Irrigated Agriculture as an Indicator of Socio-Political Stability in the Wadi el Far'a, West Bank

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A research paper submitted to the Department of Geosciences at Oregon State University for the degree of Master of Science, Geography Program.

2004

Directed by Dr. Aaron Wolf

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Acknowledgements

Kamal Abdulfattah (*Birzeit University, Palestine*), Bert de Vries (*Calvin College, USA*), Ahmed Abu Hammad (*Norges landbrukshøgskole, Norway*; former *Ministry of Planning and International Cooperation, Palestine*) and Wadi el Far'a Project Team, 2001-2002. *American Center for Oriental Research in Amman, Jordan*,

Shaul Cohen (*University of Oregon, USA*), Mark Giordano (*International Water Management Institute*, *Sri Lanka*), Ofer Heyman (*Oregon State University, USA*), Shahar Katz (*GIS - Census Bureau of Statistics, Israel*), and Hugh Turral (*International Water Management Institute*, *Sri Lanka*)

Dr. and Mrs. Richard Marston (*Oklahama State University)*, supporters of the K. Muckleston Scholarship Fund; Samira Korfali (*Lebanese American University, Lebanon)*; and Jay Noller (*Oregon State University, USA)*.

Terra Cognita Laboratory, OSU Department of Geosciences, and Caryn Davis

Dr. Larry Becker, Dr. David McMurray, and Dr. Jon Kimerling

Dr. Aaron Wolf

In hopes of peace. . .

Abstract

The Wadi el Far'a catchment is a tributary of the Jordan River located entirely in the West Bank in the Middle East. Increasing population in the catchment, along with economic development, is likely to increase water needs in this water limited region. In the water management of the region, agriculture is an essential and dominant component, currently amounting to 80%, total water use (Merrett, 2002). There are data that suggest that an increase in irrigated agriculture is both possible and desirable. First, the total irrigated area has actually decreased in recent years, due probably to current geopolitical tensions (Palestinian Hydrology Group cited in Beschorner, 1992). Second, there exists a 33% irrigated / irrigable land ratio (Elmusa, 1997). Third, (irrigated) agriculture is a major component of the economy (Allen 1999). This paper looks at the relationship between irrigated farmland and political tension, and examines the hypothesis that socio-political for a documentable increase in area of irrigated agriculture. The political boundaries and milieux delineate area of varying socio-political stability in time. It is suggested that socio-political stability promotes agricultural infrastructure, access to water, and markets needed for the investment of irrigated agriculture. A brief context of water use, land use, and agriculture in the catchment is presented vis-à-vis the geopolitical situation. A variety of Remote Sensor (RS) and Geographic Information System (GIS) data are analyzed with geographic techniques to determine any significant differences in the agricultural landscape between three distinct political eras: Period I: between the first *Intifada* (or Palestinian Uprising) and the Oslo Agreement; Period II: after the Oslo Agreement up to the second *Al-Aqsa Intifada*; and Period III: during the second *Al-Aqsa Intifada* to the present.

Introduction

Water is a prominent global issue due to a dramatic increase in population and economic development during the past century and the limited amount of freshwater. Water resources are both vital to life itself and essential to society, with applications to domestic life, agriculture, industry, power, and transportation. In comparison to other types of water use, irrigated agriculture is typically a large percentage of total water use.

More recently, urban life and development compete with these agrarian sectors for water use, land use, and political clout. Global population has tripled in 70 years (UNFPA, 2001) while water use increased six-fold (Brooks, 2002). Water use is increasing in the built-up areas, where the diversity in services and typically high wages attract a growing population, while global indicators suggest a decline in the growth rate of irrigated agriculture (FAO, 2002).

Water and land use management, particularly in water-limited regions, could benefit from an analysis of the historical trends of irrigated agriculture. Such an analysis would examine the spatial variability of water, and would direct the policy and allocation of water in the future. First, agriculture water use to grow food requires about 100 times more water than domestic water use. Furthermore, irrigated agricultural land provides about 40% of the global food supply (Brooks, 2002). Second, an estimate of irrigated agriculture over time is obtainable through classification of remote sensor data. Third, spatial variability provides context to land use planning and development.

Geography is a discipline well suited to water resource management analysis (White, 1973: 119)[1]. The discipline draws upon a rich tradition of spatial inquiries to the human and environment interface (Hartshorne, 1959). The geographical techniques of Geographic Information Systems (GIS) and Remote

1 "... probing for new answers to the puzzle of [hu]man's interrelationship with water and land." (White, 1973: 119).

Sensing (RS) are designed to address inherently spatial questions of landscape change and classification.

In general, the Middle East is a water-limited region. The Jordan River basin provides water for its five riparian political entities: Israel, Jordan, Lebanon, Palestinian National Authority, and Syria. In the literature, water is considered a crucial component of the political dynamics in the region with respects to political conflict or cooperation. Decision makers at the local level inherently evaluate the socio-political stability to determine the risk, dependence, and sustainability of water use.

In the analysis of irrigated agriculture, water management must address the socio-political dynamics and context of those data. The literature of socio-political stability and irrigated agriculture is interwoven with geo-politics, agriculture, and irrigated agriculture and political landscapes. First, geo-politics stresses the relationship between the geography and the politics; the geography determines politics. For example, Foucher (1987) discusses the borders of Israel / Palestine in terms of the human and physical natures. Second, agriculture connects the environment with the people through the people's food supply, way of life, and existence. Third, the irrigated agriculture and political landscapes evolve depending on each farmer's assessment and interpretation of the policy and political climate his/her time.

There are multiple scales of analysis in this study; the main focus is at the Wadi el Far'a catchment scale, yet this study also draws upon data at a local, national, and Jordan River catchment scales. The Jordan River data provide an international context for socio-political stability. The West Bank is the political region for Palestinian statistical data. The catchment is the hydrologic unit of analysis. The landscape is identified at more local scale where the farmer's decision to plant crops takes place.

The Wadi el Far'a catchment, a tributary of the Jordan River entirely situated in the West Bank, is essential to the Palestinian National Authority for its agriculture and water resources. This catchment is in a semi-arid climate with limited water resources. A projected 4% increase in population (PCBS, 2004) is likely to augment the development and water needs in this water limited region. Urban development in the area increases the need for local resources, and present an additional pollution source in the catchment without planning and infrastructure (Thawaba, 2001). An increase in domestic water use is likely to ensure more competition for agriculture water sources. In the water management of the West Bank, agriculture is an essential and dominant, around 80%, component of the water use (Merrett, 2002). The Wadi el Far'a catchment has the largest contiguous Palestinian agriculture for a wadi entirely in the West Bank. These limited resources are important to allocate for water resource management. There also exists political complexity in the region due to the various powers in the region. These limited resources are important to allocate for water resource management.

In response to concerns about the general environmental assessment of the catchment, a research team investigated the cultural and natural landscape of the Wadi el Far'a catchment (2001-2002). Results revealed that socio-political factors are integral to any interpretation of this wadi. This research is part of a larger component of the Environmental Assessment of the Wadi el Far'a watershed. The focus of this research is to examine the impact of socio-political stability on the spatial distribution and area of agricultural lands in the Wadi el Far'a catchment by examining remote sensor data over three political periods. For the past three decades, three periods are identified for varying conditions of socio-political stability and compared to the total area of irrigated agriculture in the Wadi el Far'a catchment. Socio-political stability, as defined in this study, encompasses the nexus of water use management, political administration, and land use. Geographic methods are used to address this situation.

Hypothesis

It is hypothesized that the area of irrigated agriculture increases with socio-political stability.

Socio-Political Stability

Socio-political stability is argued as a positive attribute for the inhabitants of the region to promote economic growth, sustainable natural resources, and mobility. Political boundaries affect water resources by the administrative boundaries placed on various government agencies and nation-states. These divisions are exercised via management, land use, and water resource management policy and implementation.

Factors

In this study, four main factors define the relationship between irrigated agriculture and socio-political stability: hydrologic and physical landscape parameters, land use – water usage, population, and political administration.2 First, hydrologic and physical landscape parameters describe the environment where people live and interact with the climate and the geomorphic land features of the catchment. Physical characteristics limit the suitable locations for both agriculture and urban development. Second, land and water use are relevant to the relationship between the inhabitants and the land. For example, societal needs and desires are variable among natural resources. There is often a sense of tradition in agriculture as part of a family heritage and inheritance of land. Third, the population forms a culture, realpolitik, and may dictate the general intensity of stability. Insight from the social-economic variables like labor and the contribution of agriculture to GDP aids the interpretation of data in time: past, present, and future. Fourth, the political administration and different entities at various scales are responsible for the complex layering of laws, regulations, and institutions that address both irrigated agriculture and, inherently, affect socio-political stability. More specifically in the context of irrigated agriculture, policy addresses accessibility

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[2] See (UNESCO-WWAP, 2003: 12-17) for more detailed factors in changes affecting water: geopolitical changes, population growth, agricultural demand, energy requirements, urbanization, economic growth and industry, globalization, technological changes, lifestyle, recreation and tourism, and climate change.

and availability to water, labor, and markets and present the relationship between policy and person with discernment of risk, dependence, and sustainability (Figure 1).

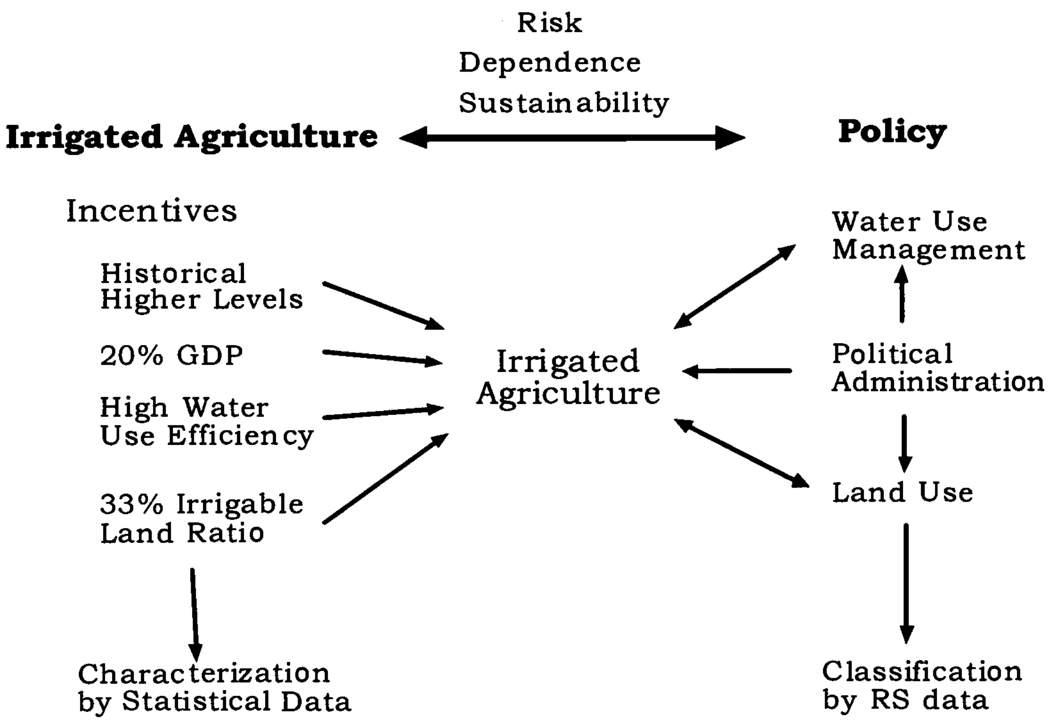


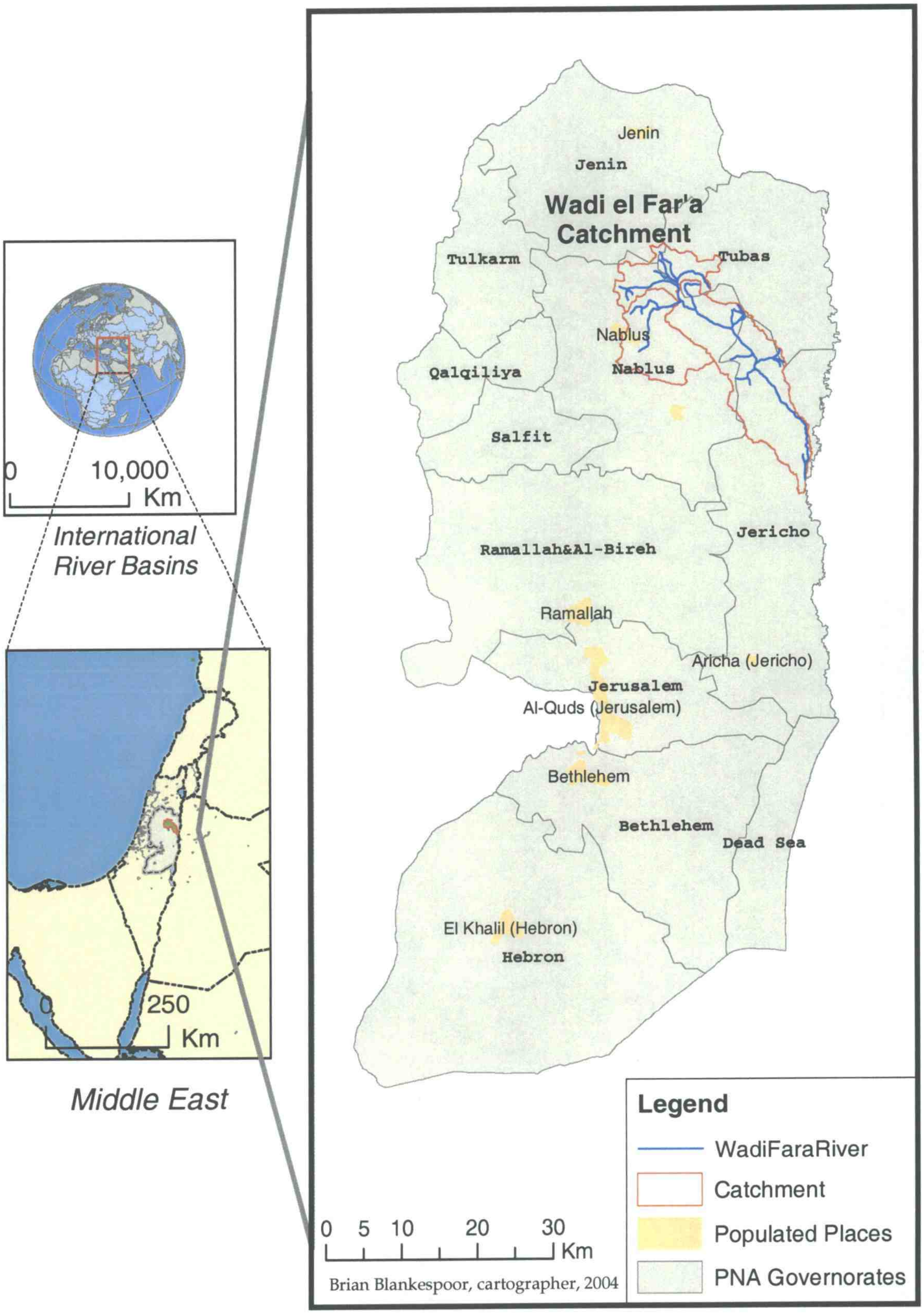
Figure 1. The relationship between irrigated agriculture and policy

Methods and Data Collection

Physical Setting

The Wadi el Far'a is a tributary of the Jordan River situated in the West Bank in the Middle East[3] (Map 1). The water flows from the northwest, at an elevation of 1100 meters, to the southeast at the confluence of the Jordan River, at an elevation of -400 meters. The catchment is 335 square kilometers with a perimeter of 166 kilometers. From source to the Jordan River the stream is 20 kilometers long. The western part of the study area abuts the city of Nablus and

[3] Far'a is from the word "branch" or tributary: Wadi el Far'a is literally translated "valley of the branch"



Map 1: Boundaries of the Wadi el Far'a Catchment

is approximately fifty kilometers east of the Mediterranean Sea. Because of the springs, wells, climate, and agricultural lands, this catchment is considered one of the richest and most fertile agricultural resources in the West Bank (MoPIC, 1999). Archaeological evidence of the past reveals various periods of settlements and agricultural practices (Dababsa et al., 2003).

Land use / Agriculture

The indigenous knowledge of agriculture is ingrained in the local culture. It is taught to one generation from another generation. Agriculture is also a crucial issue pertaining to the political stability in the Wadi el Far'a catchment. Management, policy, and politics affect agriculture and these factors are evident in agriculture as a component of the land use, water use, economy, and traditional culture.

Agriculture is important to the local food supply. A surge of agricultural development happened in cooperation with the Jordan Valley Authority. These agricultural lands have great potential to be successful due to the warm climate and the access to water; these are favorable conditions that promote plant growth before other regions (Isaac et al., 1997). However, at the regional scale, Palestinian agriculture is constrained by land, water, and access to markets (Butterfield, 2000). These constraints impact the agricultural process from seed to produce on the land, as well as the labor force, crop transportation, and markets that connect the segments of society and political regions. Furthermore, during the past half-century, irrigated agriculture has lost its prominence in the West Bank (Palestinian Hydrology Group cited in Beschorner, 1992) despite the following incentives for this method of agriculture to persist: high water use efficiency, low irrigated over irrigable land ratio (Elmusa, 1997), and importance in the economy (Allen, 1999).

It is helpful to address the historical and current impact of land-use planning on the landscape. *The West Bank and Gaza Atlas* (Benvensti et al., 1988) Water Resources Map displays the Wadi al Far'a catchment as the largest contiguous "Arab irrigated lands" on the West Bank. This catchment presents a unique opportunity from the Palestinian perspective to analyze a cohesive region and address the "lack of integrated land use planning" Isaac et al. (2001) one of the many challenges to the Arab agriculture along with water (Biswas et al., 1997).

Water Use

In the Fertile Crescent, inhabitants built irrigation systems that consisted of constructed channels for surface water flow several centuries ago (Postel, 1999). Currently, a variety of irrigation techniques, water sources, and growing methods are used in the region: water application by flood or drip; water sources from wells, springs, surface water, and agricultural ponds; and agricultural land method of open field or plastic houses (greenhouses). It is important to recognize the heterogeneity of agriculture as this study utilizes a method for identifying agricultural lands and then categorize them into rainfed or irrigated agriculture based on remote sensor data. All techniques listed here are found within the catchment (Tomazi et al., 2003).

Data Collection

Data were gathered from field seasons in the Wadi el Far'a Project (2001 – 2002). Additional data from various sources were entered in a GIS for spatial analysis and context to the agricultural areas (See Appendix I for a list of layers and data sources). Irrigation and rainfed agricultural areas were classified with remote sensor data explained in section on Methods.

The analysis of Wadi el Far'a catchment incorporated a number of people with different expertise to identify the water resources of the catchment and their potential for water development. The related topics of interest are: Natural Landscapes, Land Use, Built-Up Areas, and Water Rights (Abdulfattah and deVries: Wadi el Far'a Report, 2003). The Geographic Information System (GIS) created during this work is extensively utilized throughout this analysis and additional layers are created, for example, land use, land characteristics, well location and type, and Digital Elevation Model (DEM), and the catchment boundary (Appendix 1).

Remote Sensor Data

RS and GIS have a rich history of use for the delineation of land use and land cover. As one of the many land uses and water uses, RS data are particularly useful for delineating agricultural land use for management purposes (Schultz et al., 2003, Knox et al., 1999, Bastiaanssen, 1998). Remote sensor imaging has been used to estimate crop water requirements as well as spatial distribution of irrigation. One method of transforming data into pertinent information is by creating indices. There are many indices that aid interpretation of the landscape based on the vegetation, soil, and thermal properties (See Bastiaanssen, 1998). Turral states the importance of using remote sensor data in irrigated area mapping, so that intensification, expansion, and land retirement can be investigated (pers. comm., 2003). In addition, irrigation and time series analyses of quantitative remote sensor data may provide insight to management (Bastiaaanssen, 1998).

In this study, remote sensor data are selected based on the following criteria: amount of cloud cover, availability, price, political period, spatial and temporal resolution, and summer season acquisition to accentuate the landscape differences between irrigated and rain-fed agriculture. For a temporal comparison of the landscape, data from Thematic Mapper (TM) 14 August 1987 (Period I), Enhanced Thematic Mapper (ETM) 7 August 1999 (Period II), and ASTER 24 May 2001 (Period III) were analyzed for landscape changes. ASTER provides finer spatial resolution (15 meter in VNIR), more bands (Appendix 2), and more affordable than the Thematic Mapper series. Besides temporal comparisons, ASTER Digital Elevation Model (DEM) data provide topography at a 30 meter spatial resolution, and SPOT (1990) is the source visual detail with 10 meter panchromatic band.

The land cover classification method is a 2-way supervised classification system that compares a vegetation index against thermal data (adapted from Turral, 2002)[4]. This classification method associates the NDVI vegetation index

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[4] Also see Bastiaanssen (1998) pp 34-35 for further explanation

with agricultural lands due to the cycle of agricultural vegetation being different than the indigenous vegetation. (The semi-arid and arid climates of the summer months accentuate this distinction). Thermal reflectance separates the water application technique between irrigated and rainfed. This distinction is based on the process of transpiration theoretically being cooler for irrigated agriculture with deep roots and adequate water, whereas rainfed agriculture appears warmer due to a less developed root system and greater water stress. The supervised classification is created by delineating regions from the density of pixels by the mean to upper left (irrigated), upper right (rainfed), and below the mean of the vegetation index (non-agriculture). Visser (1989) tested different methods of delineating irrigated and non-irrigated areas and concluded that supervised classification provided the greatest accuracy compared to multiplier of reflectance ratios in Thematic Mapper (TM) or principal component analysis.

Remote sensor data are classified into areas of irrigated agriculture and rainfed agriculture by the following steps:

1.) Topography of the region is from ASTER 30 meter DEM data
2.) Stream location data of the Wadi el Far'a and tributaries are from MoPIC (1998).
3.) ArcGIS with an ArcHydro model processes the topography and stream location data to delineate a catchment boundary.
4.) Downloaded satellite data: TM, ETM, and ASTER
5.) Clipped the satellite data to the catchment boundary
6.) Calculated Normalized Difference Vegetation Index (NDVI):

Equation 1: NDVI[5] = $$\frac{INFRARED - RED}{INFRARED + RED}$$

7.) Interpolate thermal data spatial resolution to NDVI spatial resolution: ASTER (90m to 15m), TM (120m to 30m), and ETM (60m to 30m).[6]

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[5] The bands differ with respect to the satellite for Infrared (0.76 - 0.90 μm, 0.78 - 0.90 μm, 0.76 - 0.86 μm) (TM, ETM, and ASTER data respectively), however Red is the same (0.63 - 0.69μm)

[6] The following thermal data are used: TM and ETM (Band 6: 10.4 - 12.5 μm), and ASTER L2 Surface Kinetic Temperature product (°K)

8.) 2-D Scatterplots plots the NDVI and thermal data from the same geographic location (Figure 1). Color is derived by density of pixels.

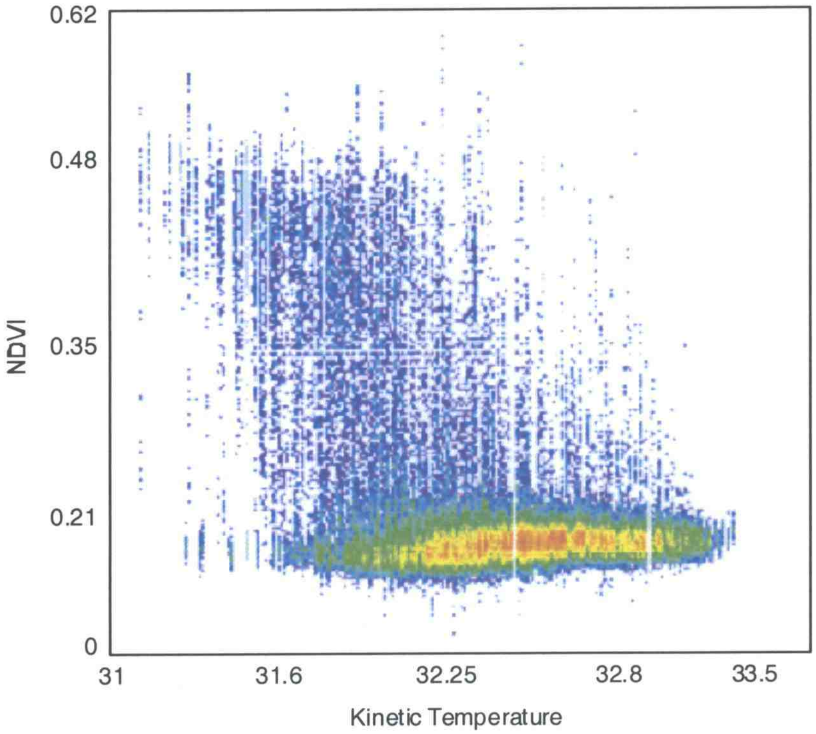

Figure 1. 2-D Density Slice Scatterplot NDVI vs. Kinetic Temperature

9.) The 2-D Scatterplot informs three different classifications based on the intersection of these data: irrigated agriculture, rainfed agriculture, and non-agriculture (as vegetation below) (Table 1). The mean is the divider between upper and lower classification for both thermal and NDVI.

10.) A supervised Spectral Angle classification with the above supervised data regions are applied to the catchment.

11.) Classification data are exported to vector format for the GIS Analysis to investigate total area and spatial distribution.

12.) Since no comprehensive ground truth data in relation to the respective date are available, a visual analysis of the classified areas of agriculture compared to the expected locations provided by MoPIC land use data (1998).

Table 1. 2-Way Classification Schema

	Thermal –Low	Thermal – High
VI – High	Irrigation Area	Rainfed
VI – Low	Stressed Vegetation	Seasonal Vegetation

Source: Adapted from Turral, 2003

Geographic Information System and Spatial Analysis

Spatial analysis was performed with a GIS. The GIS facilitates the analysis of spatial relationships among multiple layers of spatial data. Pertinent data that were available included: topography, climate, demography, boundaries, and remote sensor images for the area. A Digital Elevation Model (DEM) provides basic topographic data at 30 meter pixel from the sensor Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). Other geographic data were created from the DEM, including catchment boundary, slope, and precipitation. The catchment was delineated by the AgreeDEM method in the ArcHydro Model and divided into three sub-catchments. They were aggregated together and classified as two upper elevation, and one lower elevation sub-catchment. Precipitation data address the climatic variability during the study periods. These data were calculated from meteorological point data in Ghanem (1999) and interpolated as a function of elevation from the DEM[7,8]. Population data were compiled in order to assess the potential impact of population in terms of water and food. Since there are two political systems of influence in the catchment, population data from PCBS and the Central Bureau of Statistics (of Israel) were summarized. Current populated places are shown in Map 2. A water stress index was calculated to quantify the stress on water in the catchment. Water stress has the potential to aggravate by political instability (Dombrowsky, 2003). Yoffe et al. (2002) calculate water stress within a catchment as follows:

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[7] Precipitation data are also available from Palestinian Central Bureau of Statistics (PCBS): Nablus: 2003

[8] See also (Goldreich, 2003: 55-91) for additional equations.

Equation 2: Water Stress = Population per basin divided by Discharge per basin[9] [10]

The published average rate of 18 MCM/yr (Yaffe, 1998) is used to determine water stress by year. Boundary data were provided by the Israeli GIS Unit (pers. Comm., 2003) and MoPIC (1999) and digitized map data were from *Atlas of Palestine* (ARIJ, 1999).

Irrigated and Rainfed Agriculture

Agriculture is a crucial issue pertaining to political stability in the Wadi el Far'a catchment. Management, policy, and politics affect agriculture and these factors are evident in agriculture as a component of the land use, water use, economy, and traditional culture. Time series data are collected in order to determine the relationship between the periodicity of the data and the socio-political stability. These data reflect decisions made by the farmer at the local scale, the authorities at the municipal and regional scale, and international dynamics at the Jordan River Basin scale.

Water Resources -- Jordan River Basin

The Jordan River is widely known for the diversity of perspectives including its political situation, various historical regimes, and the complexity of issues that interrelates its water with other topics, including politics. Water use is one the primary issues in the region, relating specifically to the Israeli-Palestinian conflict.[11] Information about the Jordan River comes from a robust set of literature about water use (also land use) and politics including Rouyer (2000), Elmusa (1997), and Lowi (1993). In the Jordan River basin, there are five political entities: Israel, Jordan, Lebanon, Palestinian National Authority (PNA), and Syria. The development plans and political boundaries in the past century have undoubtedly included discussions of water resources (Wolf, 2000). Access to

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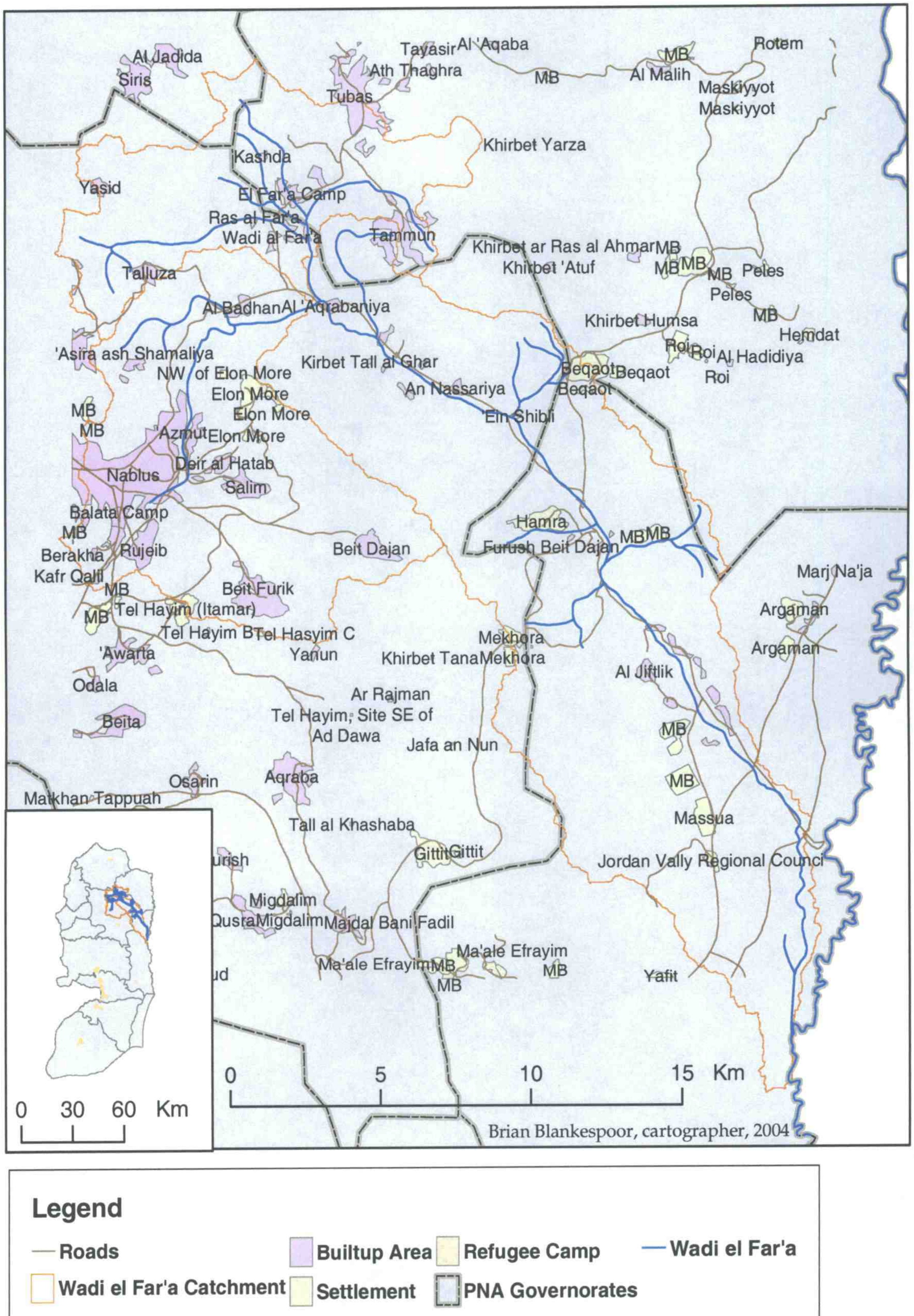
[9] (Yoffe et al., 2002)

[10] Another water stress (by country) is Malin Falkenmark's (1989) water stress: thresholds of water stress (<1700 cu.m/person/year), chronic water scarcity (<1000 cu.m/person/year) and absolute scarcity (<500 cu.m./person/year)

[11] Water is one of six topics addressed in the Oslo Agreement (1993)



Map 2: Populated Places in the Wadi el Far'a Catchment water resources in this

region is as essential to the long term stability of the people and political powers as it is to its economic and political vitality. Furthermore, some argue that water resources are a point of contention for war and have led to many conflicts in the Jordan River basin (Frederiksen, 2003; Kawash cited in Ward, 2002: 193; Shiva, 2002; Homer-Dixon, 1994; Gleick, 1993). Others, however, have argued that water can foster relations towards peace (Haddadin, 2002; Haddadin cited in Otchet, 2004 [12]; Wolf, 2000; Wolf, 1995). Suffice it to say, water resource management is vital component of the agricultural and political character of the region at both the Wadi el Far'a and Jordan River basin scale.

In terms of socio-political stability, there is a high level of complexity and uncertainty in the water resource management of the Jordan River (Kay et al. in Amery et al., 2000). In order to determine the frequency and political dynamics of the region, the Transboundary Freshwater Dispute Database has records of events in terms of conflict and cooperation. Cooperative events are considered events of socio-political stability.

Water Resources -- Wadi el Far'a

The four factors of socio-political stability (presented on page 8) are discussed in relation to the Wadi el Far'a catchment. First, the hydrologic and physical land parameters are paramount in the selection of the suitable locations for the type of agriculture and living. Water resource and land use management are responsible to address a range of needs. Even thought the catchment is one hydrologic region, there is inherent physical spatial variability in this catchment. The springs and higher precipitation areas are in the upper elevation areas of the catchment, while the El Far'a valley is more arid. There is also intra-annular variability in water. To illustrate the water year variability, meteorological data from 1946-1966 show an average of 15.9 MCM with a minimum of 8.7 MCM and a maximum of 23.0 MCM (Agricultural Census of the Hashemite Kingdom of Jordan, 1969). Second, the landscape (and therefore land use) is highly

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[12] "Water by its very nature is used to extinguish fires, not to ignite them," says former Water Minister of Jordan, Munther Haddadin, cited in Otchet, 2004.

segmented with three different regions of political authority described in the Oslo Agreement. Different incentives and socio-political perspectives affect the stability of the catchment. Third, in relation to the population, there is one Palestinian refugee camp, El Far'a camp, and there are six Israeli settlements. The two statistical bureaus for the region (PCBS and ICBS) project population to increase around 4% in the next decade more than 300,000 from the total of 240,580 (PCBS, 2003).[13] [14] Hammad et al. (2003) determined that the total land use area in the region is around one-third Palestinian and two-thirds Israeli land use, while the population is 90% Palestinian and 10% Israeli. Fourth, the Wadi el Far'a catchment scale has only two political entities: Israel and the PNA. Within the PNA, two governorates, Jericho and Nablus, encompass the wadi catchment.

Current water law and management is a culmination of many political traditions and people. The political landscape reflects the Ottoman, British, Jordanian, Israeli, and, more recently, Palestinian management of water resources. The Nablus and Jericho PNA governorates encompass the Wadi el Far'a catchment.

Methodology for examining political stability

The socio-political stability in the catchment results from dynamics at several spatial or temporal scales. The local spatial scale identifies the decision making of farmers in terms of work, location, and of particular concern the type and the amount of area of the agriculture. The catchment scale addresses the hydrologic processes and the land use within these borders. At the political regional scale, there are governorates of Palestinian National Authority, districts of Israel, political regions of authority from the Oslo Agreement, and populated places. The Jordan River scale reveals a greater political context of political entities and hydrologic context. In terms of the units of time, general periods dictated by distinct events separate the periods and will be discussed in detail.

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[13] Excluding Shihda wa Hamlan (BUCODE=150940), Kirbet Tall al Gha (150850), and Kashda (50650) because data are not available in provided estimated data.

[14] The year of the data are 2003 for Palestinian Built-Up areas and 2000 population data report states 9,239 from Israeli settlements (ICBS, 2003)

Socio-political stability is evident at different scales of analysis. Socio-political stability is complex and, in general, addresses reliability of the socio-political system. (Is the system sustainable – consistent over time? Is there resilience to the variability of socio-political dynamics?).

In terms of socio-political stability, this study identifies three political landscapes in the past decades that influenced in the Wadi el Far'a catchment in terms of water availability and access, labor, and access to markets. Two perspectives are presented considering comparable water years[15].

First, political stability produces an increase in total irrigated agriculture because there is less risk in depending on the water system, greater accessibility to infrastructural improvements and maintenance, better access to food markets, and incentives to increase. In general, higher yields and water efficiencies can be achieved with irrigated agriculture; however the incentive to apply this technique diminishes with political instability. In other words, traditional approaches often usurp newer methods for securing livelihoods in agriculture. There is recognition of ambiguity in the water policy that prevents a comprehensive stability to the water system (Dombrowksy, 2003) and hampers socio-economic development. Farmers are concerned about the sustainability of the system: risk, reliability, and dependence. Irrigated agriculture requires capital for the investment (financial risk) as well as trust in the system that water delivery will be stable in the availability (reliability) and delivery (dependence) for the growing season.

However, a second relationship between agriculture and stability suggests the converse - that socio-political stability dissuades agriculture. The basic idea is that the people involved in agriculture are driven by wages, costs, and access to labor. Historically, higher wages are earned in Israel, and agricultural labor follows better wages (World Bank, 1993). Therefore the same labor pool for agriculture works outside the catchment in socio-political stable times, while the labor pool resides in the catchment when access is limited. In addition to labor,

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[15] Shaheen (2003) presents survey data from farmers about irrigation water that explain some resilience in the application of water: 44% would reduce water intake based on limited total supply, 31% would change crops, and 25% would abstain during times of water shortage.

the inhabitants also integrate a notion of (Palestinian) nationalism about agriculture and subsistence as a means to self-sufficiency during times of instability, and thus increase the total area of irrigated agriculture.

To summarize both approaches, they emphasize accessibility despite their respective interpretations of the political situation. Since there are known periods of political stability, and thus more assumed accessibility, these periods are used to test these perspectives. Historically speaking, the incentive for development of agriculture has not been evident in recent years. Roy (1999) asserts that agriculture has not drastically changed in yield since the 1960's due to Israeli-imposed restrictions. There often exists a disconnect between the markets, laborers, and the location of the agriculture. Butterfield (2000) states that accessibility to water and to markets is the major issue for Palestinian agriculture today. Moreover, Daibes (2000) states that stability is a prerequisite to development that is needed for maintenance of water resources. However, an analysis of remote sensor data has the possibility to classify land cover for the entire region regardless of the political boundaries on the ground.

In this region, water use becomes synonymous with politics and data from different sources may come with a political slant. Water use differences are commonly distinguished in the data between Palestinian and Israeli purposes and their respective built-up and cultivated areas. This study uses data from both sources.

Political Periods

The region of the Wadi el Far'a catchment has a rich history. A variety of political powers have had influence over the inhabitants of both the Jordan River Basin and the Wadi el Far'a catchment, its tributary (See Timeline: Political Landscape of the West Bank). The Ottoman Empire inhabited this region until the British colonized the region after World War I with the British Mandate. After the British Mandate, Jordan and Israel are two dominant powers. The State of Israel is recognized in 1948. Jordan had authority over the West Bank until 1967 when the West Bank becomes an Occupied Territory by Israel.

Due to the diverse history in the Wadi el Far'a catchment; the past is indisputably coupled to current geopolitics (Foucher, 1989). After 1967, the West Bank economy became increasingly dependent on Israel for GNP, and import / export of goods (Saleh, 1990). Also, the percent of GNP as agriculture increase from 1967 to the beginning of the *First Intifada*. In 1973, Egypt and Syria launch a pre-emptive attack on Israel that augments the intraregional tension. During the 1960's Palestinian constituent groups are created like the Palestinian Liberation Organization (PLO) and Fatah. However, they gain more prominence in the wake of the war with the recognition of the PLO as the sole representative of the Palestinian people by the Arab States in 1974. During the proceeding three decades and subsequent analysis in this study, two *Intifada*, or uprising, occur, as well as an unprecedented agreement between the Israeli and Palestinians in the signing of the Oslo Agreement (1993) (Figure 3).

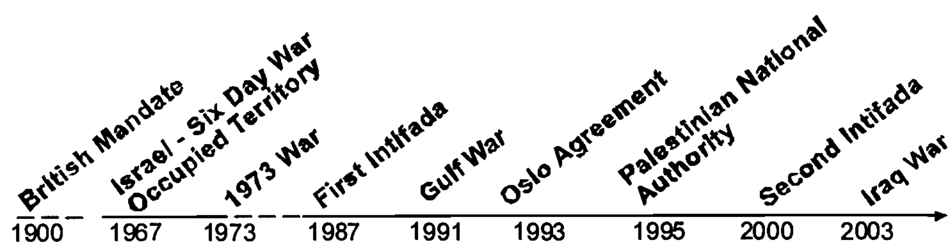

Figure 3. Political Landscape Timeline of the West Bank

In this study, three political landscapes are identified in order to test socio-political stability. The periods represent a time in between a major socio-political event like the Oslo Agreement. The periods are all in the previous three decades due to the availability of high spatial resolution remote sensor data for the comparison of irrigated agriculture.

Period I: Intifada to Oslo Agreement (1987-1993)

The First *Intifada* started in 1987. Although the PLO is quick to support it, numerous incidents between Israelis and Palestinians instigated the conflict. In the broader region, both Egypt and Jordan showed signs of hesitations to their support of the Gaza Strip and West Bank, respectively. Other demographic data contributed to increased tension: rising population density, high unemployment, limited allocation of land for agriculture or development. Although the Israeli Defense Force (IDF) dominated any military conflict, the *Intifada* publicized the plight of the Palestinians and may have contributed attention to peace movements that precursor the Oslo Agreement. In summary, this period is characterized by a lack of socio-political stability as the governing power, Israel, seeks to calm the uprising.

Period II: Oslo Agreement to Second Intifada (1993-2000)

During Period II, there is intense negotiation. In 1993, Israel and the Palestinian Liberation Organization signed the Oslo Agreement. The Oslo Agreement changed the political landscape by the addition of the PNA and segmenting political authority in the catchment between Israel and the PNA[16]. In 1993, the Oslo Agreement established the development of the Palestinian National Authority (PNA). Two points of the Oslo Agreement are highlighted for this study: (not fully implemented) joint water sharing principles and cooperative water sharing mechanisms, and land delineations. The water principles set the stage for greater cooperation, resilience, and potential stability for water users in the region. The Oslo Agreement delineated three different types of land (A, B, and C) in the West Bank[17]. With the recognition of the PNA, it delegated governorates to administer policy at the regional scale and the Palestinian Water Authority (PWA) to regulate water and wastewater[18]. Tragedy struck, in 1995, when Yitzhak Rabin was assassinated by a religious extremist. Negotiations continued, in October 1998, when the Wye River accord is signed by Benjamin Netanyahu and Yasir Arafat in Washington D.C. Finally, in May 2000, the Israeli

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[16] With regards to water, the Oslo Agreement has two points worth mentioning here: the treaty recognizes that current (1994) water resources are not sufficient for needs and the treaty recognizes the riparian entities of Israel, Palestinian and Jordan (Article 6 cited in Bickerton et al., 1998).

[17] The delineations A, B, and C are as follows: A: Palestinian full responsibility for internal security and public order in six cities; B: Palestinian full civil authority in towns and villages; and C: Israel will retain full responsibility for security and public order (The Taba Accord cited Bickerton et al., 1998: 308)

[18] The Palestinian Water Authourity (PWA) states an interest in a local approach to water (Assaf, 2000).

army withdraws from South Lebanon after twenty-two years of occupation.[19] To conclude, this period represent a period of relative socio-political stability with the introduction of institutional capacity between the entities in conflict.

Period III: Second Intifada to present (2000-2004)

The *Al-Aqsa Intifada* is the Palestinian uprising representing the current political situation. Violence erupted after Ariel Sharon visited to the Haram el-Sharif / Temple Mount in Jerusalem in September 2000. An atmosphere of suicide attacks and resentment develops including a Passover Massacre and the IDF response Operation Defensive Shield (2002). In 2003, the construction of the Israeli West Bank Barrier resumes to subdue the localized region and reduce mobility between the West Bank and Israel. During this period, there are severe restrictions of movement in the West Bank (Palestine Monitor, 2004). Socio-political stability is uncertain by the frequent attacks and incursions into the autonomous areas in the West Bank.

Results and Discussion

Land Use and Spatial Distribution

Current agriculture statistics from the Palestinian Central Bureau of Statistics (PCBS), Ministry of Planning and International Cooperation (MoPIC), and Palestinian Hydrologic Group (PHG), and results from the remote sensor classification are summarized below (Table 2). The two governorates of the PNA, Jericho and Nablus, divide the Wadi el Far'a catchment, and such political regions are convenient data collection areas for statistics and are included for local data. The rest of the data are classified within the delineated catchment boundary.

[19] See Enderlin (2002) *Shattered Dreams* for more detail

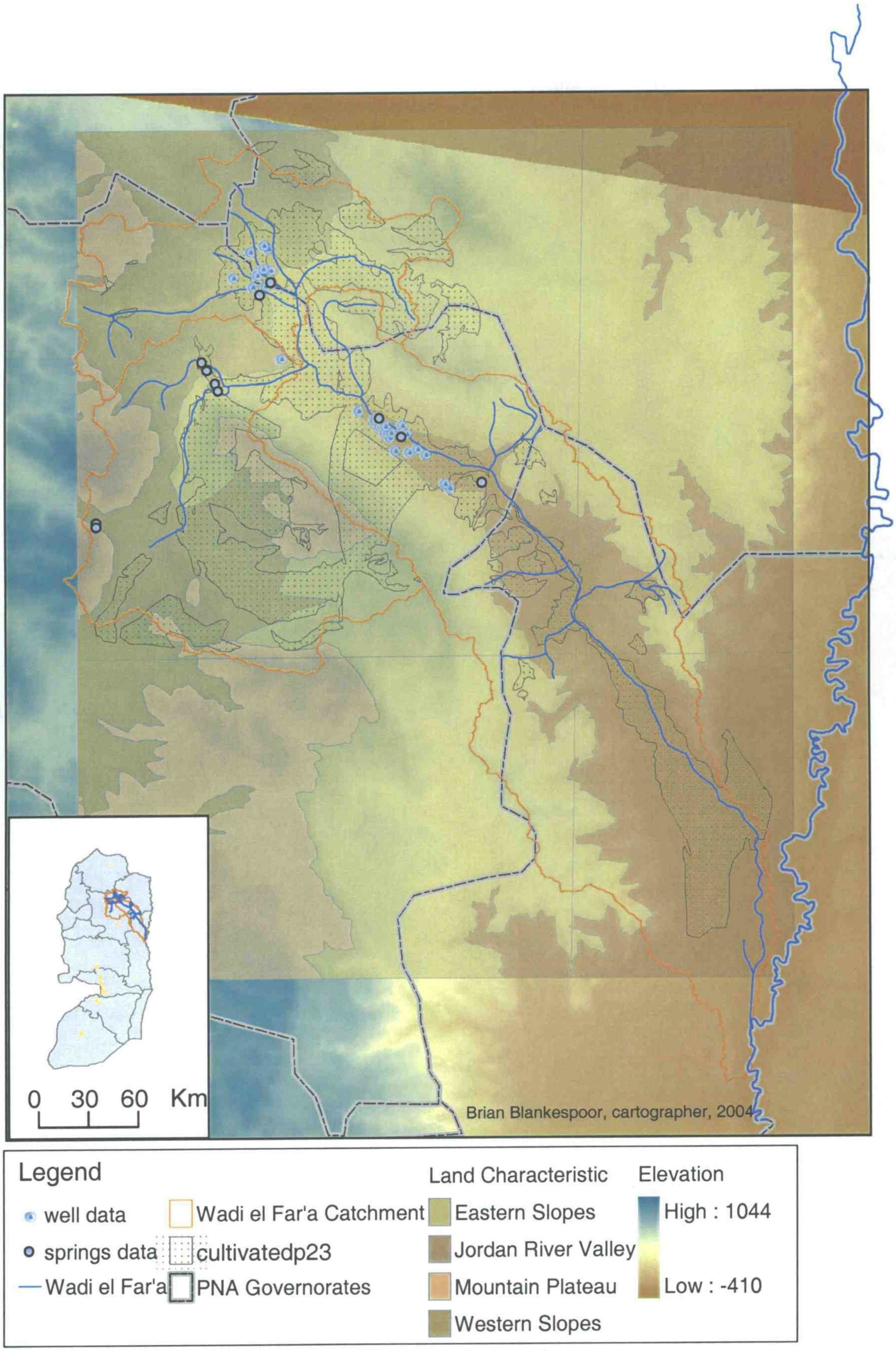
Table 2. Agricultural area data and classification.

	Agriculture (km^2)			
Region	Irrigated	Rainfed	Date	Source
Nablus	5.9	218.1	2002	PCBS, 2001 – 02
Jericho	20.0	0.0	2002	PCBS, 2001 – 02
Wadi el Far'a	3.9	13.1	14 Aug. 1987	TM
Wadi el Far'a	8.7	20.7	1990	Hammad et al., 2003
Wadi el Far'a	4.5	13.9	7 Aug. 1999	ETM
Wadi el Far'a	7.3	21.0	21 May 2001	TM
Wadi el Far'a	9.1	50.5	24 May 2001	ASTER
Wadi el Far'a	10	55.0	15 June 2003	ASTER

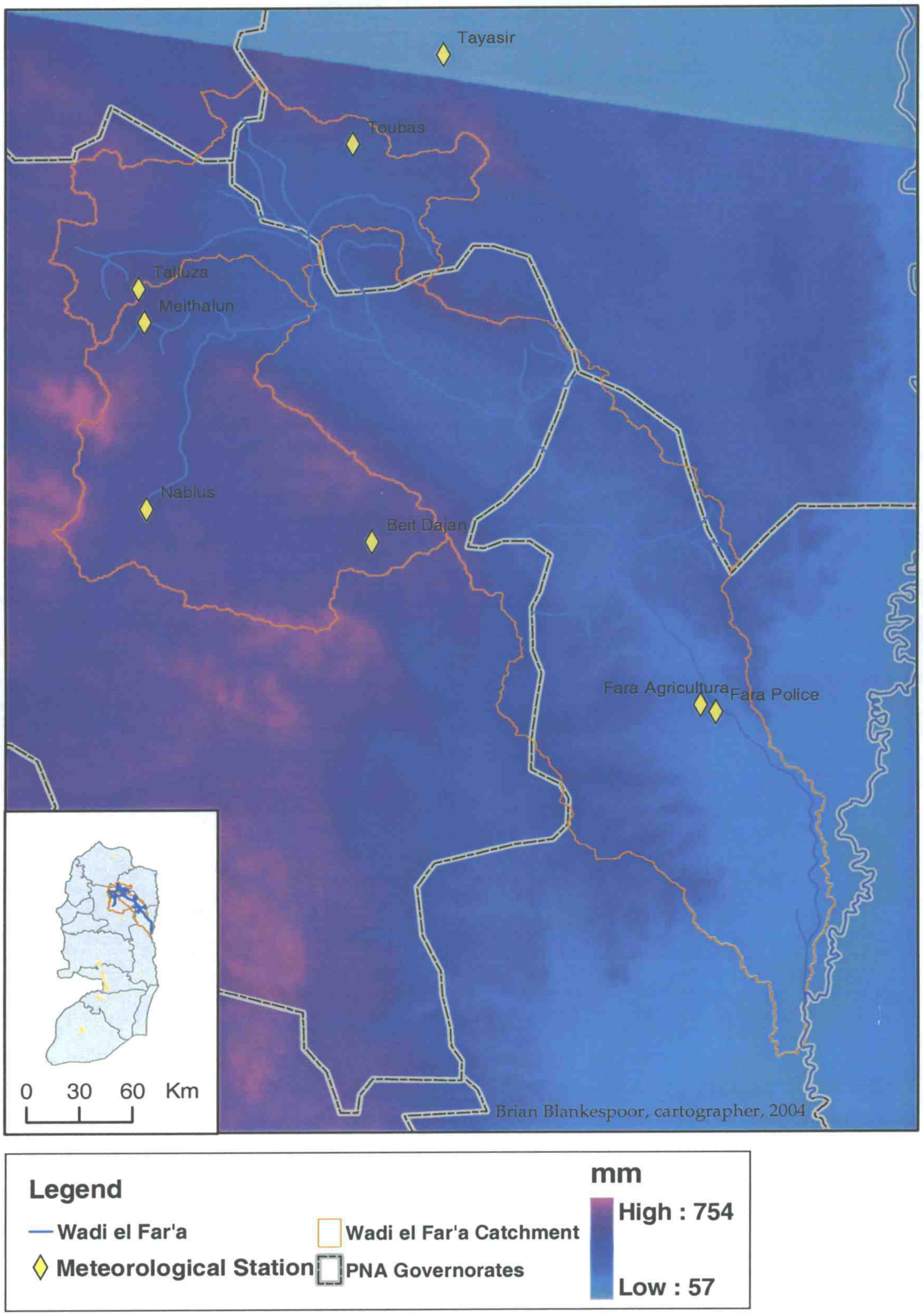
Sources: PCBS, 2001; Hammad et al., 2003, and EROS, 2004.

Water Use

The irrigated agricultural area data range from 3.9 km^2 to 10 km^2. Note that there is more than one data source for these dates. Rainfed agricultural data are all greater than their respective irrigated agricultural area except in arid climate of the PNA Jericho governorate. With regards to spatial distribution, the upper elevation sub-catchments have greater area of rainfed agriculture than the lower elevations that are dominantly irrigated agriculture. A portion of this variability is explained by the topography and the respective amount of rainfall at seven locations reported in Ghanem (1999). Map 4 displays the precipitation as a function of elevation. The topography does reveal the pattern of a preferred low slopes for agriculture (Figure 6).



Map 3. Land Characteristics in the Wadi el Far'a Catchment



Map 4: Location of Meteorological Stations and Calculated Precipitation

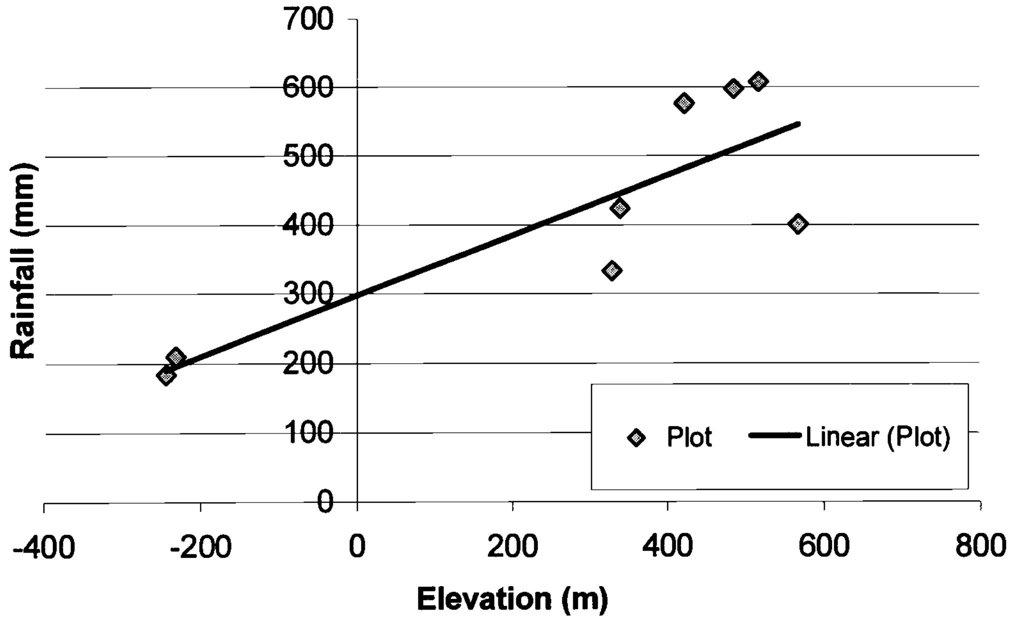


Figure 6. Rain at Stations vs. Elevation (Linear)[20]

Equation 3: $y = 0.4373x + 297.69$ where $R^2 = 0.7125$

The classified irrigated agricultural areas can be discussed in relation to the political periods I, II, and III. The comparison of irrigated and rainfed agricultural areas in Period I and Period II yielded no significant difference in total agricultural area and spatial distribution. In general, the classifications of agriculture are in the same regions with minor variation. This result is also consistent with the land use in the Palestinian Territory recorded from 1998-2002 (PCBS, 2002). The Period III data show a greater total area of agriculture (as compared to Period I and Period II). The difference in part may be due to intra-seasonal variability[21]; since these data are from earlier in the growing season.

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[20] Elevation as function of precipitation from rain stations in the catchment (Ghanem, 1999: 41-46)[20]. Linear: $y = 1.6293x - 406.75$; $R^2 = 0.7125$

[21] The difference in the average air temperature between May and August in Nablus is 3.5 C (PCBS, 1998), while the evapotranspiration in the catchment varies from around 200 to 225mm respectively (Ghanem, 1999: 46)

At the West Bank and Jordan River basin scale of analysis, these data show the general variability in cultivated area and hydrology. The data of the West Bank by the Palestinian Hydrologic Group (PHG) suggest that the recent percentage of irrigated areas of total agriculture (around 4%-6%, See Appendix 3a) is significantly lower than the pre-1967 level of 27% (PHG cited in Beschorner, 1992). However, these data reveal no significant trend and are inconclusive due to incomparable data collection methods. Another indicator of the presence of agriculture is in GDP. The percentage of the total GDP data assigned to agriculture does not correlate directly with the irrigated area classified on the image. However, there is a visual inconclusive observation of possible periodicity in relation to the political landscapes (Figure 7). There also exists variability in the amount of precipitation in each year (Table 3 and Figure 7 highlight the years with remote sensor classification and precipitation data).

Table 3. Jordan River Precipitation by year of satellite data in analysis

<table>
<tr><th>Region</th><th>Year</th><th>Precipitation</th><th>Source</th></tr>
<tr><td>Jordan River</td><td>1987</td><td>741 mm</td><td>(Stahl, 2004)</td></tr>
<tr><td>Jordan River</td><td>1990</td><td>598 mm</td><td>(Stahl, 2004)</td></tr>
<tr><td>Jordan River</td><td>1999</td><td>NA</td><td rowspan="3">Only complete to 1998</td></tr>
<tr><td>Jordan River</td><td>2001</td><td>NA</td></tr>
<tr><td>Jordan River</td><td>2003</td><td>NA</td></tr>
</table>

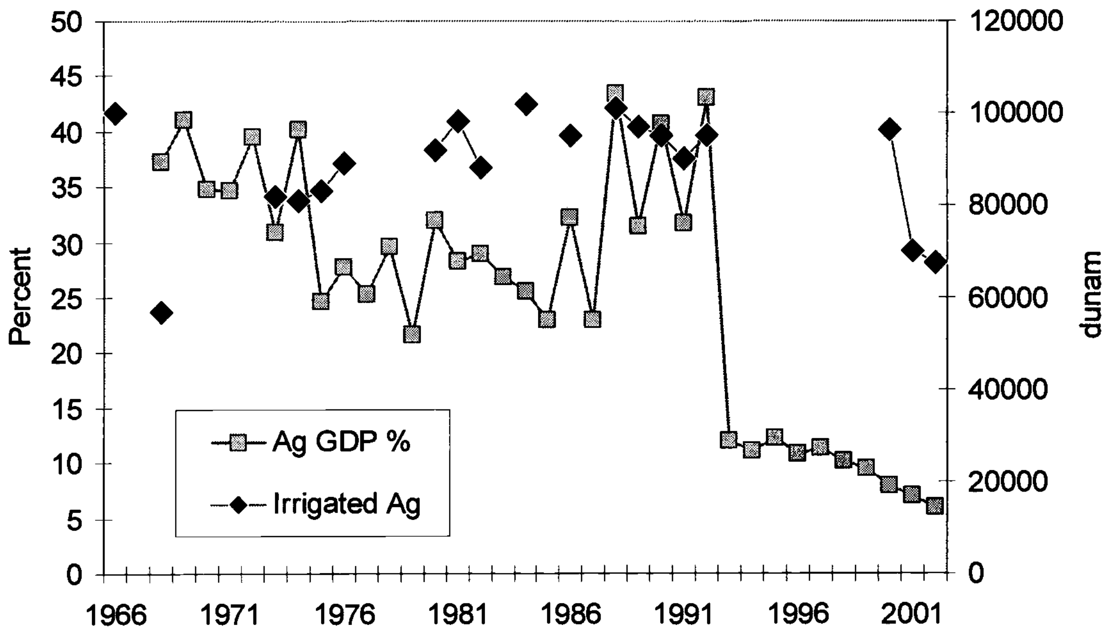

Figure 7. Agriculture GDP % and Irrigated Agriculture by year[22]

Comparison of Periods I, II, and III

These data do not support the hypothesis of a significant relationship between Period I and Period II. The results between Period II and Period III suggest an increase, yet these results are inconclusive due to the different type of data sources. The total area in irrigated agriculture in the Wadi el Far'a catchment did not significantly change more than the range of expected error from Period I to Period II. Landsat Thematic Mapper (both TM and ETM) data are analyzed for Period I and Period II, while TM and ASTER data are analyzed for Period III. As previously stated, the historical data variability does not readily correspond with the political periods. The total area in agriculture persisted throughout the study period even though there was significant change in the political situation.

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[22] Data sources: 1966-1993 (World Bank, 1993), 1995-2000 (PCBS, website), and 1998-2003 (World Bank, 2004); and data from Appendix 3a.

Three reasons are discussed for the disconnect between the results and the hypothesis. First, upon closer examination, the data may not be comparable. The time period in this study requires use of multiple remote sensors for data. While the TM and ETM remote sensors are similar, the ETM and ASTER data are not exactly comparable in spatial resolution and there are slightly different spectral bands (Appendix 2). A comparison of the results from May 2001 ASTER data and from May 2001 ETM data reveals discrepancies in the methodology; similar dates (May 21, 2001 and May 24, 2001) do not have the same results. However, it is notable that both results are greater in total area than data from Period I to Period II. Second, the data may not represent accurately the landscape over these periods. This possibility suggests that there was not sufficient data to interpret the landscape and the data are biased towards one representation of the political landscape. The analysis of similar season data is likely to minimize this effect. Third, the four main incentives for an increase in total agricultural area do not incorporate all the complexity and variability in the system. Perhaps risk, dependence, and sustainability are not conducive to growth in total agricultural areas between Period I and Period II. In fact, in response to the expected results, the observed data favor the explanation of a direct relationship between wage labor in Israel and agricultural labor determined by accessibility. The investigation of these four controls suggests that farmers are affected by the market system (Bjornlund, 2003), investment capital, and political stability[23].

Alternate explanations in the literature mention the interplay of economy, water, and markets in water usage, like irrigated agriculture. For example, two terms are used to represent the amount of water needed for the production of food in the import country, *virtual water* (Allan, 1998),[24] or *shadow water* which means the indigenous water resources that are needed to produce the imported

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[23] There exists potential and incentive for irrigation development. In the political periods in this study, the irrigation areas have not drastically risen to historical levels (for Palestinian agriculture). In addition, suitable irrigable land exists (Elmusa, 1999)[23]. No development implies a low confidence in the potential for socio-political stability.

[24] Virtual water was first suggested as embedded water (Allan, 1993; Allan, 1994)

commodities (Haddadin, 2001). Even if these concepts explain the limited amount of irrigated agriculture in the West Bank, they still assume access to markets and political-economical incentives to depend on food imports. Finally, it is also suggested that labor intensive agricultural practices may be desirable, because *virtual water* must be placed in a context of land, labor, and capital (Wichelns, 2001). Bjornlund (2003) suggests that water market mechanisms help cope the water scarcity and without them irrigation developments can not take place (*paraphrase*).

There are sources of error in the data and this analysis. The irrigation and rain-fed agriculture image classification may be incorrect since it is based on the spectral characteristics of the data. First, there is error inherent in the classification process and image resolution. The supervised training regions are subject to interpretation by the approximate high or low values compared to the mean. Also, greenhouses and recreation pools in the catchment can be mistakenly classified as irrigated agriculture[25]. Second, a number of data sources are used to make comparisons. Finally, classification data are usually compared to ground truth data in an error matrix. The ground truth data for cultivation location in this study are at a coarser spatial resolution than the remote sensor data and include both rainfed and irrigated agriculture. However, there are point source data of type of well for agricultural use that correlate well with the locations of irrigated agriculture. In addition, the precipitation data are informative to the location of agriculture, but they are not necessarily representative because of the distribution and number of meteorological stations in the catchment[26] [27].

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[25] In the past few years, recreation pools have developed as a viable option for water use with the instability of water sources and agricultural markets (Tomazi et al., 2003).

[26] Precipitation data sources: Ghanem (1999), PCBS (2003)

[27] Even when correcting for precipitation distribution as a function of elevation, there are inconclusive data to lack confidence in the regression function.

Discussion

Socio-Political Stability

Two relationships are stated for irrigated agriculture and socio-political stability. From this analysis, socio-political stability does not promote irrigated agriculture. Political administration is suggested as the most crucial factor. Furthermore, data that are relevant to accessibility and mobility of people, goods and services in the catchment are significant. Dependence on Israel is minimized during the *Intifada* as the local population tolerates a lower standard of living, the strikes on economic activity, and the IDF curfews and control of mobility and access (Shalev, 1991:150). However in socio-political stable times, there is less produce from agriculture and agriculture is seen as subsistence to the rural family (Peretz, 1986:115)

Factors

The literature of socio-political stability and irrigated agriculture is interwoven with the following topics: geo-politics, agriculture, and irrigated agriculture and political landscapes. First, geo-politics asserts the relationship between the geography and the politics; the geography determines the politics. For example, Foucher (1987) discusses the borders of Israel / Palestine in terms of the human and physical natures. Second, agriculture connects the environment with the people through its food supply, way of life, and existence. Third, the irrigated agriculture and political landscapes evolve dependent on the assessment and interpretation of the farmer of the policy and political climate of that time.

Agriculture establishes stability through connecting the people to the land through resource of food, labor, employment, and contribution to the national and local economies. Water management and policy dictates water use. Water is a contentious issue and agriculture is prominent in this region. Land use can be politically motivated, such as the land reclamation by Palestinians to protect the land from Israeli expropriation and desertification (ARIJ, 1997). How water is allocated in a water-limited region is one of the fundamental issues, as its allocation affects food security, the natural landscape, politics, and culture. In the Wadi el Far'a catchment, irrigated agriculture uses about 75% to 80% of the water. Since agriculture is major use of water, it is appropriate to use irrigated land area as a measure of water use. Likewise, since water use is a major issue in the local political atmosphere, irrigated agriculture is connected with the politics of the region. Lowi (1995) states that water use is allocated with different policies towards Israeli settlements and Arab cultivated area.

Water Resources

Water resources are important to the amount of irrigated area. The Jordan River basin ties the same resource to a politically dynamic region. In the Transboundary Freshwater Dispute Database (TFDD) 166 events in the Jordan River were recorded from 1950-2000. Events were both conflictive and cooperative, and the majority of the events are within two levels of seven of cooperation both positive and negative (TFDD, 2004).

Land Use

Remote Sensor Data and Analysis

The political instability of the region constrains data collection and makes field study difficult. In order to investigate the composition of agricultural lands, and in particular irrigated areas, the analysis of remote sensor data is a viable option. Remote sensor data are spatially comprehensive and record the environment at a fairly consistent resolution in the pixel size. In addition, land use and water management need monitoring and times series analysis where land use and land cover requires changes frequently. An alternative method (from RS) is the collection of quantitative ground data provided from interviews about total area of agriculture from a local perspective. These data can be difficult to obtain and may provide insights of a “visual geography” *per se*, rather than actual numbers.

Geographic Information Systems and Spatial Analysis

GIS is an effective tool to calculate and display the classified irrigated agriculture. The spatial distribution of irrigated agriculture combined with the natural and socio-politcal data inform natural resource management on the trends and relationships of irrigated agriculture.

Irrigated and Rainfed agriculture

Irrigated agriculture is a viable method of agriculture in the world. Lipton et al. (2003) remark the decline of irrigated agriculture on a global scale with two reasons: low agricultural prices and the best sites are already developed. Geo-politics can influence both these reasons.

In the Wadi el Far'a catchment, agriculture is a crucial issue pertaining to political stability. Management, policy, and politics affect agriculture and these factors are evident in agriculture as a component of the land use, water use, economy, and traditional culture.

Agriculture as a land use

Agricultural land use data are at the regional and the catchment scale. The regional data depict the temporal variation, while the catchment scale data provide insight for the expected location of agriculture. Various sources depict total area of agriculture data for the West Bank (Figure 8) and Israel (Figure 9). For the West Bank, the typical range of irrigated agriculture area is from 1980, a relatively steady level from 1980 to 1990, and a decline in the past decade to its current level around 2,000,000 dunams. At the catchment scale, about 85,000 to 100,000 dunams[28]. For Israel, there is an increase from 1960 to the seasonal precipitation (Kahan, 1983) and physical characteristics explain some of the landscape (agriculture) variability (Map 3). In a typical water year, there are three to five flood events for the duration of six to eighteen hours (Safat, 1990: 200). From a physical perspective, slope is a major factor in field location for agriculture due to soil stability (Philips, 1990). Hammad et al. (2003) report the

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[28] 1 dunam = 0.0009000 km^2 = 0.222397 acre = 0.0900012 hectare

land use and spatial variability of agriculture and identify about 50% of the land use in the total area of the catchment. Irrigated agriculture is about 5%: Israeli cultivated area (7.9km^2), Palestinian irrigated agriculture (8.7 km^2) (MoPIC data cited in Hammad et al., 2003). The spatial variability in the types of crops grown in the wadi vary from the plains of Tubas, Tammoun, and Tayasir with rainfed annual crops like wheat and barley. Wheat and barley are also found on the summit surface as non-irrigated annual crops. In the lower elevation part of the catchment, the El-Far'a valley is rich in agriculture: cultivated cereals in the northern part and irrigated vegetables and fruit trees (citrus plantation) in the plains of the central and northern part. The rainfed cultivation is located mainly in the surrounding hills and has a winter and a summer harvest. During the winter period, wheat and barley are staple crops. Summer crops are okra, cucumber, and tomato.

Agriculture and the economy

Agriculture is the dominant sector in the Palestinian economy (Butterfield et al., 2000) and is essential for food security within the region. Agriculture contributes from 20% to 33% of the GNP (Allen, 1999; Isaac et al., 1997; respectively). The region has supported an agricultural community for several generations. In addition, irrigation systems provide the potential for more agricultural productivity, because there is a more consistent water source than the highly variable supply from annual rainfall. This potential is closely related to the irrigation technique and crop grown (ARIJ, 1997). In spite of low yields, rainfed agriculture is prominent in the catchment. Elmusa (1997) further suggests that low-input and low-yields are evidence of the uncertainty of rainfall as well as the political instability. There is inherent risk and dependence on the hydro-political system.

Agriculture is common way of living for many people in the catchment. Food and employment are directly connected to agriculture. Irrigated agriculture has the possibility to augment the food supply beyond the typical growing season. It also provides an essential niche to stabilize the high variability of labor and water availability. In fact, Beaumont (1999) suggests that irrigated agriculture might even provide an ebb and flow of water use that prevents a more direct water conflict with domestic uses. Crops may have storage capacity that is more resilient than human use. In the same way, Merrett (2002) asserts that agricultural labor is crucial to reducing poverty in desperate political situations. Postel et al. (2001) assert that appropriate access to irrigation water and base capital to employ drip irrigation technology can significantly contribute to food security and local stability.[29]

Water use

It is notable that the amount of water used (and desired) varies across the landscape depending on the efficiency, crop, and watering technique. However, there is a detectable change in the landscape when irrigated agriculture persists during periods of minimal precipitation.

In addition, irrigation systems provide the potential for more agricultural productivity, because there is a more consistent water source than the highly variable supply from annual rainfall. This potential is closely related to the irrigation technique and crop grown (ARIJ, 1997). In spite of low yields, rainfed agriculture is prominent in the catchment. Elmusa (1997) further suggests that low-input and low-yields are evidence of the uncertainty of rainfall as well as the political instability. There is inherent risk and dependence on the hydro-political system.

Agricultural water use is likely to diminish as the competing uses increase pressure on the limited resource. The percentage of water used for agriculture in the Wadi el Far'a catchment is higher than the global comparison; however, it is notable that the industrial and domestic water uses are extraordinarily low in

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[29] "access to irrigation writer, or the means to use the water they have more productively, is a key to increasing their crop production, their incomes, and their household food security. Ironically, a technology typically associated with wealthy farmers, drip irrigation, may hold the key to alleviating a significant share of rural hunger and poverty" (Postel et al., 2001)

volume compared to an international perspective (Merrett, 2002)[30]. Thawaba (2001) calculated irrigation water use is about 31.9 MCM per year; 13.33 MCM from wells and 18.57 MCM from springs. Domestic consumption of this area is about 8.5 MCM per year (ARIJ, 1996). Water stress as defined by water available per political boundary (Falkenmark, 1989) is increasing proportionally with the 4% projected growth rate in the West Bank (PCBS, 2003) (Figure 10). Non-agriculture use could increase with expectations to other standards of living with respects to water. Therefore, water use efficiency is essential to sustainable growth.

Even though less than 6% of the total Palestinian cultivated areas are irrigated (ARIJ, 1997), water use efficiency is relatively high due to storage in the irrigated areas (Merrett, 2002). Tomazi et al. (2003) investigate the groundwater wells by types of use and found that around 75% are agricultural use (also see Froukh, 2003). Through the incentive for higher profits than irrigated agriculture, a more recent entrepreneurial idea of recreation pools has started in the region and consists of 13% of the ownership of wells (Tomazi et al., 2003). Rosegrant et al. (2002) suggest that water demand in developing countries is increasingly constrained by supply – certainly evident in the Wadi el Far'a catchment.

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[30] Merrett (2002) states 31 litres per head per day (lhd) versus the lhd in by World Health Organization, however, the PCBS (2002b) publish values for Nablus at 83.7 lhd and Jericho at 213.8 lhd

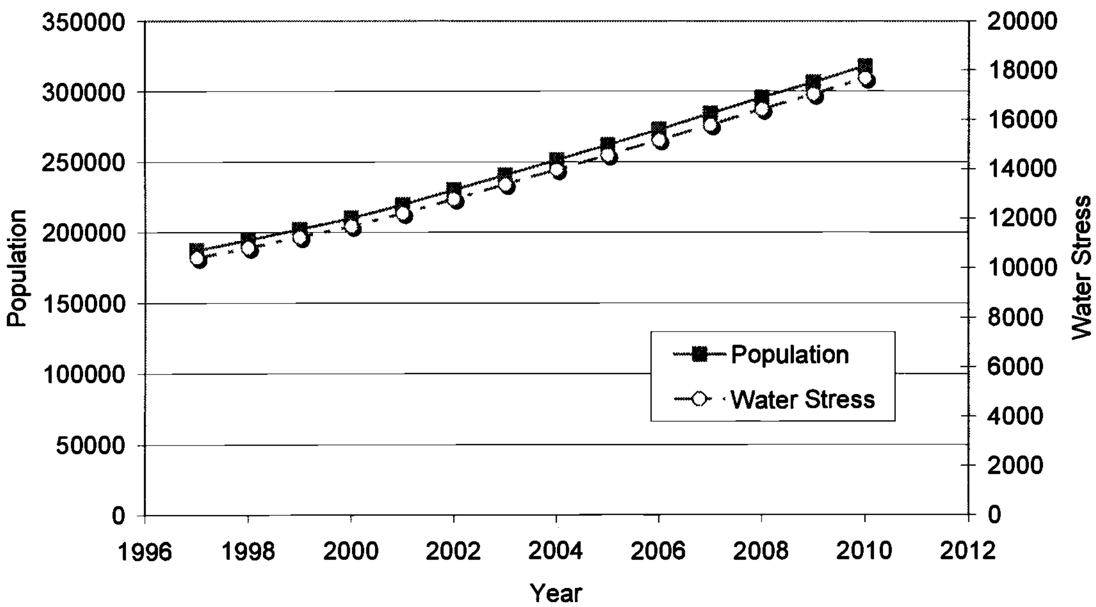

Figure 10. Projected Population in the basin and Water Stress

Agriculture and the government

A responsibility of government agencies is land and water use planning. The inhabitants are under two auspices: Israeli citizen and non-Israeli citizen policy. The Israeli perspective typically cites security and protection from terrorism as prime objectives in policy. The Palestinian point of view mentions the persecution and suppressed privileges. For example, there exist distinct restrictions on ground water use; the maximum permissible depth of a well by a Palestinian in the Wadi el Far'a region is 140 meters (Beschorner, 1992)[31]. Also, access to water sources is diminished by restrictions of passage between different regions. This is especially true during the periods of *Intifada*. During the *Al-Aqsa Intifada*, the mobility of the inhabitants is greatly diminished.

Potential development is under the auspices of the political administration. Development funds are not equally available for new structures for agriculture:

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[31] No Arab individual or village has received permission to drill a new well for agricultural purposes since July 1967, nor to repair one that is in close proximity to an Israeli well." Lowi, 1995, p.133-34

non-Israelis do not have access or permission for redevelopment in many cases (Lowi, 1995: 133-134).

It is helpful to address the historical and current impact of landuse planning on the landscape. *The West Bank and Gaza Atlas* (Benvensti et al., 1988) Water Resources Map displays the Wadi al Far'a catchment as the largest contiguous "Arab irrigated lands" on the West Bank. This catchment presents a unique opportunity from the Palestinian perspective to analyze a cohesive region and address the "lack of integrated land use planning" Isaac et al. (2001) one of the many challenges to the Arab agriculture along with water (Biswas et al., 1997).

Agriculture, traditional culture, and techniques

The indigenous knowledge of agriculture is ingrained in the local culture. It is taught to one generation from another generation. In the Fertile Crescent, inhabitants built irrigation systems which consisted of constructed channels for surface water flow several centuries ago (Postel, 1999).

Currently, a variety of irrigation techniques, water sources, and growing methods are used in the region: water application by flood or drip; water sources from wells, springs, surface water, and agricultural ponds; and agricultural land method of open field or plastic houses (greenhouses). It is important to recognize the heterogeneity of agriculture as this study utilizes a method for identifying agricultural lands and then categorize them into rainfed or irrigated agriculture based on remote sensor data. All techniques listed here are found within the catchment (Tomazi et al., 2003). It is notable that the amount of water used (and desired) varies across the landscape depending on the efficiency, crop, and watering technique. However, there is a detectable change in the landscape when irrigated agriculture persists during periods of minimal precipitation. Finally, historical base flow data are also provided (Figure 11).

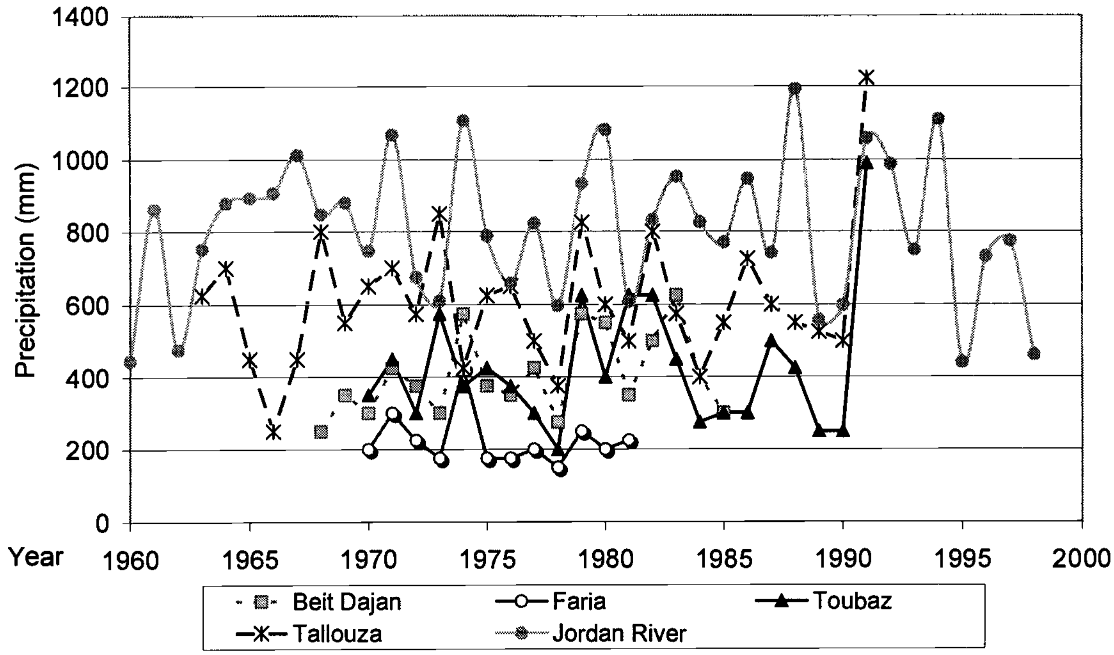

Figure 11. Precipitation (mm) in and around the Wadi el Far'a catchment[32]

Future research and Conclusions

Future Work

In order to address the outstanding issues of these results, there are suggestions listed for further work. Future work involves categories of 1) additional data, 2) methodological enhancement, 3) a more comprehensive interpretation of the landscape, 4) Oslo Agreement examination, and 5) an error analysis with more ground truth data.

First, the results can benefit from high spatial resolution and high temporal resolution data. The high spatial resolution data provide more data to delineate agricultural lands with more precision, while the higher temporal resolution aids in disseminating the inter seasonal variability for cropping patterns, climate, water availability, and length of growing season[33]. Likewise, as spectral resolution

[32] Wadi el Far'a Catchment Stations: Beit Dajan, Faria, Toubaz, and Tallouza (Adapted from Graph in Ghanem, 1999:45) and Jordan River data from GRDC (Stahl, 2004)

[33] Current meteorological data by governorate are only available for 1998 from PCBS.

(number of wavelength data) increases by remote sensor technology, spectral signatures will classify with more accuracy.

Second, since these data do not support the hypothesis, a robust method may be developed with the higher spatial and temporal resolution data. The two-way classification system is an efficient method to process a large number of data sets. A refined intensive method may yield greater accuracy in the representation and therefore it would test this method to a greater degree of accuracy. Then, it may be possible to extrapolate methods from this sample catchment to the entire West Bank. In the field, ground truth data enable the creation of an error matrix that assesses the accuracy of this classification. Also, there is a noticeable difference in the two types of remote sensor data used in this study, and future research should address this methodological issue in greater depth.

Third, agricultural land totals persist despite the incentives stated in the introduction. It is possible to this interpretation does not adequately capture the complexities of the agricultural land system. Additional perspectives may enhance and/or change the hypothesis and, thus, the expected results.

Fourth, the Oslo Agreement segmented the West Bank land in the interim period into three political regions. It is possible that the Wadi el Far'a Catchment is less influenced by political changes, because it is the most contiguous set of Arab lands in the West Bank and therefore less affected by segmentation. High landscape fragmentation areas may exhibit a low level of accessibility and hence accentuate the difference in irrigated agricultural area.

Fifth, these classifications of agriculture are subject to error analysis. Typical error analysis includes a matrix of ground truthed pixels and how they were classified on the image. This information allows one to determine the accuracy of the clarified image. Due to the lack of ground truth data in this study, an overlay of the cultivated regions as digitized by MoPIC (1999) and locations of agricultural wells are used to verify the location of irrigated agriculture. These classifications need to be assessed in greater detail by future researchers.

Agriculture provides a unique niche in the region. The Wadi el Far'a catchment for a variety of reasons is a significant place for agriculture and it is important to observe the effects of policy on agriculture in this region. The total area of irrigated agriculture can be a viable indicator of socio-political change in the Wadi el Far'a catchment in future work. Indicators gain a deeper understanding of the growing complexities of policy issues (UNESCO-WWAP, 2003)[34]. Remote sensor data provide comprehensive catchment scale data unbiased by politics. Finally, agricultural is an essential connection between people and the land. Although this analysis did not yield significant results, it indicated the complex dynamics of the region. In the future, it may be possible to use irrigated agriculture and remote sensor data as an indicator to help monitor socio-political stability and as a more objective observation for time-series analysis.

Conclusion

The Wadi el Far'a is a significant agricultural and water resource in the West Bank. Cultivated areas are classified into rainfed and irrigated agricultural areas by remote sensing image processing techniques to examine the impact of political boundary change on the spatial distribution and area of agricultural lands. Since political changes have an effect on the political stability, there exists a relationship between the political boundary changes and milieux in the Wadi el Far'a catchment and agricultural land use. It is suggested that total irrigated agriculture is coupled with political stability due to the necessary investment of infrastructure, dependence of food security, labor force, and confidence in the system to deliver water. Therefore, irrigated agriculture is considered a possible indicator of socio-political stability. The data suggest that there exists a negative relationship between socio-political stability and irrigated agriculture due to constraints on access (and therefore competition) to markets and labor, as well as a more focused local life during times of limited access. Three time periods

[34] See (UNESCO-WWAP, 2003: 29-60) for more information on indicators

are examined for the relationship between stability and total area of irrigated agriculture. Period II is a time of greater access after the Oslo Agreement and moderate irrigated agriculture. In Period III, there exists relative political instability and relatively high areas of irrigated agriculture. A comparison of Period I and Period II revealed no significant difference in total area in agriculture; whereas the Period III landscape suggests an inconclusive, yet greater total agricultural area than Period I and Period II. It is notable that intra-seasonal variability and the different data sources account for the higher detection of agriculture. Future researchers need to enhance the methodology, and explore the complex variability in stability factors and the delineation of irrigated agriculture.

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Appendices:

Appendix 1: List of Available GIS Data Layers

Type of data	Source of data	Year	Digitized by
Wadi el-Far'a Boundary	Marwan Ghanem Ph.D. Thesis	1999	Ahmad Abu Hammad
West Bank Border with Jordan River	CIA map	1996	Ministry of Planning and International Cooperation (MOPIC)
Palestine Grid	Marwan Ghanem Ph.D. Thesis	1999	Ahmad Abu Hammad
Palestinian built up areas	SPOT image	2000	MOPIC
Israeli Colonies	SPOT image	2000	MOPIC
25 M contours	British Mandate maps	1945	MOPIC
Road networks	Israeli 1:50000 maps	2000	MOPIC
Valleys	Israeli 1:50000 maps	2000	MOPIC
Ground water basins	Jordanian map 1:50000	1965	MOPIC
Soil classification	Israeli soil survey 1:50000	1986	Ahmad Abu Hammad
Geology	Israeli soil survey 1:50000	1986	Edited by Kamal Abdulfattah.Dig.by Ahmad Abu Hammad
Evaporation	Atlas of Israel	1990	Ahmad Abu Hammad
Temperature	Atlas of Israel	1990	Ahmad Abu Hammad
Rainfall	Marwan Ghanem Ph.D. Thesis	1999	Ahmad Abu Hammad
Cultural sites	Survey done by Ahmed Rojoub	2000-2002	Ahmad Abu Hammad
NO3 map	Marwan Ghanem Ph.D. Thesis	1999	Ahmad Abu Hammad

EC map	Marwan Ghanem Ph.D. Thesis	1999	Ahmad Abu Hammad
Cultivated area	SPOT image	1994	MOPIC
Land use map	ARIJ data base	1998	Ahmad Abu Hammad
Land characteristic map	ARIJ data base	1998	Ahmad Abu Hammad
Digital Elevation Model 30m (DEM)	ASTER. EROS data center website. http://edc.usgs.gov/	2001	NASA and Japan's Ministry of Economy, Trade and Industry (METI) and the Earth Remote Sensing Data Analysis Center (ERSDAC).
NDVI (15m)	ASTER – 24 May 2001	2002	Brian Blankespoor
EVI (15m)	ASTER – 24 May 2001	2002	Brian Blankespoor
Precipitation Stations	X,Y and data Ghanem (1999), adapted to current Built-Up Area	2003	Brian Blankespoor
Precipitation as a function of Elevation	ASTER DEM, Rain Stations: Ghanem (1999), PCBS	2003	Brian Blankespoor
Temperature as a function of Elevation	ASTER DEM, Temperature Wadi al Far'a Project, 2003	2003	Brian Blankespoor
West Bank Governates	West Bank (pers. comm.. Hammad, 2003)	2003	Brian Blankespoor
Israeli Administrative Boundaries	Census CBS, Israel (pers. comm., 2003)	1998	CBS, Israel
SPOT	http://archaeology.asu.edu/jordan/nimasat.html	1994	National Imagery and Mapping Agency
Soil Moisture from Land Unit Description	(Hammad et al., 2003)	2003	
Population, Pop Density	Israel Central Bureau of Statistics:	2000	CBS, Israel
Erosion Potential	Function of Precipitation	2003	Brian Blankespoor
Population 1967, 1975, and 1987	West Bank Database Project	1987	Brian Blankespoor

Built-up Population 1997-2010	From PCBS Table 4-a: Projected Mid -Year Population for Nablus Governorate by Locality 1997- 2003, Table 4-b: 2003-2010; Jericho Governate; Tub Governate	2003	Brian Blankespoor
Population 1987	Appendix 1: Arab Localities in the West Bank – 1987	1987	West Bank Database Project
Population 1975	MOI: in Appendix 1: Arab Localities in the West Bank – 1987	1987	West Bank Database Project
Population 1967	CBS: in Appendix 1: Arab Localities in the West Bank – 1987	1987	West Bank Database Project
Water Stress	Fiske and Yoffe (2001) Function with Built-Up Population from PCBS, ICBS, and WBDP	2003	Brian Blankespoor
Catchment and sub-catchment Delineation	ArcHydro with DEM and blueline	2003	Brian Blankespoor
Topographic Index	ASTER DEM, Raster Calculator	2003	Brian Blankespoor
Slope	ASTER DEM, ArcGIS Spatial Analyst	2003	Brian Blankespoor
Oslo Agreement Land Area	Digitized from ARIJ "Geopolitics 1999" *Atlas of Palestine*	2003	Brian Blankespoor

Appendix 2: Comparison of TM, ETM, and ASTER remote sensor data sources:

ASTER DATA: http://asterweb.jpl.nasa.gov/

Characteristic	VNIR	SWIR	TIR
Spectral Range	Band 1: 0.52 - 0.60 µm Nadir looking	Band 4: 1.600 - 1.700 µm	Band 10: 8.125 - 8.475 µm
	Band 2: 0.63 - 0.69 µm Nadir looking	Band 5: 2.145 - 2.185 µm	Band 11: 8.475 - 8.825 µm
	Band 3: 0.76 - 0.86 µm Nadir looking	Band 6: 2.185 - 2.225 µm	Band 12: 8.925 - 9.275 µm
	Band 3: 0.76 - 0.86 µm Backward looking	Band 7: 2.235 - 2.285 µm	Band 13: 10.25 - 10.95 µm
		Band 8: 2.295 - 2.365 µm	Band 14: 10.95 - 11.65 µm
		Band 9: 2.360 - 2.430 µ	
Spatial Resolution	15m	30m	90m

TM DATA http://www.cpc.unc.edu/projects/ecuador/metadata/landsat_tm.htm

Characteristic	VNIR	SWIR	TIR
Spectral Range	Band 1: 0.45 - 0.52 µm Nadir looking	Band 5: 1.55 - 1.75 µm	Band 6: 10.4 - 12.5 µm
	Band 2: 0.52 - 0.60µm	Band 7: 2.08 - 2.35 µm	

	Nadir looking		
	Band 3: 0.63 - 0.69μm Nadir looking		
	Band 4: 0.76 - 0.90 μm Nadir looking		
Spatial Resolution	30m	30m	120m,

ETM DATA

http://www.cpc.unc.edu/projects/ecuador/metadata/landsat_etm.htm

Characteristic	VNIR	SWIR	TIR
Spectral Range	Band 1: 0.45 - 0.52 μm Nadir looking	Band 5: 1.55 - 1.75 μm	Band 6: 10.4 - 12.5 μm
	Band 2: 0.52 - 0.60μm Nadir looking	Band 7: 2.09 - 2.35 μm	
	Band 3: 0.63 - 0.69μm Nadir looking		
	Band 4: 0.78 - 0.90 μm Nadir looking		
	Panchromatic: 0.52 – 0.90μm		
Spatial Resolution	30m	30m	60m,

Appendix 3: Cultivated Area – West Bank (WB) and Palestinian Territory (PT)

Region[35]	Growing Season	Total Cultivated Area (dun)	Percent Irrigated of Total	Irrigated Area (1000 dun)	Rainfed land (1000 dun)	Source
WB	1959	--	--	100	--	(World Bank, 1993)[36]
PT	Pre-1967	--	27%	--	--	(Beschorner 1992
WB	1966	2083333	4.8	100	1980	(Kahan, 1983: 21)
WB	1968	2035714	2.8	57	1988	(Kahan, 1983: 21)
WB	1973	2050000	4	82	1941	(Kahan, 1983: 21)
WB	1974	2025000	4	81	1939	(Kahan, 1983: 21)
WB	1975	1627451	5.1	83	1878	(Kahan, 1983: 22)
WB	1976	2022727	4.4	89	1931	(Kahan, 1983: 22)
WB	1980	1614000	5.7	92	1859	(Kahan, 1983: 22)
WB	1981	1661000	5.9	98	1909	(Kahan, 1983: 22)
WB	1982	--	--	88	--	(World Bank, 1993)
WB	1984	--	--	102	--	(World Bank, 1993)
WB	1985	--	--	104	--	(World Bank, 1993)
WB	1986	--	--	95	--	(World Bank, 1993)
WB	1987	--	--	94	--	(World Bank, 1993)
WB	1988	--	--	101	--	(World Bank, 1993)
WB	1989	--	--	97	--	(World Bank, 1993)
WB	1990	2100000	5	110	--	(cited in Sbeih, 1994: 340)
WB	1990	1793000	5.3	94.9	--	(Agricultural Statistics Quarterly, 1990 (1), p.65[37]
WB	1990	--	--	95	1698	(World Bank, 1993)

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[35] WB = West Bank; and PT = Palestinian Territory

[36] Table IX and Table XII

[37] cited in Awartani, 1994: 26.

Region	Growing Season	Total Cultivated Area (dun)	Percent Irrigated of Total	Irrigated Area (1000 dun)	Rainfed land (1000 dun)	Source
WB	1991	--	--	90	1704	(World Bank, 1993)
WB	1992	--	--	95	1602	(World Bank, 1993)
PT	1993/94	1827003	--	--	--	(PCBS, 2003)
PT	1994/95	1904925	--	--	--	(PCBS, 2003)
PT	1995/96	1829880	--	--	--	(PCBS, 2003)
PT	1996/97	1834658	--	--	--	(PCBS, 2003)
PT	1997/98	1861380	--	--	--	(PCBS, 2003)
WB	1997	--	6	--	--	(Isaac et al., 1997)
PT	1998/99	1612013	--	--	--	(PCBS, 2003)
WB	1998	209000 ha	6	12 ha	--	(UNESCO-WWAP, 2003)
PT	1999/00	1836789	--	--	--	(PCBS, 2003)
PT	2000/01	1815547	--	—	--	(PCBS, 2003)
WB	2000/01	1632377	5.9	96.31	1614	(PCBS, 2003)
WB	2001	1365700	5.1	69.9	--	(PCBS, 2003)
WB	2002	1389.5	4.9	67.4	--	(PCBS, 2003)