INTEGRATION OF PROCEDURES AVAILABLE IN LOW COST IMAGE PROCESSING AND GEOGRAPHICAL INFORMATION SYSTEMS.
An application on human settlement and landscape ecology in the depression of El-Fayoum (Egypt).

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1. Introduction

Agriculture in Egypt, as in many other countries in the arid and semi-arid regions, is suffering from salinization of the soils. Soil salinity is one of the most serious problems in agriculture under irrigation. A decline of soil productivity of 30% may occur and is attributed largely to difficulties in optimizing the combined irrigation and drainage system. However, this is not a technical problem in the first place, but a social one. The increase of the population during the second half of this century, caused also an increasing demand of water. A more strictly policy of the water supply was needed, causing important social tenses.

2. The depression of El-Fayoum

El-Fayoum refers to the administrative governorate which is located in a deep, near-circular depression in the limestone plateau of the northern part of the Western Desert of Egypt (fig.1). It is situated south-west of Cairo at a distance of about 60 km and nearly 35 km to the west of the Nile. The depression is limited at the north-western side by a shallow brackish lake, called Birket Qarun, with an area of about 200 km^2 and forming the deepest part at about 45 m below the present sea level. The lake is fed by water of the Nile brought into the depression for irrigation. About 1800 km^2 of the depression is filled with rich alluvial sediments and more than 1350 km^2 is cultivated. This area represents about 5.3% of the total cultivated area of Egypt.

El-Fayoum Governorate is divided into 5 provinces : El-Fayoum, Ibshawai, Itsa, Sinnuris and Tamiya (fig.2). Although the latest population census dates from 1986, no data are available yet. The census of 1976 gives 1.14 million people living in the governorate, which was about 3% of the total population of Egypt. The estimation of the actual population gives 1.44 million inhabitants. The rural population accounts for 76% and is mainly distributed in 140 villages or small towns. Thus the population density increased from 370 inh./km^2 in 1947 to an estimated value of about 800 inh./km^2 in 1985.

The population is not equally distributed all over the depression, but shows a concentration in the central part and on the most fertile soils. Consequently, the population pressure increases here most rapidly and most of the fertile soils are affected in the first place.
Salinization occurs almost generally in the depression and reaches dramatic values. Detailed monitoring of the

evolution of the population pressure, the irrigation system and the process of salinization become more and more vital tasks.

3. The problems

Many problems do occur to realize this kind of global landscape ecological monitoring. Some of them are :

- accurate and detailed demographic statistics are not available since the census of 1976;
- the detailed demographic data which are necessary for making prognoses of the future growth, refer only to rather large administrative units and do not reflect the real population distribution of the settlements;
- inventories of the soil conditions are very general and do not reflect the rapid changes in the environment;
- collecting and integrating all necessary information for a regional and local land assessment is very difficult.

Clearly, the use of satellite remote sensing and the use of geographical information systems (GIS) seem to offer interesting solutions. Unfortunately, no financial possibilities to develop such operational systems, nor a sufficient number of trained researchers are available. Consequently, the approach should be very pragmatic, using every tool which is available at this moment. The general idea is to integrate any kind of land information on a PC standard, because these are more or less widely available in administration. The sources for the land information system are all existing maps, aerial photographs, statistics as well as remote sensing data from Landsat TM.

4. Population pressure and salinization

This contribution presents only as an example one of the first attempts to relate these different sources of data on a regional and local PC-based Land Information System. Basic questions were :

(1) determine an estimation of the actual population for each settlement site;

(2) make an inventory of the actual situation of the soil conditions related to the process of salinization;

(3) assessment of the human pressure on the land;

(4) test if any relation between population pressure and salinization exist, and if any determine 'hazard or high-risk zones'.

a. Settlements and population

The population is mainly concentrated in about 140 villages ranging from about 200 to 3000 inhabitants. Each district has also a town or even a small city. The villages are almost randomly distributed all over the depression. They can be detected and delineated easily upon Landsat TM imagery (on band 3 black & white and false color composites with bands 2.3.4). Visual interpretation proved to be rapid and accurate because of the natural capability of the human perception in dealing with complex contextual information and because most localizations are approximately known. Shape and size could be determined and compared with the aerial photographs dated 1956. Figures 4 and 5 show the image of El Minya (about 13000 inhabitants) on the aerial photograph and on the Landsat TM (band 3). The new extension of the town can be seen clearly. Thus, a complete and updated settlement mapping could be achieved and which is presented in figure 2 where the administrative boundaries are added also. No changes occurred in the territories and sites of the settlements during the last 40 years, only their sizes changed.

A population census on a communal level is only available for 1947. From the census of 1976 only data on the district level are generally available. Both have been use to make an estimation of the population of each village in 1985, the year of the Landsat TM registration. A logistic growth model was used. The carrying capacity was estimated using the territorial size. Determining the carrying capacity is not easy because of lack of appropriate ground data, especially in the past. Simulation of the logistic model was used to find the best fit of the predicted population with the general census data. This resulted in a rural population density of about 800 inhabitants/km^2. Such an approach is only valid for rural settlements in which is initially physical isotropic. The results are strongly biased for cities and large territories containing heterogeneous land qualities. Another estimation of the carrying capacity can be based upon the village sizes. The correlation between the population in 1947 and the sizes of the villages interpreted upon the Landsat TM imagery, proved to be highly significant. Consequently, most of the population growth seems to be absorbed in the larger towns and not in the rural villages.

b. The process of salinization.

Several field surveys showed a rapid increase of the salt affected soils in the depression. The soils have been classified as Aridisols, Entisols and Vertisols. Most important physical factors for developing soil salinity are the basin like topography, the severe aridity, the high evaporation rate, the shallow ground water table. Most important human factors are the inadequate drainage system and the social stress at some locations were the human pressure is high and the amount of available water is somewhat restricted. This clearly shows that only a holistic approach may result in some kind of success. Landscape as a whole, with its natural and human components, should be considered as valuable resource which can only be managed in a integrated and ecological way (M.Antrop,1983).

Accurate mapping of the different degrees of salinization could be carried out in a very satisfactory manner using Landsat MSS (6th July 1981) and TM (12 July 1985) imagery and the most simple interpretation techniques (Th.Ghabour & L.Daels,1986). Photographic images of different spectral bands were combined producing diazo color composites. The scenes were optical enlarged to a scale of 1:100,000 and interpreted visually. Additional information was collected from the stereoscopic aerial photographs when necessary. The resulting map is presented in figure 3 and shows clearly the increasing salinization in the peripherical zone of the depression as well as some 'high risk' spots in the central part between some settlements.

5. The use of a GIS

MAP2 is the PC version of the Map Analysis Package (MAP) adapted by De Dorschkamp (The Netherlands) (see A.Van den Berg et.al.,1984,1985). It is a low cost GIS and runs on any PC XT or AT having at least 640 kb of RAM memory. It is a raster based GIS which has a large set of procedures for map comparison and spatial analysis. Although the package was primary developed for educational purposes and has therefore a limited capacity, it became widely used in landscape ecological research, in landscape assessment and land evaluation. The main drawbacks are the input and output procedures which are not users friendly. Data must be entered in raster format and no facility is available for vector to raster conversion. Output of the maps is only possible on a matrixprinter and not on the screen, which gives a serious limitation for a fast interactive analysis. Because only text screens are used the package can be used on any PC configuration. The price and the flexibility determined this choice for the development of GIS on scales of the governorate, district and communal level. Thus, information from image interpretation, maps, field surveys and statistics could be combined.

The procedures for spatial analysis proved to be particularly useful. As an example, distance zoning was carried out from the drainage and irrigation channels, using terrain elevation data in a Digital Terrain Model (DTM) based upon the topographical map (fig.6). Spatial association with the interpreted salinity map (fig.7) and with field survey maps proved to be significant in most cases. This analysis supported the hypothesis that salinization increases with the distance from the water channels and is more severe for drainage channels than for irrigation channels.

6. Perspectives

Although digital imagery contains more precise information, it is still very difficult to use this to perform practical work because of the restricted availability of the hardware in developing countries. This is particularly true for many small scale projects. Fortunately, low cost software for digital image processing becomes available for PC too, as the PCIPS (Myers, 1985). Most procedures of image enhancement can hardly be used for more ecological ways of spatial analysis. Nevertheless, this kind of software may be interesting for a more easy input of information in a raster GIS. Also, output of the GIS can be improved using digital image software to produce coloured maps of better readability than matrixprinted maps.

7. Conclusions

In the field of land evaluation and landscape assessment any type of remote sensing imagery is an important and even fundamental source of information. Many enhancement and interpretation techniques (analog as well as digital) treat that information with a very loose link with the complex and holistic reality on the terrain. The main reason seems to be that the necessary terrain information is not always available and if so, it has seldom the expected perfection. Meaningful interpretation with really practical use for the local and regional planning authorities, can seldom be achieved without an integrated landscape ecological approach. Techniques for spatial analysis available in GIS-packages are even more useful then enhancement procedures. Although an integration of
both is required. Anyhow, the skilled human interpreter remains indispensable.

8. Literature

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Fig.1 : The depression of El Fayoum on Landsat TM band 3 (12 July 1985).

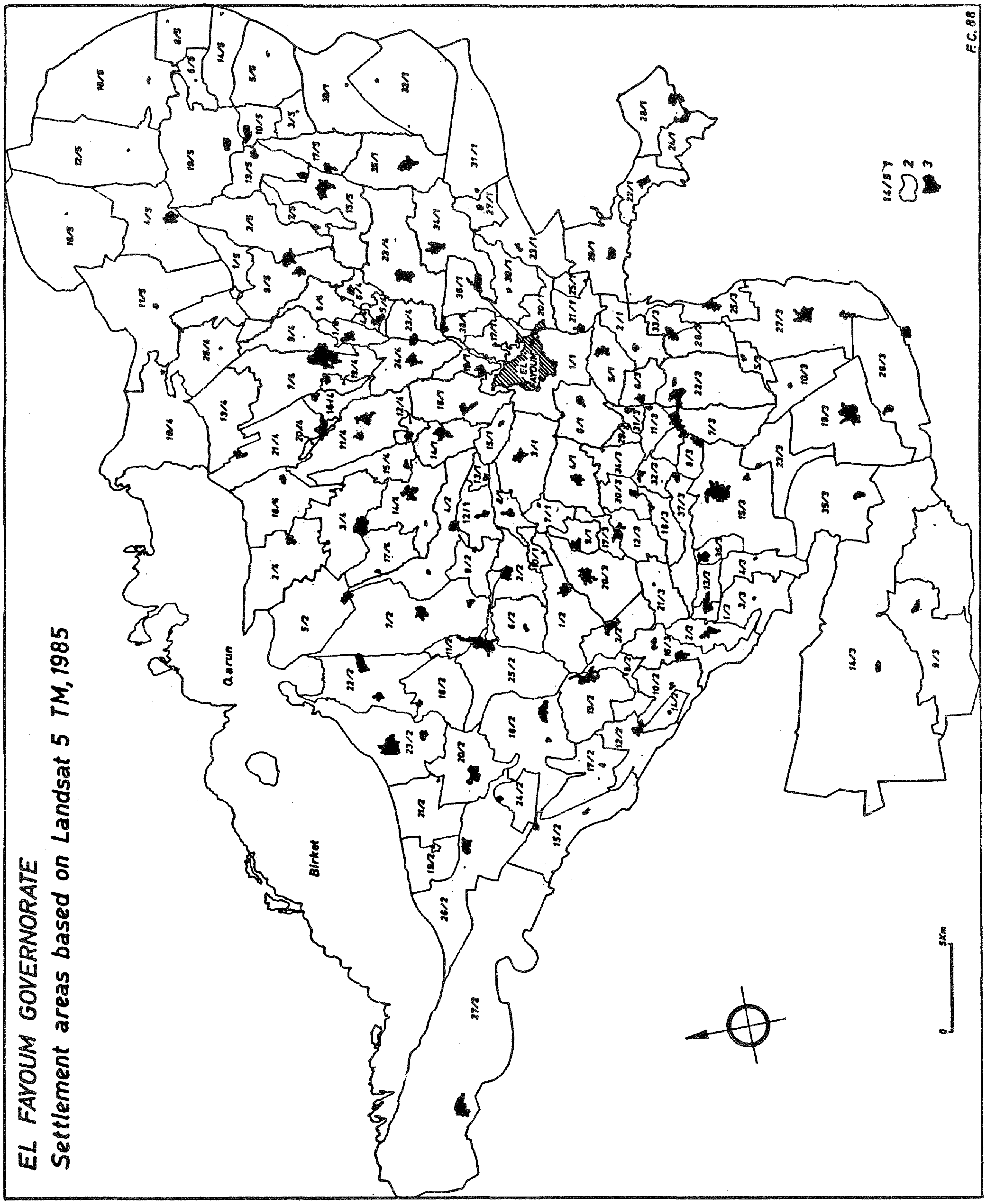


Fig.2 : Administrative divisions of El Fayoum Governorate and the settlement shapes and sizes interpreted upon Landsat TM.

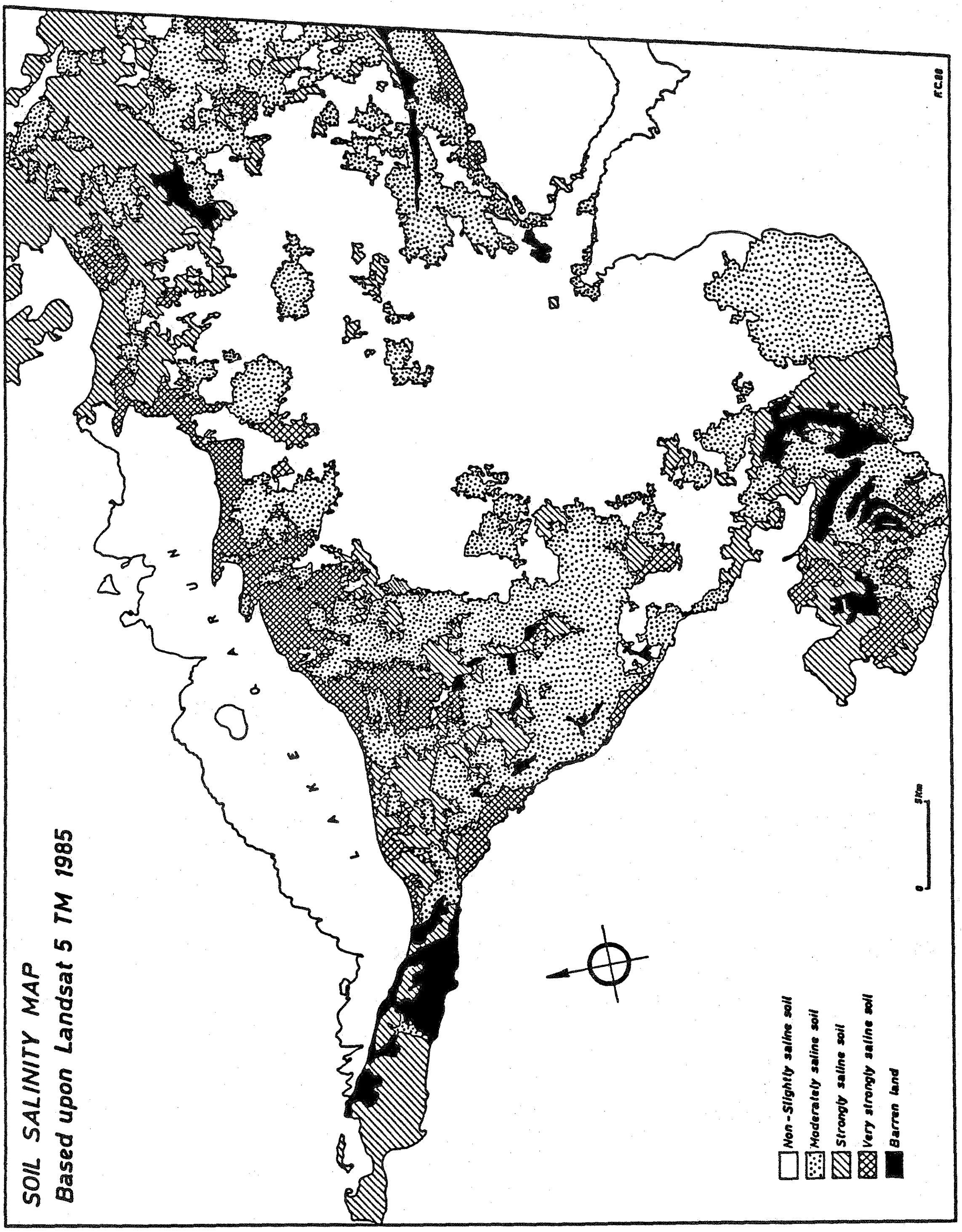
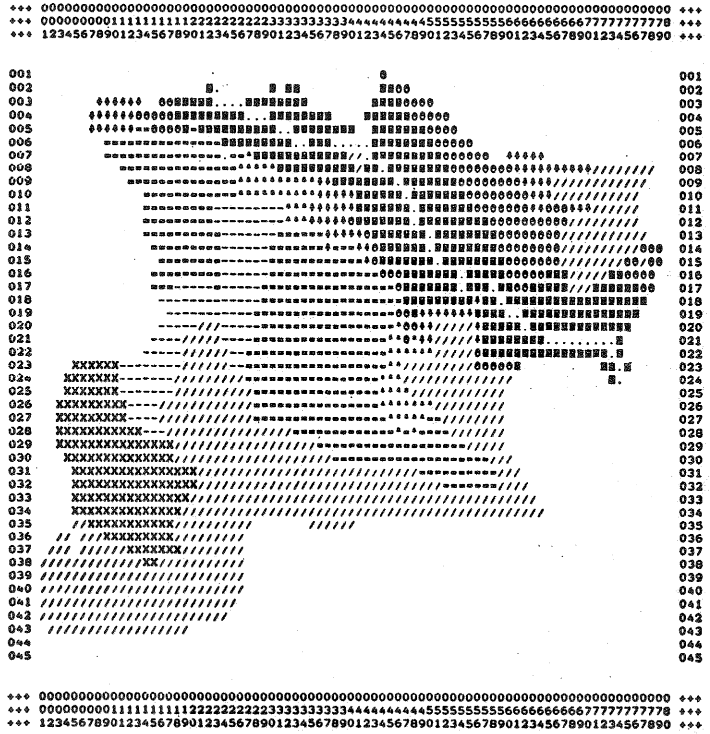


Fig.3 : Soil salinity in El Fayoum based upon visual interpretation of a Landsat TM colour composite.

Fig.4 : Aerial photograph of the town El Minya in 1956.

Fig.5 : Landsat TM image (band 3) of the town El Minya in 1985.



AP NAME: DRAISPD
HEADER : Distance zoning downhill : main drain channel El Minya
SCALE : 100

SYMBOL	VALUE	LABEL	CELLS	COVERAGE +B	COVERAGE -B
	B	....	1506	41.83	.00
....	0	Drainage channel	46	1.28	2.20
■■■■	5	500m	373	10.36	17.81
0000	10	1 km	144	4.00	6.88
♦♦♦♦	20	2 km	86	2.39	4.11
∘∘∘∘	30	3 km	65	1.81	3.10
====	40	4 km	228	6.33	10.89
====	50	5 km	213	5.92	10.17
----	60	6 km	86	2.39	4.11
----	70	7 km	51	1.42	2.44
XXXX	80	8 km	168	4.67	8.02
////	90	9 km	47	1.31	2.24
////	100	10 km	587	16.31	28.03

Fig.6 :

Part of the MAP2 GIS of El Fayoum : commune El Minya. Distance zoning around the main drainage channels, related to the topography.

AP NAME: XSALDRAI
HEADER : Combination distance zoning of drainage with salinity in El Minia
SCALE : 100

SYMBOL	VALUE	LABEL	CELLS	COVERAGE +B	COVERAGE -B
	B	....	1511	41.97	.00
0000	0	build area	132	3.67	6.32
====	2	non sal < 1 km	602	16.72	28.82
XXXX	3	mod sal < 1.5km	437	12.14	20.92
====	4	non sal 1-2.5km	489	13.58	23.41
XXXX	5	mod sal 2-2.5km	92	2.56	4.40
====	6	non sal > 3 km	99	2.75	4.74
XXXX	7	mod sal > 3 km	15	.42	.72
////	9	very sal > 3 km	223	6.19	10.67

Fig.7 :

Part of the MAP2 GIS of El Fayoum : commune El Minya. Combination of the interpreted salinity map (Landsat TM, 1985) and the distance zoning around the main drainage channels.