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CHALLENGES IN RESOURCE MANAGEMENT IN RAINFED AGRICULTURE IN WADI NAGHAMISH, NORTH WESTERN COASTAL REGION, EGYPT

Abdel-Kader, Fawzy H.; John FitzSimons*; Mohamed Bahnassy and Ashraf Moustafa

Soil and Water Sciences Department, College of Agriculture, El-Shatby, Alexandria University, Alexandria, EGYPT.

*Schools of Rural Planning and Development of Plant Agriculture, University of Guelph, CANADA.

Planning for sustainable management of the existing agro-pastoral production systems in the North Western, NW coastal region of Egypt is the challenge of effectively integrating in a practical, cost effective manner a wide range of necessary formally and informally gathered quantitative and qualitative biophysical and socio-economic information. For an area on the NW Coast, data derived from remote sensing imagery are combined with topographic information and geo-referenced field data in a comprehensive GIS database to provide the biophysical inputs to models of Bedouin production decisions based on local knowledge and management systems under series of climatic scenarios. The study identifies the state of the environmental constraints of climate, soil, water, and rangeland and the human coping strategies of the agro-pastoral production systems at a representative watershed, NW Coast of Egypt. The study outputs could support sustainable land and water management and participatory agricultural development process in rainfed agriculture of Egypt.

Keywords: Drylands, Agro-pastoral systems, rainfed agriculture, GIS, coping strategies, rangeland, North Western coastal region, Egypt.

The North Western, NW coastal region of Egypt extends 350 km from west of Alexandria to the Libyan border and is home to about 120,000 agro-pastoralists. Like most semiarid regions, the area possesses a fragile natural resource base and offers limited alternatives for sustainable increases in agricultural productivity under purely rainfed conditions.

The region faces many challenges found in similar dry land areas of the Middle East. How to reverse environmental degradation and manage the natural resource base whilst providing sustainable livelihood for its inhabitants. As a result of political, economic and environmental factors, the dry land agro production systems of the North West Coast of Egypt have experienced significant change in the past fifty years. There has been a significant increase in small ruminant population with feeding of cereal grains/concentrates encouraged by government pricing policies and subsidies and by the extension of low yielding minimal input barley cultivation into rangelands. The national government attempts to sedentarize nomadic populations have led to a breakdown of traditional controls on the use of grazing land. The increase in livestock populations and their sedentarization have raised fears of irreversible environmental degradation and increased poverty for the inhabitants. There is an urgent need to manage these production systems on a more sustainable basis.

Many development projects in the NW coast have been less than successful because they have failed to understand the dynamics of the production systems and have failed to effectively involve inhabitants in the development process. The main challenge is to *effectively* integrate, in a practical, cost-effective manner, a wide range of necessary formal and informal quantitative and qualitative biophysical and socio-economic information to ensure that needs where constraints are identified and practical solutions adaptable by inhabitants are generated.

The general objective of the study is to identify the state of the environmental constraints of climate, soil, water, and rangeland and to understand the human coping strategies of the agro-pastoral production systems in a representative watershed in the NW coastal region. The study outputs could support sustainable land and water management and participatory agricultural development processes in rainfed areas in Egypt. The paper highlights the main outputs of an IDRC funded project on "Participatory Land and Water Management in the Dry land Agro-pastoral Systems: NW Coast of Egypt" (Abdel-Kader, and FitzSimon, 2002).

STUDY AREA

The study area is located 270 km west of Alexandria and extends 30 km south from the coast between Wadi Naghamish and El-Grawala. The area contains three distinct agro-ecological zones. Zone 1 extends up to 5km from the coast with the deepest soils and the higher rainfall. Production systems are predominately trees (figs and olives) with some cereals, small ruminant and limited rain fed vegetable production. Zone 2 extends from 5km to 15 km inland. Production systems have fewer trees and more cereals and livestock. Zone 3 extends from 15 km inland. Production systems in the zone are dominated by livestock (small ruminants and, to a lesser extent, camels) with some cereal production.

The region is inhabited by Bedouin tribesmen who moved into the area in the 17th century. Nine sub-tribes are represented in the study area. Each sub-tribe is comprised of a number of *aila* (patrilineage clans) with a clan territory (*watan*) and led by an *akla*. The *ailas* are in turn composed of *be'ets* or extended households, representing two or three generations. *Aila* territories are generally contiguous although it is not uncommon to find a few isolated *be'ets* from other sub-tribes located within a given *aila*.

Historically, Bedouin land has been communally owned with well established rules of community access. Movable property (such as flocks) were individually owned and landed property vested in tribal descent groups (Behnke, 1980). Egyptian law, however, does not grant legal title to communal ownership and all desert land is owned by the state. The Desert Law 124 of 1958 and its subsequent amendment (Law 100 of 1969) allowed individual tribesmen to gain legal title to land cultivated with trees. However, many Bedouin in the study area still do not hold formal legal title to their cultivated land.

METHODOLOGY

This multidisciplinary study involves integrate land evaluation and watershed planning and management farming systems analysis and indigenous knowledge/ local knowledge and management systems, for a typical Wadi System (Wadi Naghamish) in the NW Coast of Egypt. Research techniques used included both formal and participatory research but also remote sensing for data acquisition together with modelling as well as GIS for analysis and integration. A conceptual framework within which such a process can be developed has been proposed by Huizing *et al.* (1992). This framework involves the integration of land evaluation and farming systems analysis concepts. Land evaluation provides a spatial dimension, examining the nature and potentials of land based upon evaluation of biophysical resources, land and water. Farming systems analysis examines the present farming and land use by describing their various components and respective linkages at a variety of levels of aggregation from that of an individual crop or livestock activity to the regional level. It also plays a role in identifying potential improvements to existing production systems which can then be linked to a program of adaptive agricultural research.The methodology involved the following main tasks:

1. Topographic Maps Analysis and Generation of Digital Elevation Model (DEM): Eighteen 1:25000 topographic map sheets were digitized using TERRASOFT GIS software. The contour lines and spot heights were exported to ARC/Info. The coverage's were read and build as line and point themes, respectively. Another coverage (shape file) was obtained

from on screen digitizing of the main drainage lines from the SPOT panchromatic image. All the three coverage's (contour lines, spot heights, and drainage lines) were exported to ILWIS 3.12a (2003) for the generation of DEM.

2. Rectification of SPOT 10 m. and SPOT XS 20 m images. The raw SPOT images were geometrically rectified using the Ground Control Points (GCP) collected in the field using GARMIN GPS unit attached with Real-Time Differential unit. Thirty-four GCP were collected in the field. An image-to-map process was followed in ENVI image processing software to carry out the geometric rectification. The RMSE obtained for this process was 0.31.
3. Preparation of the 1:25000 mapping base: The combination of geographically rectified SPOT 10 m panchromatic and SPOT XS 20 m "naturalized" colour satellite imagery superimposed with contours and other information digitised from topographic maps was created as a mapping base. In addition, GPS was used to accurately georefernce infrastructure and in participatory mapping activities.
4. A rapid soil survey was conducted. Soil samples were analyzed for soil nutrient status, salinity, organic matter content and the current land use and natural vegetation of the site recorded. Each sample site was GPS referenced.
5. Participatory Rapid Appraisal (PRA): Participatory transects were made across the study area with members of the Bedouin community to record and compare Bedouin terms for soils and vegetation with those obtained. The transects recorded general land use and seasonal grazing patterns. In addition to baseline data, information was gathered from community informants to create decision tree models for: a) cereal planting decisions in relation to soil type, rainstorms and flock size, b) location specific small ruminant movements by month, flock size and rainfall type year. The livestock movement generated information used to generate a feed calendar for estimating the consumption of the various hand feed and the proportion of livestock food intake obtained from grazing cereal stubble and rangeland. A participatory rangeland typology was developed and mapped with Bedouin shepherd key informants. The informants were asked to identify the principal rangeland species combinations, winter and year-round, the overall winter and summer grazing quality of these combinations, their spatial extent and the palatabity of the individual component species. Informant perceptions of the quality of each range vegetation association for winter and summer grazing were identified. A relative four-point scale was used whereby 0 is not grazed; 1 is poor; 2 is medium and 3 is good. An overall grazing score was created by combining summer and winter.
6. Two modeling tools were used: (a) Areas of water accumulation by rain

run-on were estimated and mapped for the study area using the Digital Elevation Model in GIS database and simple hydrological functions accessible through the Arc View Spatial Analyst Extension. The SWAT (Soil and Water Assessment Tool) model (Neitsch *et al.* 1999) was used to generate the main watershed and its sub-basins and their attributes. Three parameters were used to estimate the runoff volume in the drainage sub-basins. Rainfall, drainage area and runoff coefficient based on the topography, land use and soils characteristics of the drainage area, (b) Relative estimates of water generating soil erosion using (RUSLE) Revised Universal Soil Loss Equation (Wischmeier and Smith, 1978; Renard *et al.* 1997). Inputs were GIS coverage's of soil type, land cover, slope and cultivation practices. The technique used for estimating the LS factor of the RUSLE was proposed by Hickey (2000).

RESULTS

1. Environmental Conditions

1.1 Climatic constraint

Rainfall in the study area is low and extremely variable. Long term records from the Mersa Matrouh airport indicate a mean annual rainfall of 144 mm for the period 1921-1993 with a coefficient of variation of 45%. Fifteen kilometers inland in Zone 3, annual precipitation is less than half that found in the coastal zone. In addition to being annually variable, rainfall is also spatially variable within each zone. Precipitation occurs in the form of storms of varying intensity between October and February. The amount and variability of precipitation indicate that the region is clearly subject to non-equilibrial ecosystem dynamics (Ellis, 1994).

Historic data of annual rainfall near the study area was examined using the long term record from the Mersa Matrouh airport station whose record goes back to 1922. The data indicates the extreme annual fluctuation between an all time minimum annual rate of 25 mm to an overall maximum of 310 mm. The data indicate that the mean annual rainfall is 142.6 mm with a C.V. value of 45.8%. The data of direct monitoring of rainfall in the study area showed that the amount of annual precipitation varied from 80 mm in 1993/94 to 244 mm in 1999/2000. The frequency analysis of the data indicated that a rainfall of 150 - 200 mm could occur every two years, while 200 to 250 mm could occur every five years. For December, a total rainfall of less than 15 mm/month could occur every year, while 15 to 35mm/month could occur every 2 years. Regarding the month of January, a total rainfall of less than 10 mm could occur every year, whereas the 20 to 25mm could occur every two years. Since the rainfall is highly variable and the opportunities for collecting water from surface run-off is highly limited, concerns have been expressed about the long term impact of climate change. The 70 year climate record for Mersa Matrouh was analyzed in more detail to determine if there are any indications of trends. There is no obvious overall trend, but the number of years per decade when rainfall exceeded a set threshold value (175 and 200 mm) appears to increase at least in the decade of 1982-1992. This trend is also evident over the 1993-1996 period when 1 of the 3 years produced precipitation above threshold values.

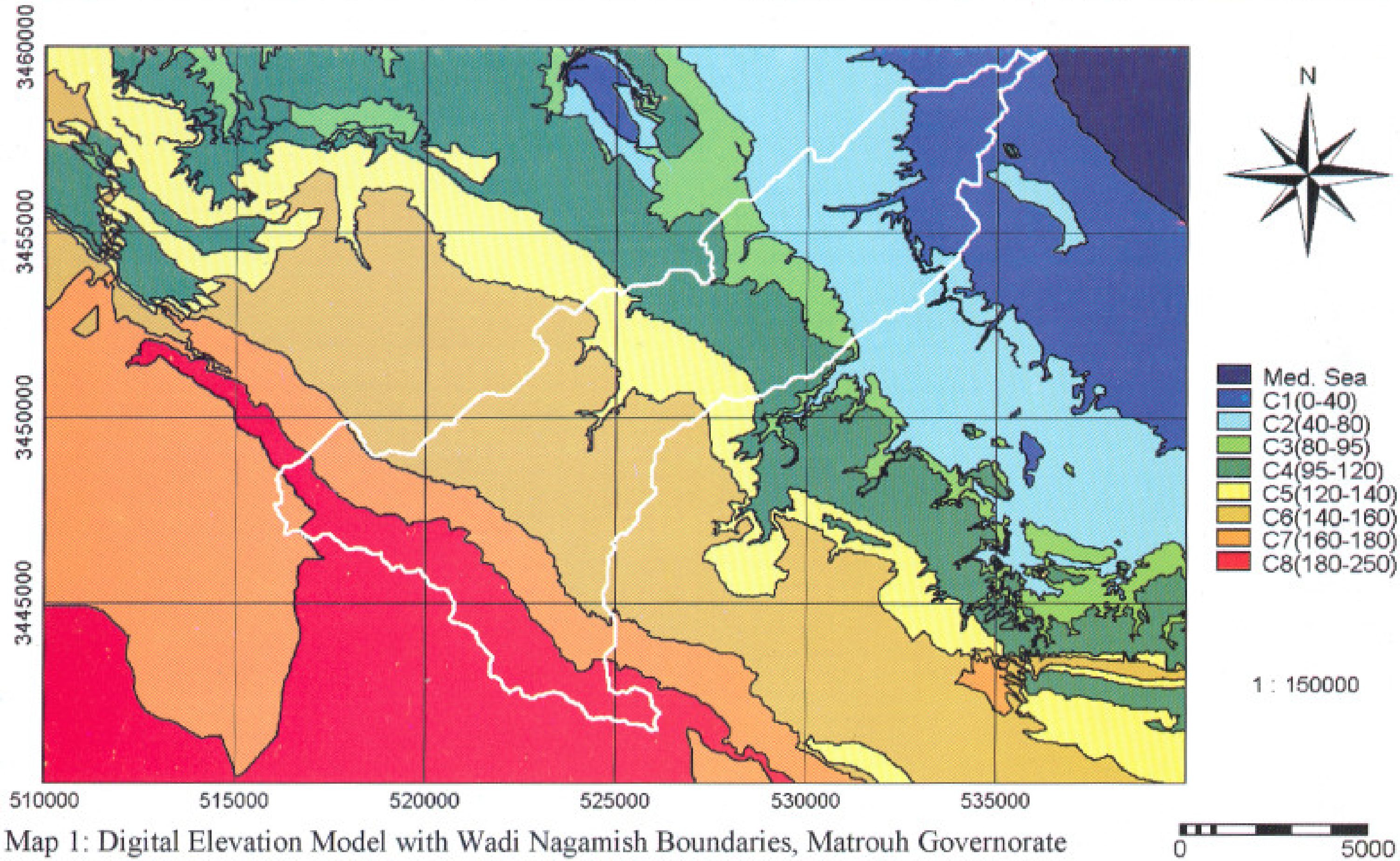
1.2 Soil limitations

Based on visual interpretation of SPOT PAN and XS images, DEM (Map 1), as well as field and lab data, different soil polygons were digitized on screen. Twenty-eight soil sub units were identified according to soil depth, texture and salinity. It is clear that the very shallow, sandy loam, slightly saline soils occupy about 47% of the study area, followed by the shallow, loamy sand, slightly saline soils with about 15% of the total area. Eight main soil mapping units were identified based on the original 28 soil sub-units and their taxonomic units (Table 1). Map 2 shows the spatial layout of the main soil mapping unit. The physical and chemical characteristics of representative soil profiles are given in tables (2 and 3).

A parametric land evaluation procedure in the Arc View database was applied. The method takes into consideration three types of land use, namely, tree plantation, land under cereals, and grazing areas. Four soil qualities were used in the land evaluation procedure comprising soil depth, texture, salinity, and stoniness. Each soil quality was rated on a scale of 1: 00 to represent the order of limitation for each one (Table 4). It is clear that the area is dominated by class IV, which is suitable for grazing with 94% of the total area, followed by class III which is suitable for barley and wheat. Classes I and II, which are suitable for orchards represent only 1.2% of the total area and are located mainly in the Wadi system and in deep depressions.

1.3 Water availability

Sixty-six sub-basins were identified in the Wadi Naghamish catchment area. The runoff volume for each sub-basin was estimated for three annual rainfall scenarios, 75 mm, 150 mm, and 230 mm. It is shown that the catchment areas of the sub-basins would generate a total runoff volume of 459,000 m^3 (0.0048 m^3/m^2, equivalent to 4.8 mm rainfall) for a 75 mm rainfall; 1,584,000 m^3 (0.0167 m^3/m^2 equivalent to 16.7 mm rainfall) for 150 mm rainfall (Map 2).; and 5,784,000 m^3 (0.061 m^3/m^2 equivalent to 61 mm rainfall) for 230 mm rainfall. The area, which could be irrigated by the estimated volume of runoff, was estimated on the basis of annual crop water requirements. A total of 184 ha which is equivalent to 20% of the currently cultivated area could be added in the case of 75 mm rainfall scenario. This area could be increased to 634 ha or 69% of the currently cultivated area for the case of the 150 mm rainfall scenario, and to 2062 ha or 226% of the currently cultivated area for the case of 230 mm rainfall scenario.



Map 1: Digital Elevation Model with Wadi Nagamish Boundaries, Matrouh Governorate

TABLE (1). Soil mapping units, Wadi Naghamish, Matrouh Governorate.

Code	Mapping Units Description	Sub-Unit Code	Sub-Units	No. of Polygons	Area (ha)	Area (%)
0	Rock Outcrop	100	Rock Outcrop	9	704.37	6.85
1	V Sh.Sand to Loamy Sand Non-Saline to Sl.saline	211	V.Sh.Sandy Non-Saline	45	3634.47	35.36
	(Lithic Torripsamments)	212	V.Sh.Sandy Sl-Saline			
		221	V.Sh.Loamy Sand Non-Saline			
		222	V.Sh.Loamy Sand Sl-Saline			
2	V.Sh.Sandy Loam to Loam Non-Saline to Sl.Saline	231	V.Sh.Sandy Loam Non-Saline	19	1476.59	14.36
	(Lithic Torriorthents)	232	V.Sh.Sandy Loam Sl-Saline			
		242	V.Sh.Loam Sl-Saline			
3	Sh.Sandy to Loamy Sand Non-Saline to Mod.Saline	311	Shallow Sandy Non-Saline	54	2002.76	19.48
	(Lithic Torripsamments)	321	Sallow Loamy Sand Non-Saline			
		322	Shallow Loamy Sand Sl-Saline			
		323	Shallow Loamy Sand Mod-Saline	45	1510.94	14.70
4	Sh.Sandy Loam to Loam Non-Saline to Mod.Saline	331	Shallow Sandy Loam Non-Saline			
	(Lithic Torriorthents)	332	Shallow Sandy Loam Sl-Saline			
		341	Shallow Loam Non-Saline			
		342	Shallow Loam Sl-Saline			
		343	Shallow Loam Mod-Saline	49	524.50	5.10
5	Mod. Deep Sand to Loamy Sand Non-Saline to	411	Mod. Deep Sand Non-Saline			
	Mod.Saline (Typic Torripsamments)	421	Mod. Deep Loamy Sand Non-Saline			
		423	Mod. Deep Loamy Sand Mod-Saline	79	214.69	2.09
6	Mod. Deep Sand Loam to Loam Non-Saline to Mod.	424	Mod. Deep Loamy Sand Saline			
	Saline (Typic Torriothents)	431	Mod. Deep Sandy Loam Non-Saline			
		433	Mod. Deep Sandy Loam Mod. Saline			
		441	Mod. Deep Loam Non-Saline			
		443	Mod. Deep Loam Mod-Saline	17	110.49	1.07
7	Deep Sand to Loamy Sand Non-Saline	511	Deep Sand Non-Saline			
	(Typic Torripsamments)	521	Deep Loamy Sand Non-Saline Deep Sandy Loam			
8	Deep Sandy Loam Non-Saline (Typic Torriorthents)	531	Non-Saline	21	100.37	o.98
	Total				10279.18	

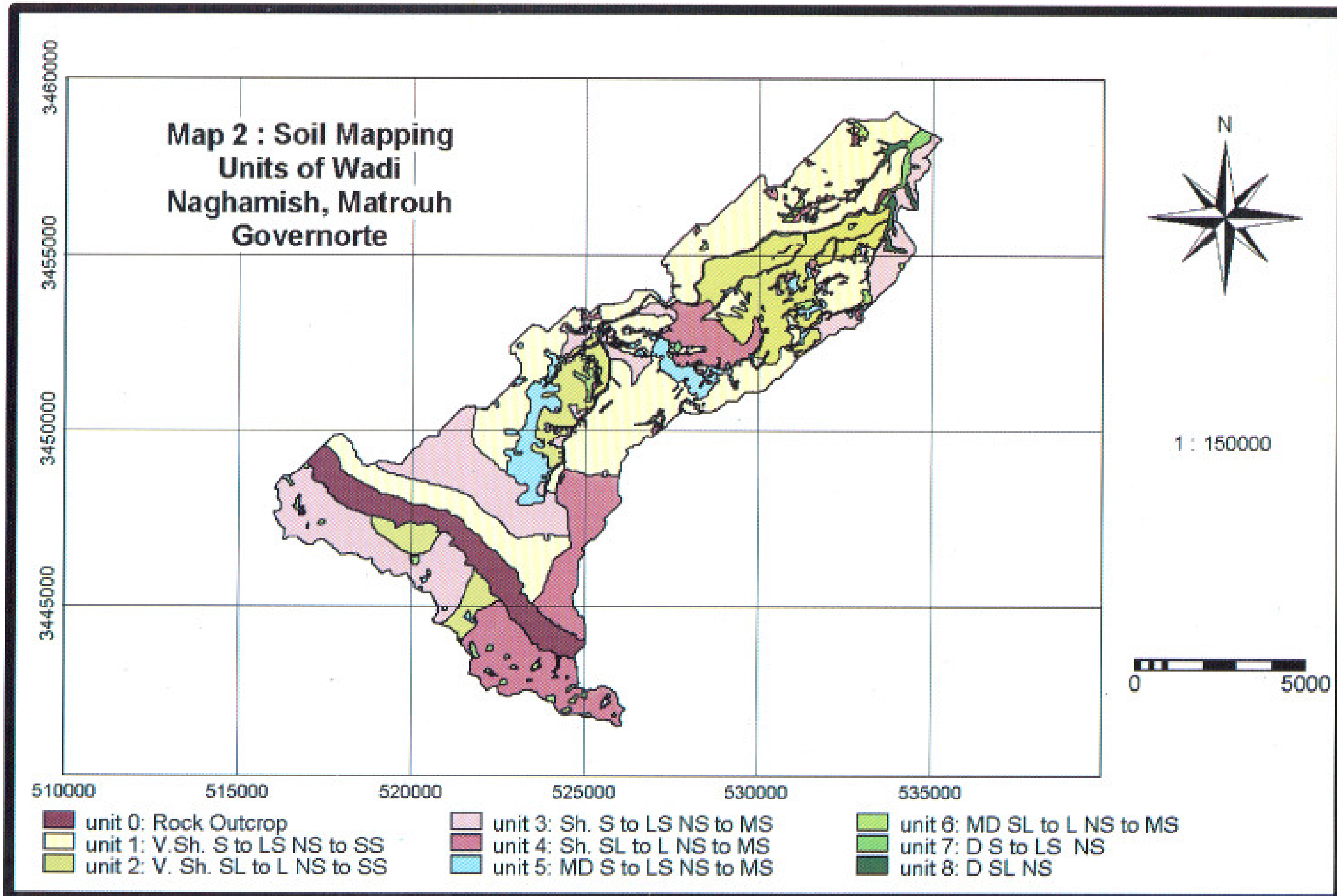

Map 2 : Soil Mapping Units of Wadi Naghamish, Matrouh Governorte
3460000
3455000
3450000
3445000
510000
515000
520000
525000
530000
535000
N
1 : 150000
0
5000
unit 0: Rock Outcrop
unit 1: V.Sh. S to LS NS to SS
unit 2: V. Sh. SL to L NS to SS
unit 3: Sh. S to LS NS to MS
unit 4: Sh. SL to L NS to MS
unit 5: MD S to LS NS to MS
unit 6: MD SL to L NS to MS
unit 7: D S to LS NS
unit 8: D SL NS

TABLE (2). Main Chemical and Physical Characteristics of Representative Soil Profiles, Wadi Nagamish, Matrouh Governorate.

physiographic unit	soil sub-units	code and	pH*	EC*	Ca	Mg	Na	K	HCO_3	SO_4	Cl	$CaCO_3$	Sand	Silt	Clay	Texture Class
		depth (cm)		dS/m	Cations meq/l*				Anions meq/l*			%	%	%	%	
Wadi system	511	P12(0-10)	8.24	2.57	9.7	8.3	8.3	0.3	2.8	0.1	21.0	13.79	86.41	9.20	4.39	S
		(10-15)	8.31	4.26	5.7	4.7	29.0	1.7	1.3	2.7	37.0	11.48	89.35	5.17	5.48	S
		(15-30)	8.41	0.37	2.6	0.6	1.4	0.2	1.0	0.3	2.0	10.11	87.32	8.27	4.41	S
		(30-100)	7.65	6.20	8.1	3.4	51.6	2.3	1.6	10.0	50.1	13.79	79.60	10.92	9.48	LS
Salt Marsh	424	P12(0-15)	7.55	70.00	111.1	89.0	391.6	12.2	8.7	0.1	845.0	17.93	76.67	11.30	12.03	LS
		(15-30)	7.83	7.80	17.5	8.5	59.8	2.2	2.1	15.9	60.0	17.93	78.00	12.90	9.10	LS
Depression	531	P23(0-30)	7.89	0.58	11.2	4.2	2.1	0.4	1.6	1.4	2.8	8.49	71.46	10.34	18.20	SL
		(30-60)	8.03	0.42	4.4	3.6	1.7	0.2	0.9	1.0	2.0	7.08	63.21	24.78	12.01	SL
		(60-100)	8.13	0.35	3.2	1.8	1.6	0.3	1.0	0.8	1.3	9.91	63.01	20.76	16.23	SL
Plateau-stony plain	221	P8(0-10)	8.67	0.61	2.1	2.2	3.0	0.3	2.2	0.1	4.3	14.71	81.20	9.28	9.52	LS
	331	Z12 (0-10)	7.90	1.62	22.5	12.5	6.9	6.8	12.2	8.1	5.6	19.15	79.30	18.10	2.60	SL
		(10-20)	7.40	0.98	17.5	5.0	5.4	2.2	6.2	0.4	6.0	21.62	66.80	28.00	5.20	SL
		(20-30)	7.50	1.25	10.0	2.5	6.9	1.8	5.3	0.2	5.7	24.45	69.20	23.10	7.70	SL
Inland dunes	511	P18(0-20)	8.19	0.80	4.4	2.0	1.8	1.0	1.5	2.7	3.4	9.43	88.10	10.70	1.20	
		(20-60)	8.15	0.56	5.0	3.2	2.0	0.6	1.2	1.9	2.5	7.55	94.40	2.18	3.42	
		(60-100)	8.30	0.45	8.0	3.0	1.6	0.3	1.3	1.0	1.8	7.08	93.38	4.50	2.12	
Hummocky Land	431	H20 (0-20)	7.30	2.00	8.6	4.2	9.0	1.0	2.5	8.6	11.7	35.60	70.15	12.16	17.69	SL
		(20-40)	7.70	0.84	2.9	1.8	5.6	0.6	3.1	4.2	3.6	33.15	79.60	9.92	10.48	LS
Sediments in drain	421	H22 (0-15)	7.60	1.19	4.3	2.4	6.1	1.3	3.0	7.1	4.0	46.52	88.32	5.70	5.98	S
		(15-50)	7.50	5.06	26.1	10.0	18.4	2.4	1.2	52.5	3.2	40.60	76.15	12.30	11.55	
		(50-70)	7.70	3.20	16.0	8.8	11.1	0.9	1.7	11.1	24.0	43.50	78.66	11.63	9.71	
Old alluvial fan	421	P15(0-60)	8.52	0.50	2.8	1.8	1.8	0.2	1.9	0.1	3.0	18.39	83.15	2.49	14.36	LS

* Soil paste extract

TABLE (3). Nutrient Properties of Representative Soil Profiles, Wadi Naghamish, Matrouh Governorate.

physiographic Unit	Soil Sub-Units	Code and depth (cm)	O.M. %	N (total)	Av P	Av K	Fe	Zn	Mn	Cu
							ppm			
Wadi system	511	P12(0-10)	0.02	169.4	4.18	68.89	11.52	0.72	3.83	2.38
(wadi course)		(10-15)	0.04	201.9	4.19	94.55	14.48	0.58	5.44	3.72
		(15-30)	0.32	201.9	4.49	100	5.98	0.74	4.9	0.21
Salt Marsh	424	P12(0-15)	0.05	68.1	0.91	194.4	18.04	0.42	2.9	0.52
		(15-30)	0.04	211.5	4.55	302.55	13	0.8	1.71	1.2
Depresions	531	P23(0-30)	nd	251.1	1.9	309.09	1.2	0.5	2.31	1.6
		(30-60)	nd	176	2.77	268.7	4.16	1.12	6.01	0.81
		(60-100)	nd	109.33	1.8	288	8.19	1	1.69	0.37
Plateau-stony plain	221	P8(0-10)	nd	81.1	2.94	224	9.92	0.42	4.74	2.4
Inland dunes	511	P18(0-20)	0.16	90.72	5.16	134	5.8	0.48	3.5	0.44
		(20-60)	0.13	126.11	2.77	337.3	7.81	0.45	2.96	1.16
		(60-100)	0.06	104	2.91	348.45	8.53	0.66	1.39	0.48
Hummocky Land	431	H20 (0-20)	0.02	42.8	1.52	28.35	7.31	0.51	3.2	1.21
		(20-40)	0.04	51	0.77	18.33	6.41	0.34	1.21	0.63
Sediments in drain	421	H22 (0-15)	0.04	77.5	2.02	39.5	8.51	0.29	3.81	1.03
		(15-50)	0.07	84.6	1.62	60.4	6.3	0.43	1.21	1.4
		(50-70)	0.02	46.3	0.37	23.9	4.92	0.32	1.08	0.9

TABLE (4). Soil quality rating for land evaluation of Wadi Naghamish, Matrouh Governorate.

Soil quality	CLASS I	CLASS II	CLASS III	CLASS IV
Soil depth (cm)	> 75	30 - 75	15 - 30	< 15
Soil texture	Any class	sand	Any class except sand	any class except sand
Salinity (EC, dS/m)	< 4	4-8	8-16	> 16
Stoniness	None	Rare	Few	Dominant

1.4 Water erosion risk

The estimated RUSLE soil loss in ton/ha/year indicated that most of the area is not subject to severe erosion hazard. Rates of soil loss ranged between less than 1 ton/ha/year to 2 ton/ha/year, on about 97% percent of the total area.

1.5 Rangeland quality

Eighty-nine percent of the land cover of the study area is composed of rangeland of varying quality and species composition. The various individual species identified by key informants, together with their Bedouin names and their palatability for sheep, goats and camels were identified. On the basis of "year-round" species, 26 individual range types were aggregated into five main groups: Group 1 is dominated by with *Thymelia hirsuta* dominant; Group 2 by *Lycium sp.*; Group 3 by *Atriplex*; Group 4 by *Salsola vermiculata*; and Group 5 by *Anabasis* sp. In terms of overall cover in the study area, Group 4 is the dominant range cover (58%), followed by Group 5 (18%) and Group 1 (11%). On a zonal level, this pattern is present in zones 1, 3 and 4. Group 1, however, is predominant in zone 2. As a general pattern, grazing quality, both summer and winter, improves with distance from the Coast. However, ninety-nine percent of rangeland is rated poor in winter in north zone 1 compared to less than five percent in south zone 4 in the same season. In summer, ninety-nine percent of range in zone 1 cannot be grazed compared with less than ten percent in zone 4.

However, although in the past, the small ruminant agro-pastoral production system could be described as "rangeland dependent", the present analysis indicates that rangeland grazing, although important, now contributes significantly less to total small ruminant feed intake, especially in "average" and "poor" rainfall years.

2. Farming Systems

The farming system analyses document the human response to the environmental conditions (soil and water limitations and constraints) where the traditional coping strategy of inhabitants is to maximize crop and livestock production under the rainfall conditions of a given year. The production systems in the study area are characterized by coping strategies involving two sets of actions. The first set includes flexibility and diversity, variety of crop and livestock activities, movement for cropping, mobility of livestock for grazing, selection of crop for rainfall condition of the current year. The second set includes water harvesting, "run-on" cultivation collecting and concentrating surface run-off, cultivation of depressions, check dams, slow run-off in seasonal stream beds.

2.1. Cereal production systems

Barley cultivation based on runoff farming is the dominant and traditional form of cereal cultivation in the study area. However, within the past 20 years, wheat has been introduced to the area. Subsidized seeds have become available through the government organized cooperatives. Whilst barley grain and crop residues are basic elements in the small ruminant production system, wheat is used to contribute some flour for household bread making and, more importantly, as grain for fattening kids, lambs and culled ewes. For a variety of reasons, the Bedouin view wheat as a difficult crop. It requires more water and is thus planted on good land in years of good rainfall. Even then, yields are significantly less than those of barley (Table 6). Wheat is also viewed as an expensive crop both in terms of labour and machinery because it requires better land preparation than barley (usually two ploughings) and because it must be harvested by cutting with a sickle instead of pulling the entire plant from the ground as is the case for barley. Furthermore, Bedouin believe that sheep and goats do not find the straw of wheat palatable. In overall terms, 75% of cereal fields fall within the shallow to moderately deep category and 15% are slightly to moderately saline.

The area planted cereals and the proportion planted barley and wheat varies each year in relation to environmental conditions as well as other factors such as availability of seeds and personal circumstances. Cereal land in the study area is not voluntarily fallowed or rotated. Given the limited land base and the variability in precipitation, Bedouin attempt to maximize the cereal area planted each year in order to support their small ruminant flocks. Uncultivated field in any given year reflect either inadequate rainfall, lack of seed or other circumstances (usually personal). Variability in rainfall thus ensures that marginal lands are not planted every year. If the rainfall during this period (October to February) was low and subsequent precipitation during late February or March is insufficient, the grain will not fill and the crop will be used for green grazing.

The study documents a Bedouin cereal planting decision tree in relation to rainstorms. The main factors are the timing and intensity of rainstorms, soil/land type and in certain circumstances, flock size. In all cases, cereal planting is initiated following the first significant rainfall event in middle to late October, although the earliest planting date varies a few days between zones (Table 5). Rainstorm events totalling at least 15 mm within seven days will initiate the planting of all cereal land, whilst a lesser storm of 8mm will initiate the planting of cereals in depressions which are closer to the coast. A rainstorm of >21 mm is a prerequisite for barley plantation in the southern zone (Table 5). Even if storms of these magnitudes occur within the planting period, subsequent rainfall may not be sufficient to ensure harvesting of the crop for grain. In this case, the field will be green grazed by the owner if he has a flock, or rented out for green grazing, usually in March.

Reported barley grain yields ranged from a high of over 800 kg/ha on deep loamy sand non-saline (*semina*) soils in a good year to 143 kg /ha on calcareous loamy (*horra*) soils in an average year. No grain yields were reported for calcareous (*horra*) and stony shallow (*arkoob*) soils in a year of poor rainfall. Bedouin respondents indicated that as a general rule, barley yields in an average year were about half those in a good year and on those deep and moderately deep loamy soil (*semina* and *newssa*) in poor rainfall year yields were reduced by two-thirds.

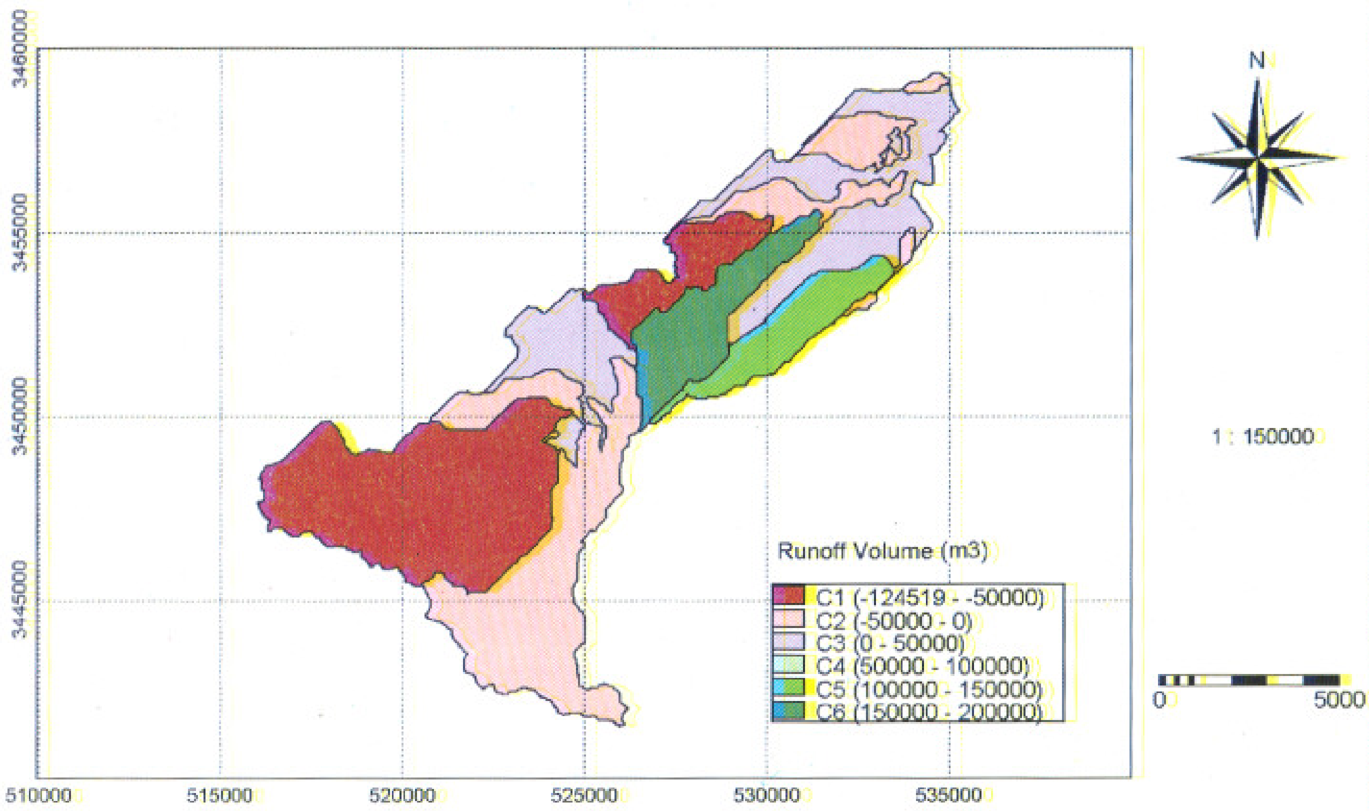
TABLE (5). Within-Zone Cereal Planting in Relation to Rainstorm Events, Wadi Naghamish, Matrouh Governorate.

Zones				Wheat		
	Planting Dates		Minimum Precipitation in 7 Days	Planting Dates		Minimum Precipitation in 7 Days
	Start Date	Last date for grain		Start Date	Last date	
Zone 1	Oct 20th	Dec 20th	>8 mm * >15 mm	Oct 20th	Jan 15th	15 mm
Zone 2	Oct 15th	Dec 20th	>8 mm * >15 mm	Oct 15th	Jan 1st	15 mm
Zone 3	Oct 20th	Jan 19th (Jan 24th)	>15mm			
Zone 4 North	Oct 15th	Jan 19th	>15mm			
Zone 4 South	Oct 1st	Jan 30th	>21mm			

* Initiation of planting in depressions

Yields of wheat were provided only for a "good" rainfall year and ranged from 200 kg/ha on deep loamy non-saline (*semina*) soils to 83 kg/ha on stony shallow (*arkoob*) soils.

In addition to cultivating cereals on their own land, many Bedouin employ a variety of strategies to generate additional cereal production to support their small ruminant enterprises. These involve rental and share cropping both within and outside their family *aila* or agro-ecological zone and share harvesting the barley of others for a share of the production, also within or outside their own *aila*.



Map 3 : Water Balance for the 150 mm Rainfall Scenario

2.2. Small ruminant production systems

The small ruminant (sheep and goat) /cereal /rangelands system is the core element of Bedouin agro-pastoral activity in the NW coastal region. Small ruminant production and to a lesser extent camels, do not only generate income, but form the principal capital asset of households in the more southerly zones where orchard cultivation is limited or impractical.

The analysis indicates a considerable variation in the small ruminant population in relation to annual rainfall and the considerable variability in feed sources and consumption both between flocks of different sizes and composition within agro ecological zones and between zones. The analysis further indicates (Table 6) that the quantity of purchased feeds employed in production of small ruminants (the feed gap) is considerable (129%). Given the limited natural resource base of most households and the flock sizes, it is clear that efforts to improve on-farm feed production will require a variety of strategies designed to suit different flock situations and that with current flock sizes a significant reduction of the feed gap will be difficult to achieve. Almost half the small ruminants in the study area is found in the most southerly zone 4. The overall sheep/goat ratio is 4:1 which is similar to the ratio for the NW coastal region reported by Duivenbooden (1987). At 2.26:1, the sheep/goat ratio is lowest in zone 1 and slightly more than double that figure in southerly zone 4.

The main feed inputs for the breeding flock are purchased concentrates, cereal grain (primarily barley), barley stubble and rangeland grazing resources. Farm produced wheat grain and stubble was available in higher rainfall years, and green barley grazed instead of being harvested for grain and straw in lower rainfall years. In years of very low precipitation, the flock is either dependent on purchased hand feeds or moved (except pregnant ewes and ewes with lambs less than one month old) to grazing on the new irrigated lands at edge of the Nile Delta or to the Siwa Oasis.

The movement of the small ruminants for feed within the study area is critical. Only the smallest flocks remain within the *aila* year round under all conditions. From the flock location calendars, it was possible to generate an estimate of the number of sheep at each location under each set of condition. In overall terms, only 40% of the sheep remain within their zone all year round in a "good" rainfall year. What is surprising is that this figure only declined by 5% and 6% in average and poor rainfall years. Also, the time which animals stay outside their respective zones in each type of rainfall year was estimated. The analysis indicates that 74% of total sheep months are spent within the area in a good year, 81% in an average year and 45% in a year of poor rainfall. The increase in the percentage of sheep-months spent in the area in a year of average rainfall reflects the degree of substitution of on-farm hand feeds for grazing resources, both rangeland and cereal residuals. On a zone basis in all rainfall year types the percentage of sheep months spent within the zone increases to the south and reflects the differential pressure exerted on grazing resources as indicated by the zonal stocking rates and discussion of rangeland quality in each zone presented earlier.

The study proved the small ruminant feed gap. To estimate the dimensions of this feed gap, the production of feed (cereals) within the study area and feed consumption by sheep and goats were considered. Annual barley production was estimated from the yield data for different soil types applied to the area in cereals of each soil type generated from the GIS database. On the consumption side, barley grain, maize and concentrates by zone in each rainfall year type was considered. In overall terms, external feeds (maize and concentrates) would fill 40% of this feed gap in a good year, 75% in an average year and over 80% in a poor rainfall year. However, there are marked differences between zones within each year rainfall type, largely as a result of the relative contribution of barley grain to this feed group.

The study compared estimated barley production in each zone with estimated barley consumption in good and average years – the "Feed Gap" as defined for the purposes of this study. In a year of good rainfall, the study area shows a barley deficit in zones 1 and 4 and a surplus in zones 2 and 3. This is to be expected given that much of the cultivable land in zone 1 is occupied by orchards and zone 4 has large flocks, a comparatively limited cereal area in depressions (*hataya*) and low and highly variable rainfall. A considerable quantity of barley is transferred to these zones from other areas of the NW coastal region. The comparison for a year of average rainfall (Table 6) indicates a deficit in all zones except zone 3. The deficit is particularly marked in zone 4. It is uncertain whether this deficit results from an over-estimate of consumption although it is known that producers in this zone make considerable use of share cropping in other areas of the NW coastal region to supplement their on-farm barley production.

TABLE (6). Barley Production vs. Barley Consumption in Average Rainfall Year, Wadi Naghamish, Matrouh Governorate.

Zone	Barley Production (tons)	Barley Consumption (tons)	Surplus/ Deficit (tons)
Zone 1	19.942	32.839	-12.897
Zone 2	56.835	154.604	-97.769
Zone 3	117.856	41.832	76.024
Zone 4	102.281	451.232	-348.951
Total	296.914	680.507	-383.593

3. Implications for Development

3.1 Potential for water harvesting

A field survey in 2000 used the GPS to spatially locate each cistern in Wadi Naghamish watershed. A total of 85 cisterns was found in the different sub-basins. The spatial analysis of the Digital Elevation Model (DEM) flow accumulation indicated that an additional 266 potential sites for cisterns and underground reservoirs can be found in the different sub-basins (Map 4) based on the following assumptions: flow accumulation is 150, average amount of rainfall 250 mm, average runoff coefficient 10%, pixel size $100m^2$ of SPOT 10 m panchromatic.

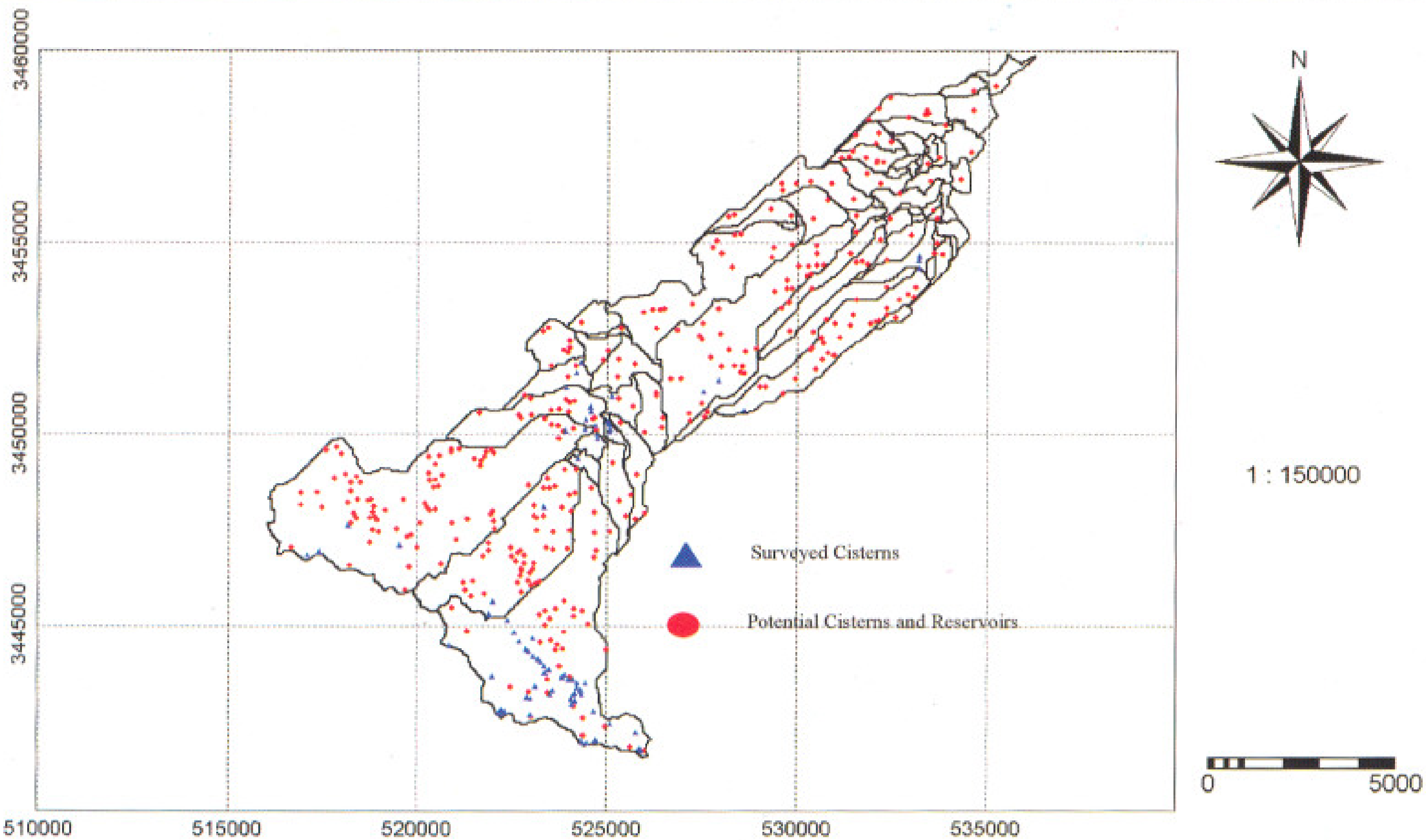
3.2 Potential for rangeland improvement

The potential increase in rangeland area was estimated using the GIS overlay procedures. Three criteria were used, slope, soil depth and water accumulation. For slope, areas with less than 5 degrees are suitable for water harvesting (FAO, 1994). Soils were classified according to depth as shallow, medium and deep. Flow accumulation generated from a DEM was utilized. However, this assumes that all rain becomes runoff with no loss by interception, infiltration or evaporation. The flow accumulation values generated were categorized simply as low, medium and high. Both, the classified slope and soil depth were added to each other using the map calculator, and then reclassified into two categories to show the areas of low slope and medium and deep soils. The resultant grid file was overlain (added) with the classified flow accumulation to show the areas relevant for range improvement. Potential areas for crop development based on water harvesting were determined using the concept of accumulating run-off. Currently cropped land, orchards and cereal fields are excluded and the overall value for potential improvement of rangeland was put on a scale of 1 to 5. Only classes 3 and 4 are considered as having potential. The analysis indicates that about 39% of the total acreage (10554 ha) in the study area could be improved based on the criteria selected.

CONCLUSION

1. The integration of the Remote Sensing and GIS technologies with DTM and land quality data as well as socio-economic information was vital for identifying environmental constraints to production and for understanding human coping strategies in the Naghamish watershed, NW coastal region.
2. The temporal (annual and seasonal) and spatial climatic variability results in temporal and spatial fluctuation in natural resource productivity. Land quality is limited by shallow soil depth, low soil moisture capacity and low fertility level. Land use is large scale (micro-features in a macro context) involving multiple, frequently non-contiguous "watersheds". Livestock assets are mobile. Producer's land resources are fragmented and involve various forms of individual and common property.

3. Sedentarization, subsidized feed policies in the past and extensive use of purchased feeds have increased pressures on water, rangeland and the more productive soils.
4. The participatory approach of this study was successful in both quantitatively describing the nature and dynamics of current agro-pastoral production systems under different rainfall year type conditions and dimensioning the small ruminant "feed gap" for different producer types under those conditions.
5. The production systems are characterized by a coping strategy that involved two sets of actions. The first set includes flexibility / diversity of variety of crop/ livestock activities, movement for cropping, movement of livestock for grazing, and selection of crops for rainfall conditions of the current year. The second set includes water harvesting, "run-on" cultivation, cultivation of depressions are building check dams to slow run-off in seasonal streambeds.
6. The study outputs could support participatory agricultural development processes for sustainable land and water management in rainfed agriculture in Egypt.



Map 4 : Spatial Distribution of Surveyed and Potential Cisterns and Reservoirs in Wadi Naghamish Sub-Basins

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تحديات إدارة الموارد بمناطق الزراعات المطرية بوادى نغامش – الساحل الشمالى الغربى – مصر

فوزى حسن عبد القادر – جون فيتزسيمون* – محمد بهنسى – أشرف مصطفى
قسم علوم الأراضى والمياه – كلية الزراعة – جامعة الاسكندرية – الاسكندرية – مصر
* قسم تخطيط وتنمية المناطق الريفية للانتاج الزراعى – جامعة جولف – كندا

يواجه تخطيط الادارة المستدامة للنظم الرعوية الزراعية بمصر منهجية تكامل عدد من الطرق الكيفية والكمية للحصول على المعلومات الطبيعية والاقتصادية والإجتماعية. بمنطقة ممثلة بالساحل الشمالى الغربى أدى تكامل معلومات الصور الفضائية مع تلك الخاصة بالخرائط الطبوغرافية ومعلومات أرضية ذات احداثيات محددة فى نظام معلومات جغرافى GIS متكامل إلى نمذجة القرارات المتعلقة بالنظم المزرعية البدوية تحت سلسلة من التغيرات المناخية.

عملت الدراسة على تحديد المعوقات البيئية للمناخ والتربة والمياه والمراعى بوادى نغامش شرق مطروح الساحل الشمالى الغربى كما عملت على تحديد الاستراتيجية الزراعية التى يواجه بها السكان المحليين تلك المعوقات.

تدعم مخرجات تلك الدراسة الإدارة المستدامة للموارد الأرضية والمائية والإدارة بالمشاركة لعملية التنمية بالمناطق الزراعية المطرية بمصر.