage of treatment is feasible and environmentally safe, primary, secondary or tertiary treatment.

g. Sustainable, sound and balanced regulations, laws and guidelines that should take development needs along with protection needs. This should be connected with local public awareness programs to develop an environmental ethic.

h. Creation of research and educational centre for testing and applying new agricultural techniques. This also will help farmers and researchers to adopt sustainable ethic toward their environment (environmental awareness). The center will also be responsible on testing the quality of the products and check the standards of the quality, so that these standards are internationally recognized and accepted, which, in turn,will facilitate exportation to other countries.

i. Suitability and feasibility analysis for different crops; agriculture spatial adaptation to water conditions and land (by land unit description and agricultural sensitive areas).

j. Provide spatial analysis and understanding for future urban expansion, so that area delineation with regard to urban use and future expansion will be specified according to suitability as well as needs for future development.

k. Laws, regulations and guidelines for the protection of significant natural resource areas including: sensitive agricultural areas, water sources, cultural sites and nature preserves.

l. Construction of small measurement stations for stream characterization data – sediment, erosion and runoff data. This will serve for describing the history of the area.

m. Construction of spatial as well as non-spatial data bases for the area. This will serve as a data bank for any future studies in planning, development, monitoring and environmental dynamics of the area.

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