POTENTIAL IMPACTS OF GLOBAL WARMING:
GRID CASE STUDIES ON CLIMATIC CHANGE

DRAFT

OTTO SIMONETT, GRID- GENEVA, 6, RUE DE LA GABELLE, 1227CAROUGE, 19.12.89

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SUMMARY

Global Warming and it's implications to mankind and to the environment is a widely discussed topic today. How much temperature will increase and how long it will take is still uncertain, but potential impacts can already be anticipated.
In the UNEP/GRID case studies certain parameters were assumed to model potential impacts of climatic change using Geographic Information Systems.
Main goals of these case studies are to create global environmental awareness, to support UNEP's activities and to demonstrate of Geographic Information Systems as a tool for environmental analysis.
In this report, the results of the GRID case studies are briefly described, emphasis is laid upon cartographic and statistical presentation of our material

INTRODUCTION

Global Warming
Uncertainty is still the prevailing factor in the prediction of future climate, but one fact is certain: Temperatures on earth are rising. This warming is caused by the so called 'greenhouse effect'. Increasing concentrations of trace gases in the atmosphere, Carbon dioxide in particular, absorb some of the infrared radiation emitted by the earth, on the long run this process will lead to temperature increases. Besides carbon dioxide, other important greenhouse gases are methane, nitrous oxide, the chlorofluorocarbons (used in aerosols, refrigeration and industry) and ozone. Produced at an increasing rate, by the year 2030 the effect of carbon dioxide and the other gases combined are approximately twice as severe as they are today. Estimates of temperature increase range from $1.5°$ C to $4.5°$ C according to various models (UNEP/GEMS 1987).
A slow temperature increase is being observed already: Mean global temperature has risen nearly $1°$ C during the last century.
General descriptions of these rather complex processes are given in the literature (UNEP/GEMS 1987, CCA 1987).

Impacts of Climatic Change
What does this warming mean to the global ecosystems and what are its impacts on the human population? The increasing temperatures will obviously change the climate as a whole, rainfall patterns and other factors, such as windspeed or evaporation. This will affect natural vegetation as well as agricultural systems, food crops cannot be grown where they have been grown for centuries. For certain countries, such as Finland or Iceland these impacts may be beneficial, food production could be accelerated (Parry et al. 1988). But as a whole, particularly under the aspect of uncertainty, impacts are likely to be negative. Different cropping patterns, altering global trading patterns as well, could lead to a general destabilization of the political systems.

Another impact of warmer temperatures would be sea-level rise. Mostly caused by thermo-expansion of sea water - it now is assumed that the influence of the melting of the polar ice caps is negligible - sea-level is expected to rise between 20 - 165 cm in the next 50 - 100 years. A trend can already be observed: since 1900 sea-level has already risen approximately 10 centimeters (Bolin et al. 1986).

BACKGROUND

UNEP activities concentrating on climatic change are, among others, the organization of conferences and the setting up of international conventions to reduce the greenhouse gases. This requires a certain awareness of the greenhouse effect among decision makers as well as the general public.

By the year 2040:

Expected temperature increase: **1.5 - 4.5 ° Celsius**
Expected sea-level rise: **20 - 165 cm**

Table 1: Basic assumptions for GRID case studies

Using the parameters shown in Table 1 as guidelines, the GRID case studies have the purpose to support the overall UNEP activities as well as to demonstrate Geographic Information Systems (GIS) technology . For selected geographical areas we try to predict impacts of climatic change, **sea-level rise** and **crop suitability**. Geographic Information Systems are used to in the modeling process, to be able to derive accurate statistical figures and to visualize our findings with powerful computer graphics. In addition, these case studies were also used to evaluate GIS technology.

It can be argued, whether GIS is the appropriate tool to conduct such studies; if the analysis could not be done easier and cheaper manually. However, the advantages of GIS are obvious:

Analysis. Overlay techniques allow the comparison of different thematic layers for the same geographical locations.

Statistics. Some parameters, such as areas and perimeters, are automatically computed, attribute data can be used for more sophisticated statistical analysis.

Updating. New maps and other data can easily be incorporated into the database.

Output. Graphics in various forms (screen, printer, plotter, slides etc.) can be produced directly from the system.

The tool GIS has proven to be quite useful for climatic change predictions although their full potential has not been utilized for these case studies. It can well be envisaged that our type of approach could be used by governmental agencies and scientific institutions in countries affected by climatic change impacts.

CASE STUDY AREAS

The GRID case studies concentrate on two topics: Sea-level rise and Crop suitability models. While areas vulnerable to sea-level rise can be located relatively easily, the impacts on crop suitability could affect the whole world. For our sea-level rise studies we selected areas in Bangladesh and Egypt, the two countries the most vulnerable on earth, if vulnerability can be rated at all (UNEP 1989). The rest of the case studies we selected according to data and model availability and local contacts.

The locations are shown on a world map (Figure 1), a brief discussion will explain our choices:

UNEP's Oceans and Coastal Areas Programme (OCA-PAC) and the Mediterranean Task Team on Climatic Change have identified five particularly vulnerable areas to sea-level rise: The Ebro delta in Spain; the Rhone delta, including Marseille in Southern France; Venice with the Po delta in Italy; the **Nile Delta** in Egypt and lagoons in Tunisia, the Garet El Ichkeul and the Lac de Bizerte. Impact studies have been conducted for all these areas in a traditional, descriptive manner, the results have been presented at a meeting in Split in October 1988 (UNEP/OCA 1988).
GRID choose the **Nile Delta**, because in terms of population and cropland it is one of the most vulnerable areas to sea-level rise on earth (UNEP 1989) and useful cartographic data were readily available (Sestini 1988).

The country most seriously affected by sea-level rise is **Bangladesh** (UNEP 1989). Already very exposed to storm surges today, an augmentation of the niveau of the sea would be disastrous.

Since climatic change is mostly caused by emissions produced in developed countries, it is important to show that impacts can also occur there. The whole state of **Florida** consists of very low lying land, higher marine water levels would have severe impacts. Tropical storms, such as hurricanes could easily lead to unprecedented catastrophic events.
Through contacts to Metro Dade County / OCSIS, the local planning authority of **Dade county, Florida**, it was possible to obtain very accurate terrain and other data for **Miami,** which gives an ideal case to demonstrate potential damages to a heavily populated metropolitan area in a developed country.

In conjunction with the **Uganda** Ministry for Environment Protection GRID has already created a nation-wide database on natural resources (GRID 1987). For **Kenya,** GRID has also collected a large number of environmental datasets. Agro-Ecological models developed in Kenya (Kenya Soil Survey 1985) were available to simulate climatic change impacts. Developing countries like Uganda and Kenya often rely very heavily on a few agricultural products for export earnings and are therefore very sensitive to climatic change impacts.
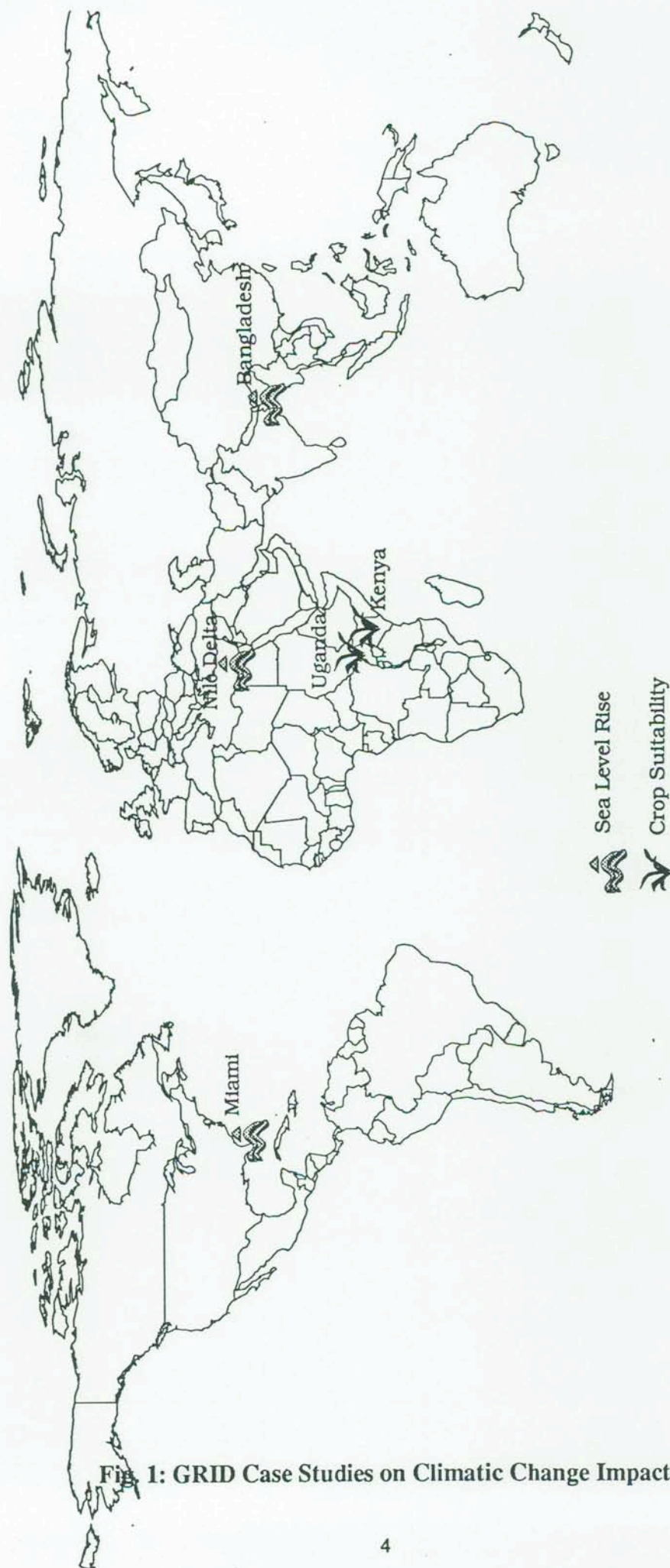
Fig 1: GRID Case Studies on Climatic Change Impacts

GRID Case Studies on Climatic Change Impacts

Sea Level Rise

Crop Suitability

Bangladesh

Nile Delta

Uganda

Kenya

Miami

METHODOLOGY

Geographic Information Systems

Geographic Information Systems are computerized systems for the INPUT, STORAGE, ANALYSIS and OUTPUT of geographical data (Goodchild 1989). Common denominator of all data in a GIS is their geographical location, which allows the comparison of different datasets from different sources at various scales. Analysis with GIS includes simple overlay functions as well as more sophisticated tasks: Network modeling, three dimensional terrain analysis and others. Today, in developed countries Geographic Information Systems are widely used for planning purposes and they could also be useful in Third World countries with their vast natural resources to manage.

The GRID case studies have been conducted with ARC/INFO, a commercially available GIS on a VAX 3600 minicomputer at GRID Nairobi and Geneva. The system handles data in a vector type format with points, lines and polygons as basic features; attribute data is stored in relation to these geometrical entities. More information about this system can be found in the literature and brochures (ESRI 1989)

Source map data has been entered through a manual digitizing process, the maps are traced by an operator on an electronic input device. With the advancement of more powerful microcomputer systems, it will be very likely that case studies of this extent could also be run on such smaller, personal systems.

Graphical output has been produced in various forms: slides, transparencies, color ink jet plots and black and white laserprinter maps. Demos have been set up on Apple Macintosh computers with powerful presentation software (Supercard, Hypercard and Videoworks). This option allows us to send demo diskettes to institutions and individuals operating the same equipment, as well as transfer them onto video systems.

Methodology and Data Sources Sea-level Rise

The most important component of sea-level rise studies is high resolution terrain data. Such data is not always available, either because of security reasons, or, as it is more often the case, because it simply does not exist. To find suitable terrain data was one of the most difficult tasks of the GRID case studies.

For parts of the **Nile Delta**, contour maps at a scale of 1:100,000, with 1 meter contour intervals could be obtained as a redraw from the originals maps. For the simulation of a sea-level rise of 20 cm, however, contours with 1m intervals are not sufficient. Human artifacts, such as railway dams or small walls are not resolved at this scale. For the rest of the delta, the data situation was even more crucial. Because of this lack of accurate data we confined ourselves to show sea-level rise increments of 50 cm only.

With the most difficult data situation we had to cope in **Bangladesh**. The best map available has 5 ft (ca. 1.5m) contour intervals and we were not able to calculate reasonable interpolations. We had to adjust our parameters for Bangladesh to show 1.5 and 3.0 m sea-level rise only.

Metro Dade County /OCSIS (Miami) provided us with very accurate terrain information: contour maps with 1 ft intervals at a scale of 1:12,500. This solved the problem of human artifacts, very small topographic features are resolved at this contour interval.

Population, infrastructure and agricultural data was required to overlay with the future sea-levels for the prediction of damages. This data, too, varies enormously in availability and quality between the case study areas:

Population Density for the **Nile Delta** dates from 1971, we extrapolated the figures to 1982 levels. The cropland / non cropland map has been derived from a Landsat image of 1988 (Remote Sensing Center 1988) through visual interpretation of a black and white paper print.

The **Bangladesh** population density map of 1977 has been updated to 1989 figures (World Resource Institute 1988). No other maps have been digitized for Bangladesh. If better terrain data would be available in future it would be well worth to incorporate the World Bank Land Use and Land Cover maps (World Bank 1981) into the study.

By far the most comprehensive additional data was available for **Miami**. Land Use, Population Density, Hospitals, Groundwater and a wide range of other thematical maps were received from Metro Dade. Probably the most important data for Miami are the land and infrastructure values per square mile. This enabled us to explain sea-level rise in terms of Dollars, a 'language' much better understood than population or crop figures.

All maps were digitized with ARC/INFO. Some manual enhancements of the contour maps, such as the addition of spot heights and ridge lines were necessary prior to digitizing to prevent misinterpretation by subsequent processing steps. TIN (Triangular Irregular Network), a module of ARC/INFO, was then used to interpolate a Digital Terrain Model (DTM). A DTM is a three dimensional model of topography stored in a computer. It can be used for many purposes, such as the derivation of slope and aspect, three dimensional display and the interpolation of contours. The DTM then was contoured; contours at new intervals, potential future shorelines, were automatically interpolated. Some editing of the contours with ARCEDIT was necessary in order to get good cartographic products. Fully automated processing of the terrain data would not have lead to useful results, all the manual enhancements were essential.

In a subsequent processing step the 'future sea-levels' were overlayed with the thematical data (population, infrastructure, agriculture), to predict vulnerability in maps as well as with statistics.

These sea-level rise impact studies depend on high resolution terrain data, which are not always available. Some global efforts should be undertaken to survey the entire coastlines and create high resolution terrain maps.

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Other factors, accelerating the destructive effects of sea-level rise, such as subsidence and wave impacts, are not taken into consideration in our model. However, if enough data is available, more sophisticated analysis could be conducted with GIS, taking into account above-mentioned and other parameters besides relying on altitude only.

Methodology and Data Sources Crop Suitability

Our climatic change impact on crop systems studies are based on agro-ecological models developed in Kenya, which have been described in detail in the Agro-Climatological Zone map of Kenya (Kenya Soil Survey 1982) and the Farm Management Handbook of Kenya (Jätzold & Schmidt 1983).

Climatological input parameters are moisture availability (mean annual rainfall / mean annual potential evaporation) and temperature (mean annual). Source of the crop suitability data (based on moisture and temperature) is the Agro-Climatological zone map of Kenya (Kenya Soil Survey 1982). Optimal temperature ranges indicated are 21 - 23° C for Robusta coffee and 15 - 20° C for tea; moisture ranges are > 50 % (r/E ratio) for coffee and > 70 % for tea. Actual crop maps, where available, have been used to check the model's validity under current conditions. Simplifications in the models and map generalization (scales smaller than 1:1,000,000), may lead to very general results only. However, our analysis also indicates, how GIS could be applied for more sophisticated modeling of crop suitability at a larger scale. The system allows modification of parameters and the results of the modeling can immediately be visualized. Interactive modeling with direct interventions by scientists and other users could be a way to get meaningful results as well as to improve the models. What this would request, is better cooperation between scientists, analysts and decision-makers and, above all, Geographic Information Systems, which are more user-friendly than they are today.

RESULTS

This part is a brief presentation of the most important results of the GRID case studies on climatic change impacts. Only the most important figures are given, more weight is put on the graphical presentation of the scenarios. Since the main purpose of our work is to create environmental awareness amongst decision-makers and the public, this summary shall give input for discussions.

Sea-level Rise: Nile Delta

The Nile Delta is one of the oldest intensively cultivated areas on earth. It is very heavily populated, with population densities up to 1600 inhabitants per square kilometer. The low lying, fertile floodplains are surrounded by deserts. Only 2.5 % of Egypt's land area, the Nile delta and the Nile valley, is suitable for intensive agriculture (Diercke 1981). The most important cash crop grown in the delta is cotton, which has been in constant cultivation there since 2000 BC.

Most of a 50 km wide land strip along the coast is less than 2 m above sea-level and is protected from flooding by a 1 to 10 km wide coastal sand belt only, shaped by discharge of the Rosetta and Damietta branches of the Nile (Sestini 1987). Some valuable agricultural land on the delta has only recently been reclaimed. Erosion of the protective sand belt is a serious problem and has accelerated since the construction of the Aswan Dam. From 1915 to 1964 erosion at Rosetta was in the order of 30m per year; today's recession at Rosetta has increased to between 80m and 150m per year (Sestini 1987).

Our case study area covers the most heavily populated part of Egypt's Mediterranean coast: the tip of the Nile Delta between Alexandria and Port Said, reaching inland beyond Ismailia and Zagazig (30.5 Latitude). This area of over 25,000 square kilometers (land only) includes all of Egypt's coastal cropland and major cities vulnerable by predicted sea-level rise.

Rising sea-level would destroy weak parts of the sand belt, which is essential for the protection of lagoons and of the low-lying reclaimed lands.

The impacts would be very serious:

◊ One third of Egypt's fish catches are made in the lagoons. Sea-level rise would change the water quality and affect most fresh water fish.

◊ Valuable agricultural lands, which have been reclaimed would be inundated.

◊ Alexandria and Port Said are ideal locations for Industry and commercial activities, such as thermal power plants, oil refineries, textile and chemical industries. Vital, low lying installations would be threatened.

◊ Recreational tourism along the beach has been growing rapidly during recent years. Beach facilities would be endangered.

◊ Essential groundwater would be salinated.

The dramatic flooding of the tip of the delta with 50 cm sea-level rise only might in fact not be as dramatic as displayed in our graphics. Dykes and other protective measurements already in place since the land reclamation would probably prevent the worst flooding. At any rate, the 50 cm increase could already cause serious groundwater salination, not talking about the increasing impacts of wave action.

At 1 m existing dams would not withhold the water, if no new protective construction works will be built, 15% of Egypt's arable land and 12% of its population are in danger.

The following maps (Figure 2) show subsequent potential sea-levels on the Nile Delta, summary statistics are given in Table 2:

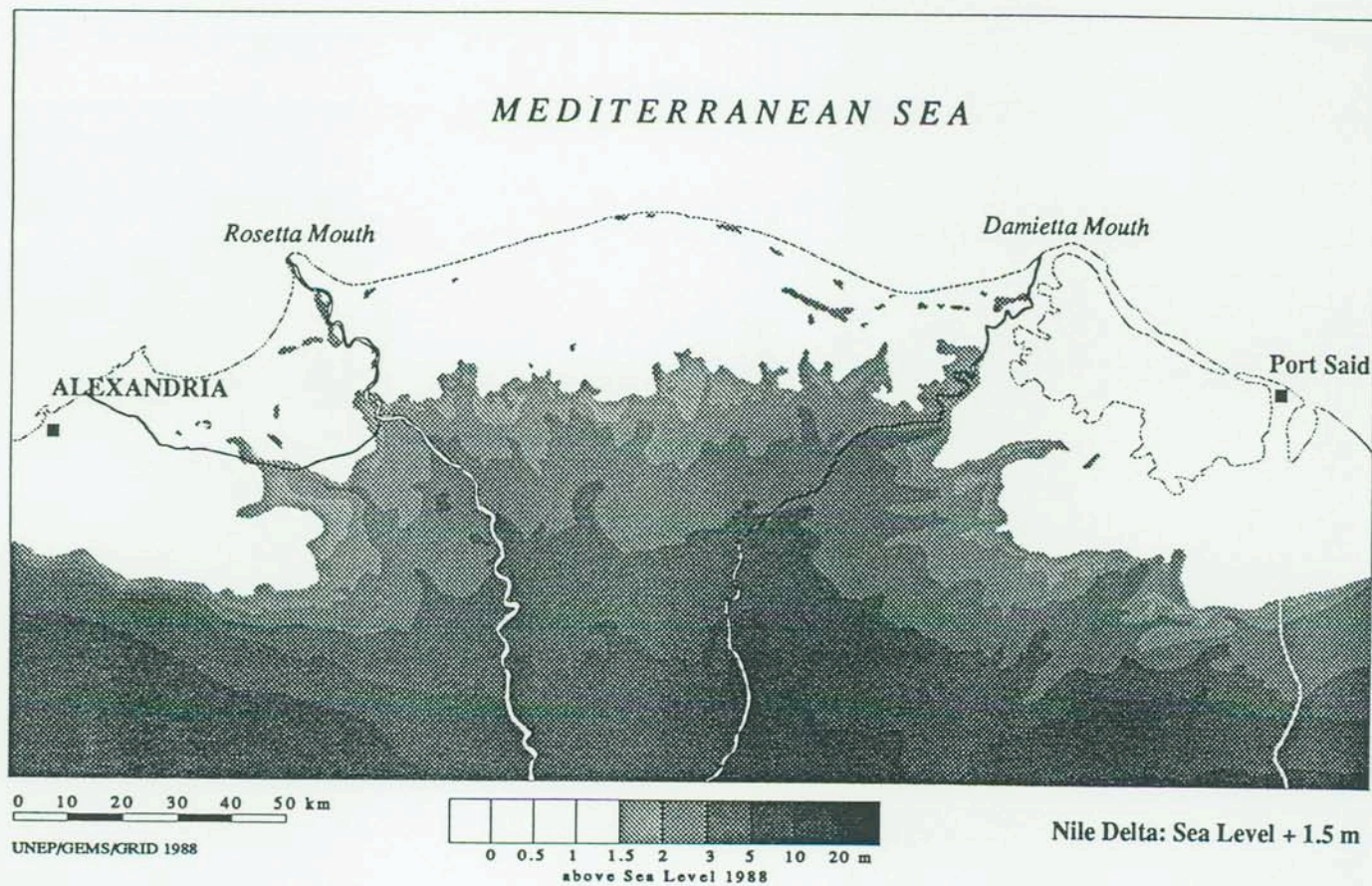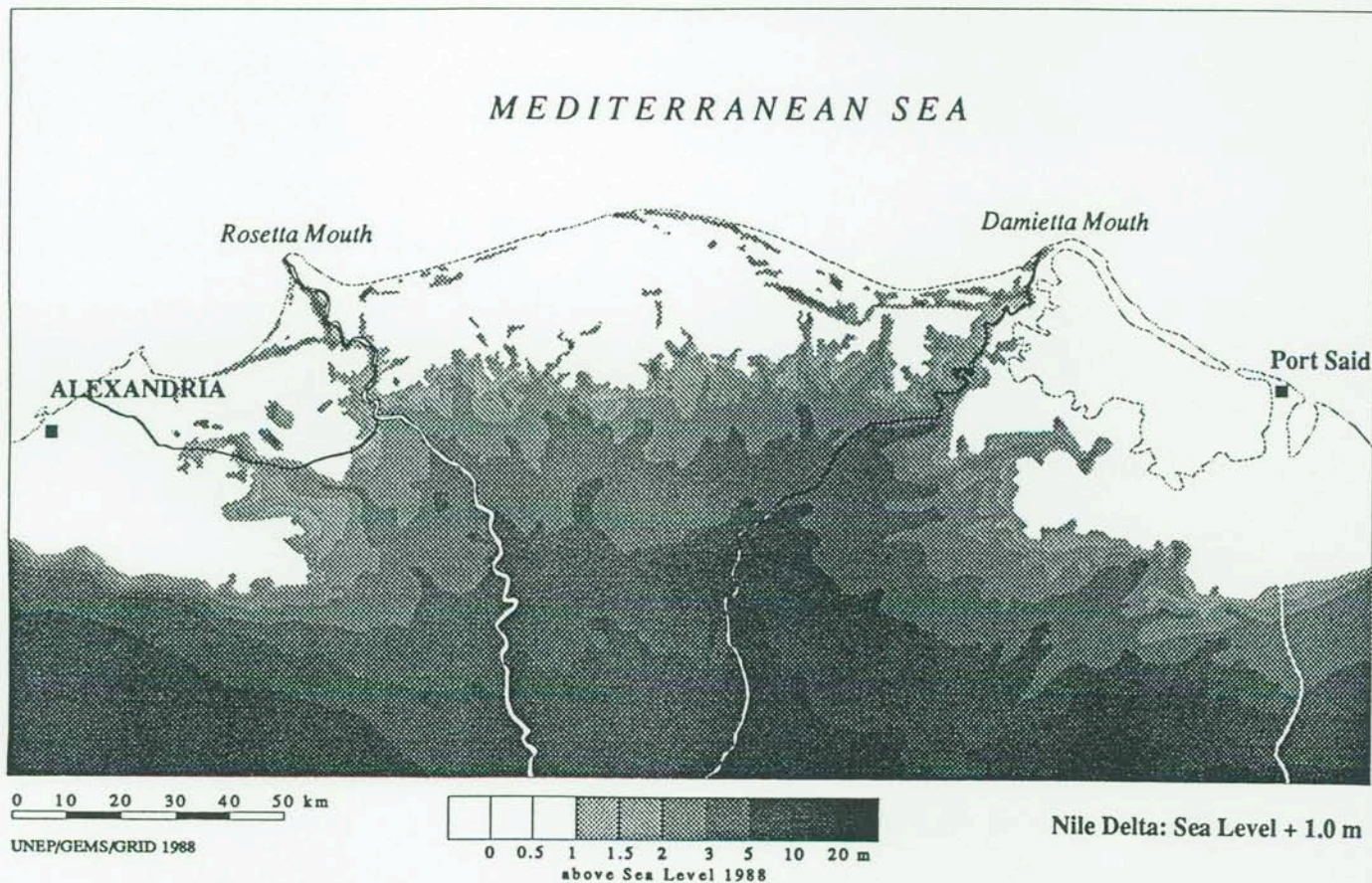| scenario	cropland '000km2	population 1989 ('000'000)	population 2025 ('000'000, est.)
50 cm	1.8 (6 %)	3.8 (7 %)	6.7 (7 %)
100 cm	4.5 (15 %)	6.1 (12 %)	10.7 (12 %)
150 cm	5.7 (19 %)	7.4 (14 %)	13.0 (14 %)
200 cm	6.6 (22 %)	7.9 (15 %)	13.9 (15 %)
300 cm	8.7 (29 %)	9.6 (19 %)	16.9 (19 %)
Egypt total*	30.0 (100 %)	51.4 (100 %)	90.4 (100 %)

* source: World Resource Institute 1988

Table 2: Nile Delta: Summary Statistics
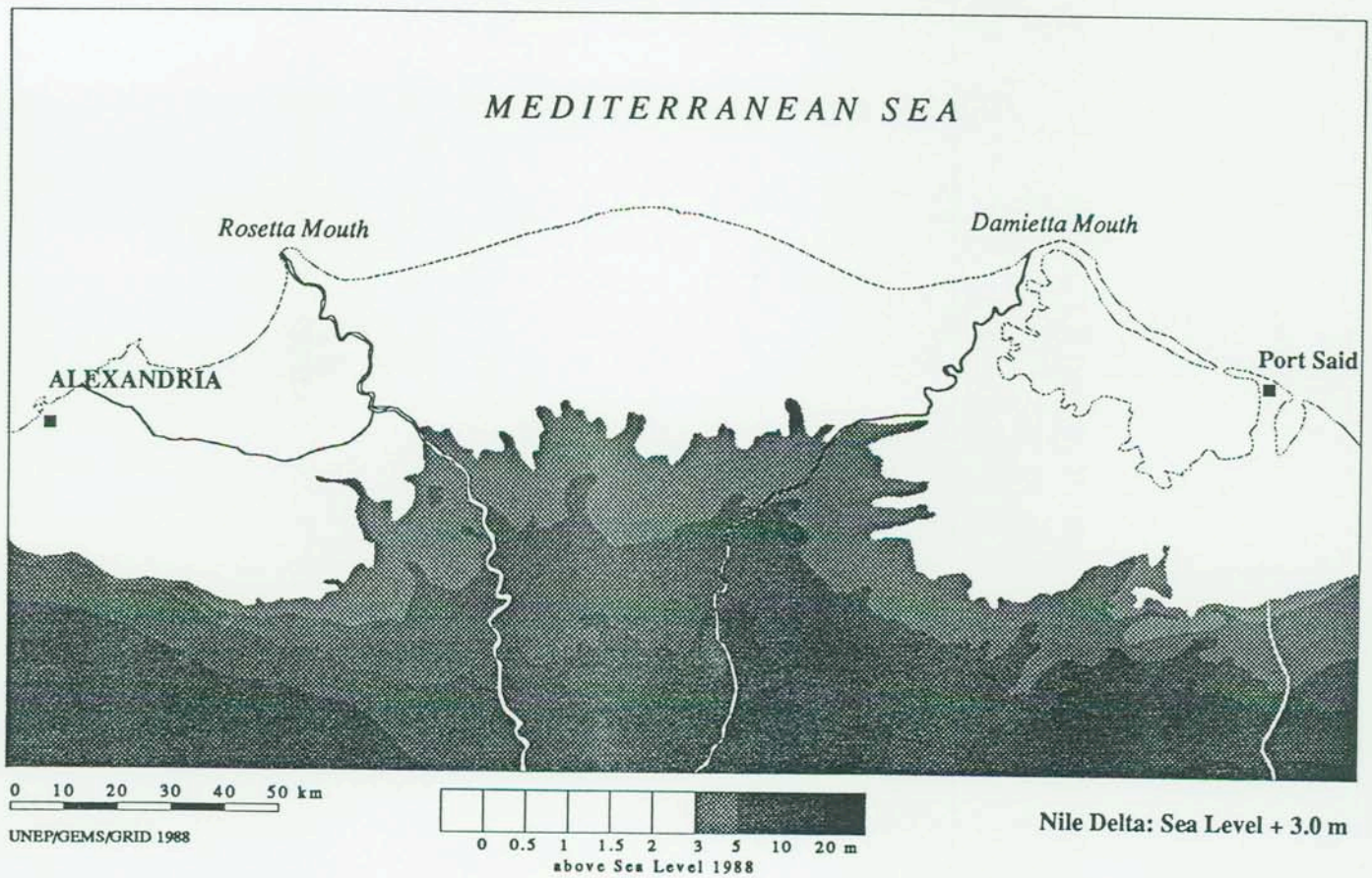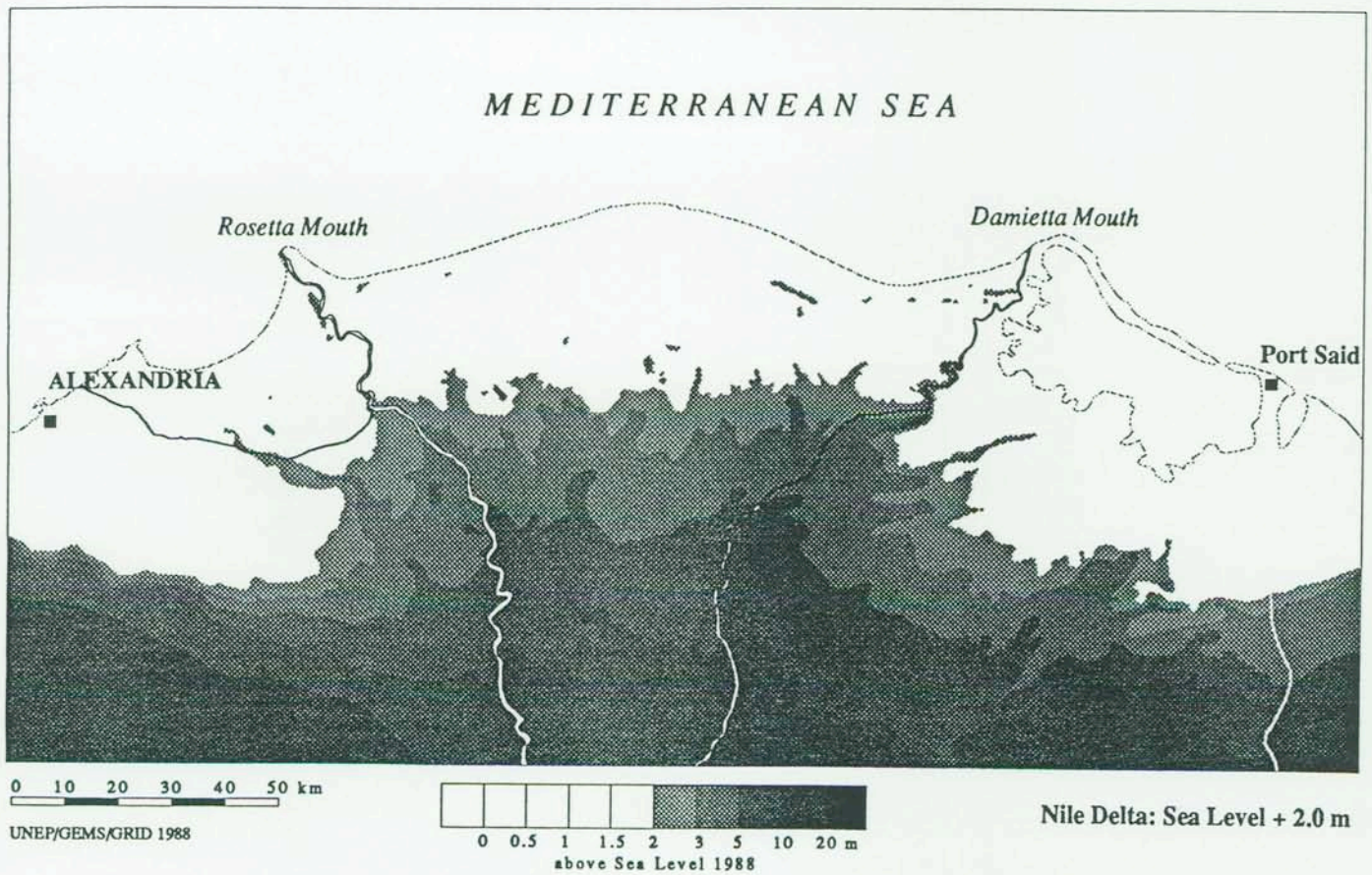(Figures derived through Geographic Information Systems analysis)
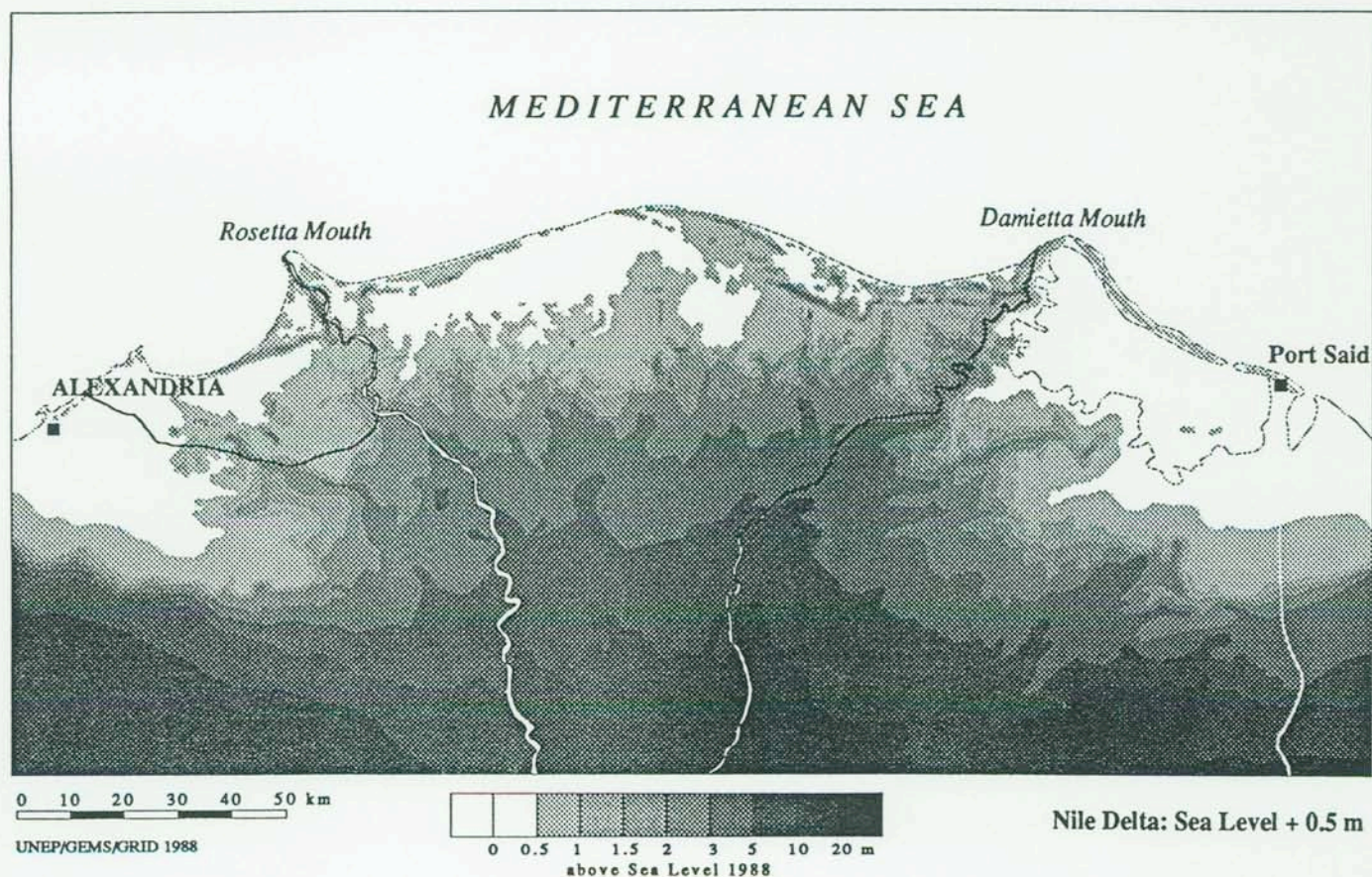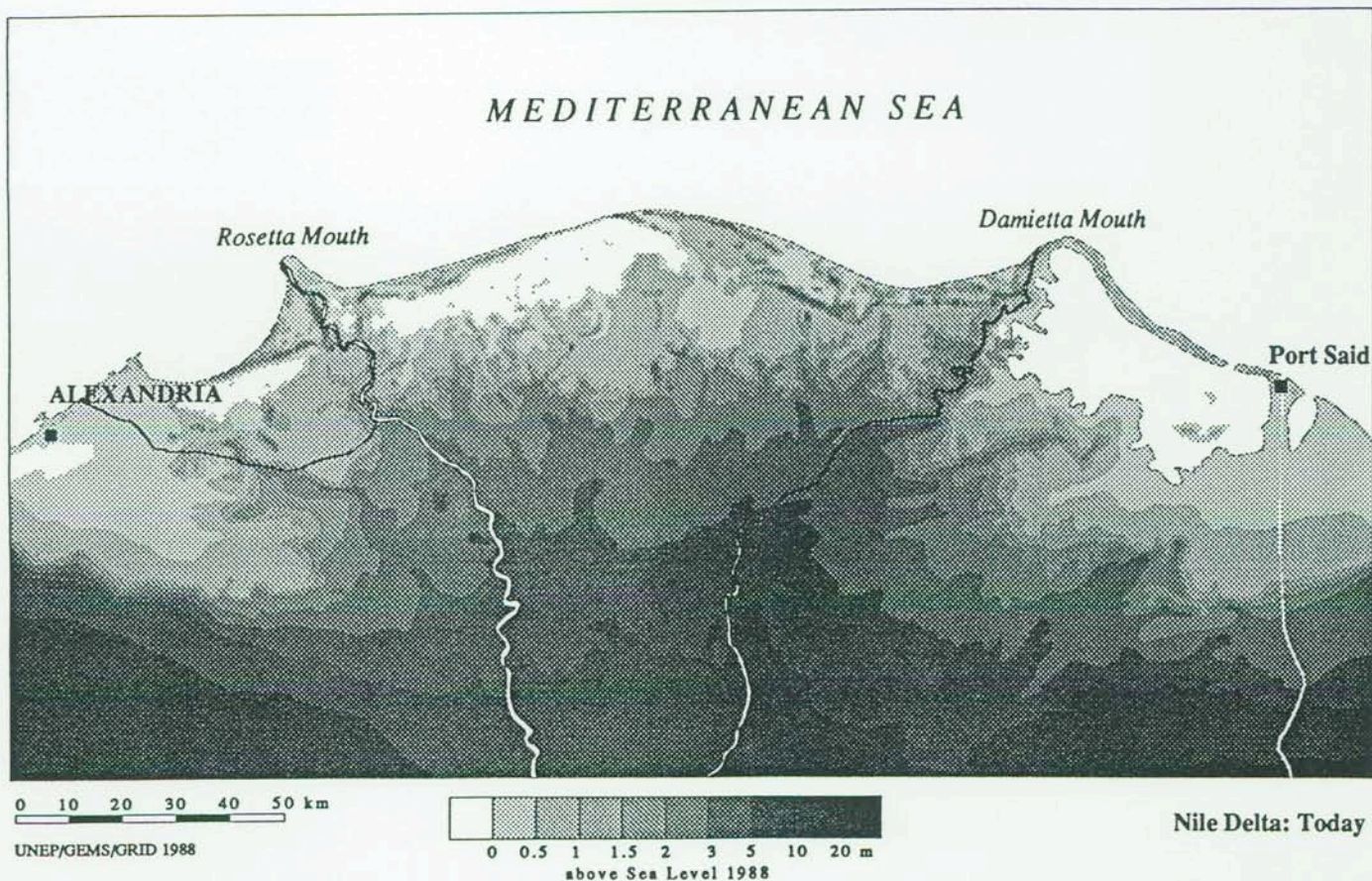
Fig. 2: Nile Delta Sea-level Rise Scenarios

MEDITERRANEAN SEA

Rosetta Mouth

Damietta Mouth

ALEXANDRIA

Port Said

0   10   20   30   40   50 km

UNEP/GEMS/GRID 1988

0   0.5   1   1.5   2   3   5   10   20 m
above Sea Level 1988

Nile Delta: Sea Level + 1.0 m

MEDITERRANEAN SEA

Rosetta Mouth

Damietta Mouth

ALEXANDRIA

Port Said

0   10   20   30   40   50 km

UNEP/GEMS/GRID 1988

0   0.5   1   1.5   2   3   5   10   20 m
above Sea Level 1988

Nile Delta: Sea Level + 1.5 m

11

MEDITERRANEAN SEA

Rosetta Mouth

Damietta Mouth

ALEXANDRIA

Port Said

| 0 | 10 | 20 | 30 | 40 | 50 km |

UNEP/GEMS/GRID 1988

| | | | | | | | | | |
0 0.5 1 1.5 2 3 5 10 20 m
above Sea Level 1988

Nile Delta: Sea Level + 2.0 m

MEDITERRANEAN SEA

Rosetta Mouth

Damietta Mouth

ALEXANDRIA

Port Said

| 0 | 10 | 20 | 30 | 40 | 50 km |

UNEP/GEMS/GRID 1988

| | | | | | | | | | |
0 0.5 1 1.5 2 3 5 10 20 m
above Sea Level 1988

Nile Delta: Sea Level + 3.0 m

Sea-level Rise: Bangladesh

Bangladesh, one of the world's poorest nations, with a GNP of US$ 150 per capita (1986, World Resource Institute 1988) is also the country most vulnerable to sea-level rise (UNEP 1989). Population growth of 3% annually will almost lead to a doubling of Bangladesh's population by the year 2025, the total population then will be 212 million (World Resource Institute 1988).

The population is already severely affected by storm surges, catastrophic events in the past have caused damage up to 100 km inland (JRO 1977). It is hard to imagine to what extent these catastrophes would be accelerated sea-level rise.

As stated earlier, due to the rather poor quality of input data, only very coarse estimates, to be handled with care, could be given for Bangladesh. We extended the scenarios up to 3 m, thus using the same parameters as Delft Hydraulics (UNEP/DELFT 1989).

scenario	land area '000km2	population 1989 ('000'000)	population 2030 ('000'000, est.)
150 cm	22 (16 %)	17 (15 %)	34 (15 %)
300 cm	33 (25 %)	27 (24 %)	54 (24 %)
Bangladesh tot.*	134 (100 %)	112 (100 %)	224 (100 %)

* source: World Resource Institute 1988

Table 3: Bangladesh: Summary Statistics
(Figures derived through Geographic Information Systems analysis)

Our comparative figures (Table 3) are slightly higher than the ones given by Delft Hydraulics (UNEP/DELFT 1989), but in the same order of magnitude. These figures are hardly comprehensive: Millions of people threatened by processes beyond their reach of action.

Digital terrain modeling techniques have been used to display the Bangladesh scenarios (Fig. 3). A three dimensional view of the country has been overlaid with the current coastline and major rivers and potential future sea-levels at 1.5 m and 3.0 m.
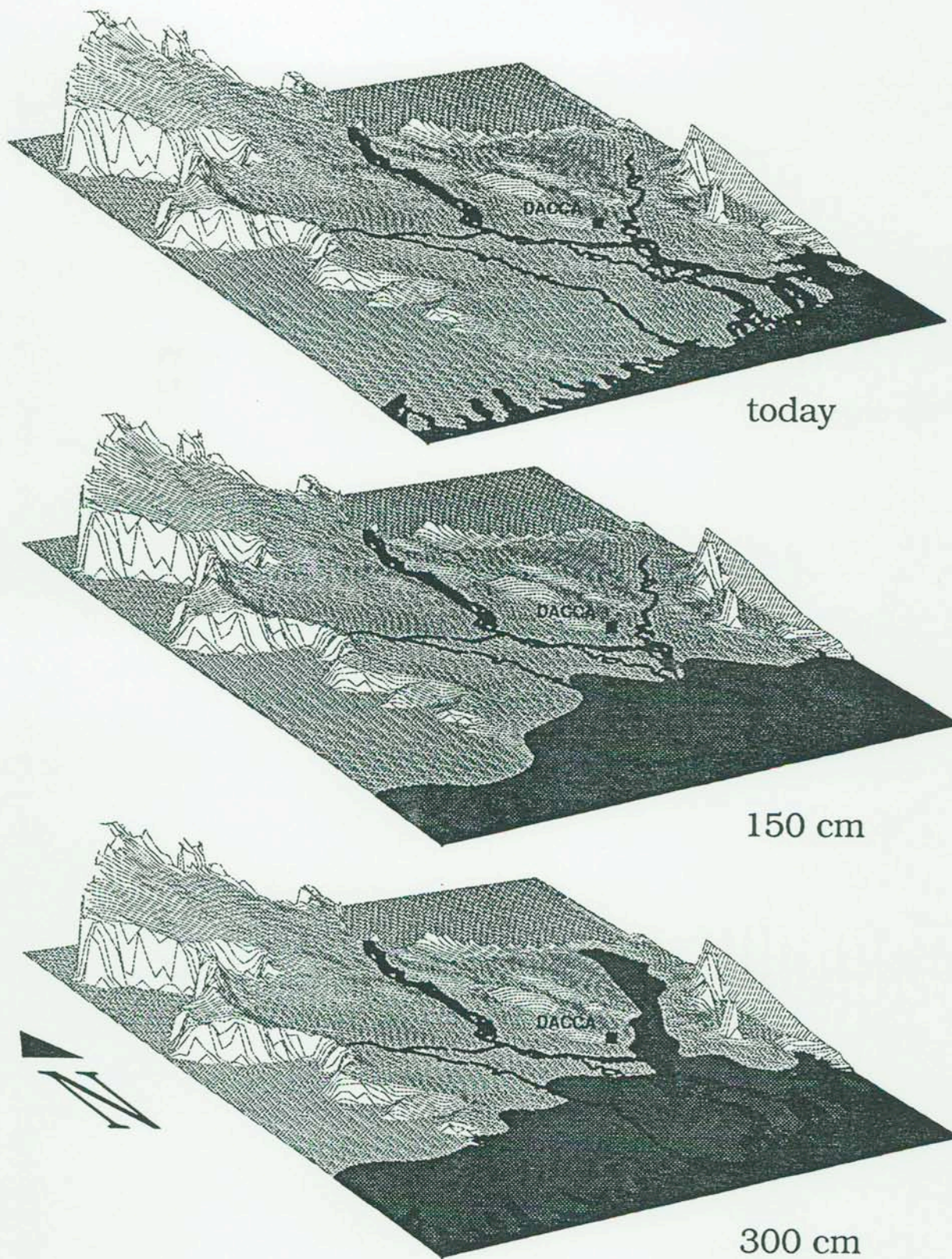
today

150 cm

300 cm

Fig. 3: Bangladesh Sea-Level Rise Scenarios

Sea-Level Rise: Miami

Most of Miami, with a population close to two million, lies below 3 meters above sea-level. This just gives an indication of how vulnerable this city would be to sea-level rise.

For our case study we were in the fortunate situation to have very accurate data available; we could go beyond the display of population and land in danger only. Probably the most interesting result of our case study is the display of actual land, building and infrastructure values for the sea-level rise scenarios. It is very important to show - in the context of expensive pollution reduction measures - how much climatic change impacts could cost.

Although we were able to calculate impacts at 1 foot (30.5 cm) intervals for this particular case study area, the standardized half meter scenarios are shown here only. On the maps (Fig.5) a rough land use classification (residential, industry/business, agriculture/parks) and the road network are shown so that sea-level rise can be related to urban patterns. The more vulnerable low-lying southern part of Dade county, fortunately is not very populated, however, with Turkey Point nuclear power plant and Homestead air force base some vital installations lie in this area. While the main part of the city is relatively well protected to sea-level rise up to 2 meters by an elevated ridge parallel to the coast, Miami Beach is severely exposed to it.
Loss figures are given in Table 4, just in their order of magnitude they are very impressive.
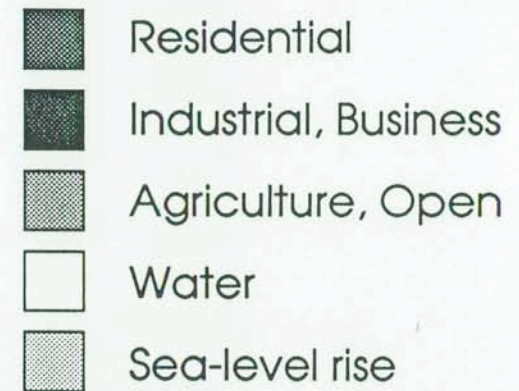
Scenario	population ('000)	land value (billion $)	building val. (billion $)	total value (billion $)
50 cm	77 (4 %)	1.4 (6 %)	1.2 (4 %)	4.4 (6 %)
100 cm	114 (6 %)	2.0 (9 %)	1.7 (6 %)	6.0 (10 %)
150 cm	190 (11 %)	3.5 (15 %)	3.0 (11 %)	9.9 (16 %)
200 cm	602 (34 %)	8.9 (39 %)	9.6 (36 %)	24.5 (40 %)
Total	1772 (100 %)	22.8 (100 %)	26.8 (100 %)	60.8 (100 %)

Table 4: Miami: Summary Statistics
(Figures derived through Geographic Information Systems analysis)
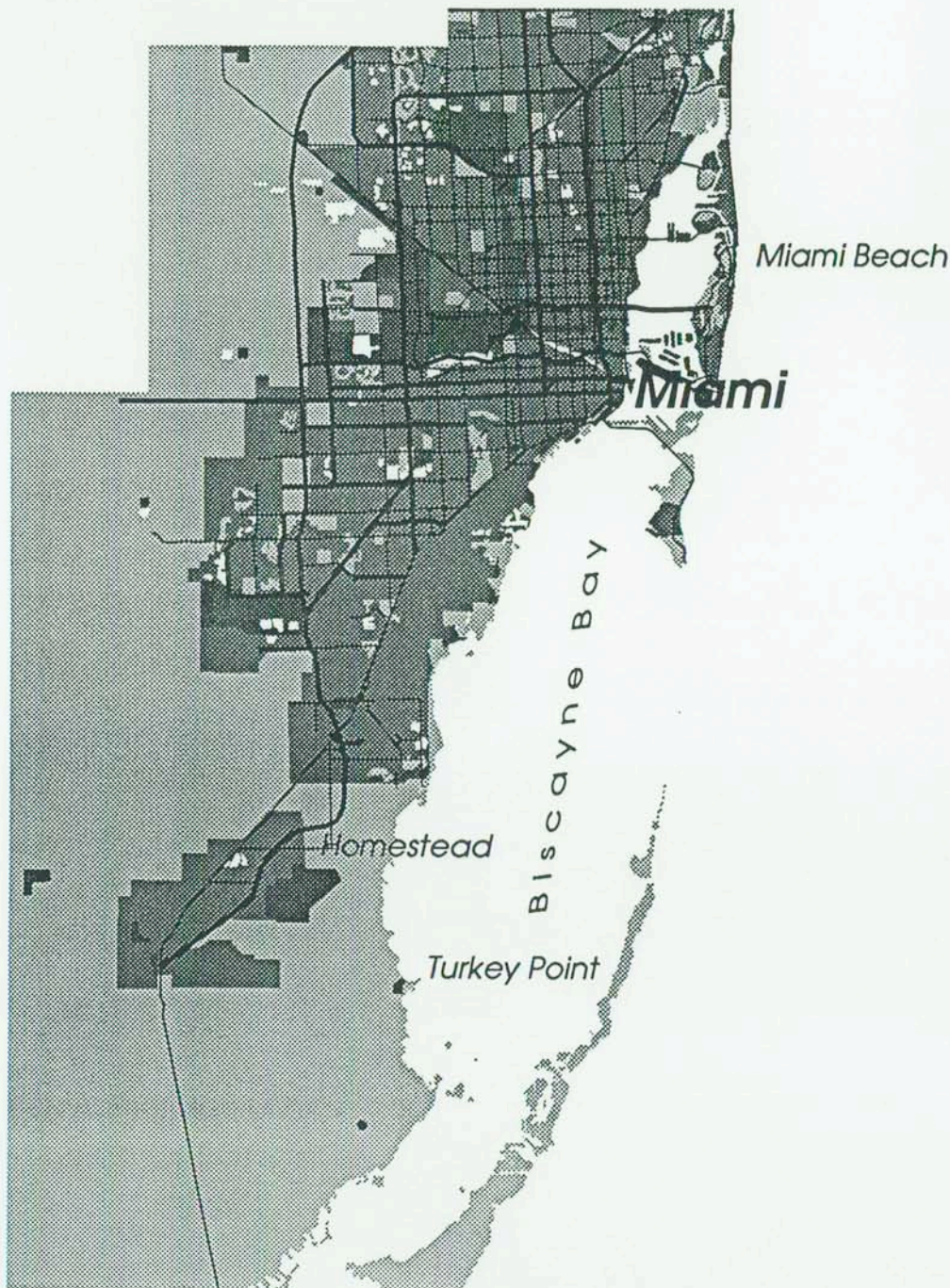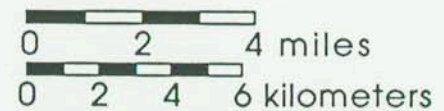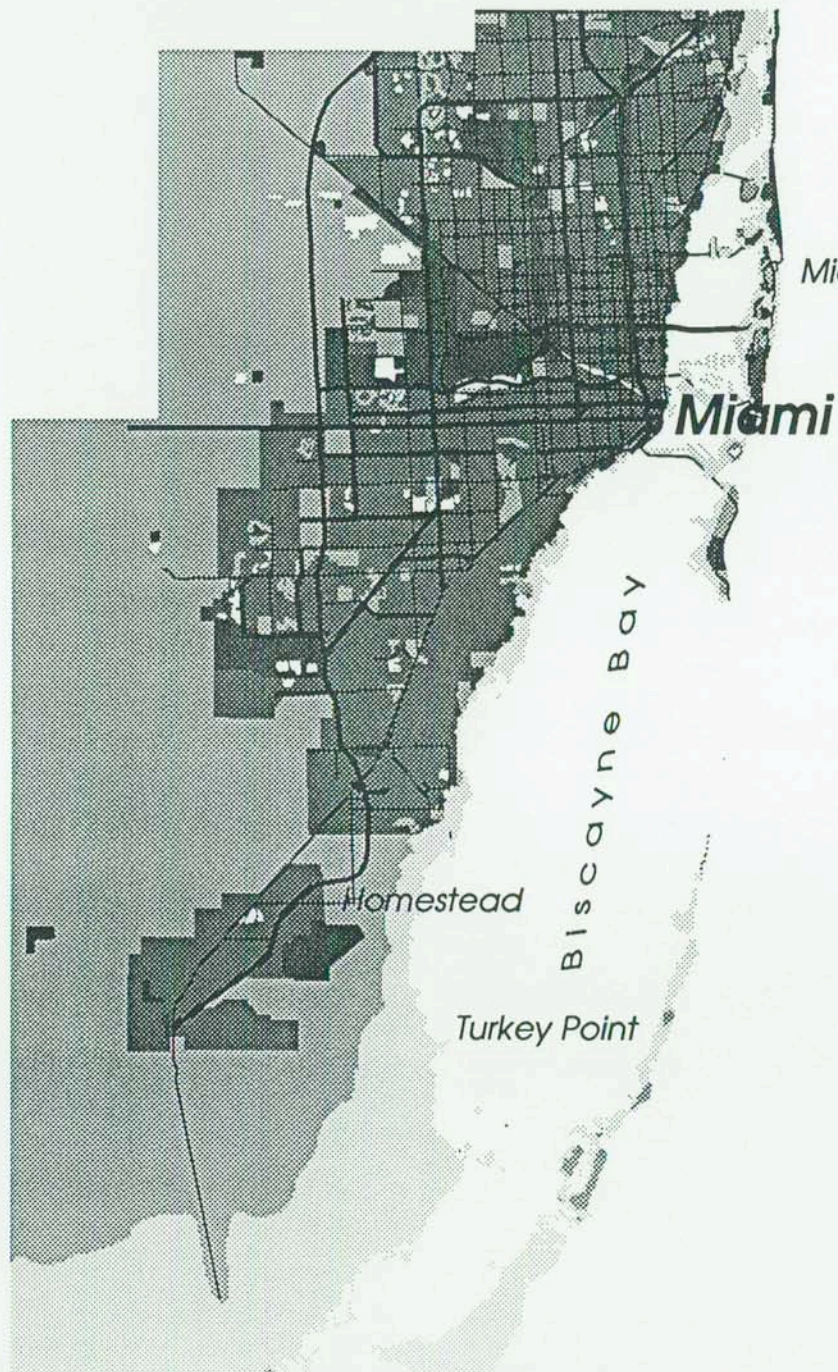
Miami

Sea-Level Today

Miami Beach

Miami

Biscayne Bay

Homestead

Turkey Point

Residential

Industrial, Business

Agriculture, Open

Water

Sea-level rise

N

scale

| 0 | 2 | 4 miles |

| 0 | 2 | 4 | 6 kilometers |

Fig. 4: Miami Sea-Level Rise Scenarios

Miami

Sea-Level + 50 cm

Miami Beach
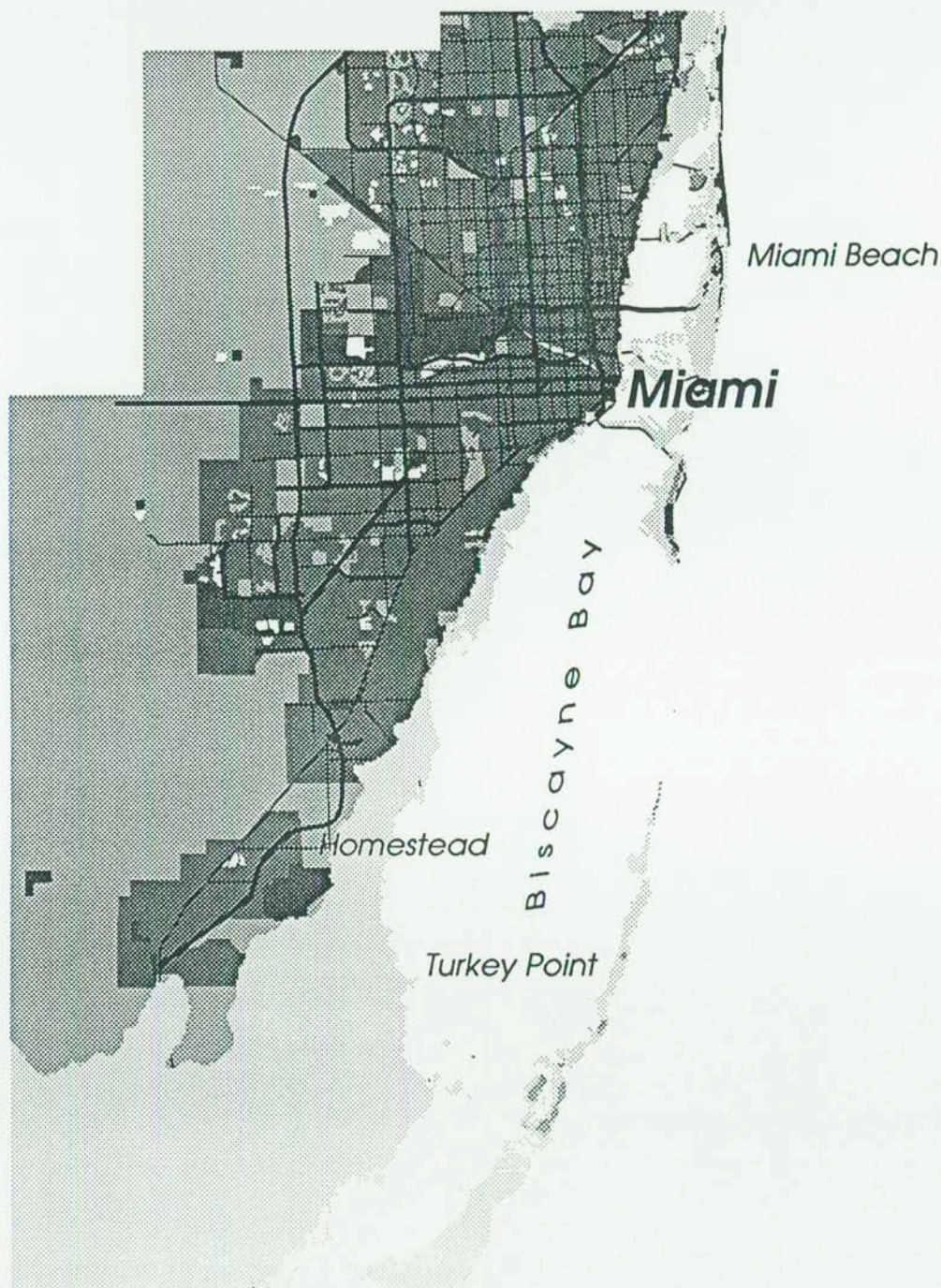
Miami

Biscayne Bay

Homestead

Turkey Point

- ▓ Residential
- ▓ Industrial, Business
- ▓ Agriculture, Open
- ☐ Water
- ▒ Sea-level rise

N

scale

| 0 | 2 | 4 miles |

| 0 | 2 | 4 | 6 kilometers |

Miami

Sea-Level + 100 cm
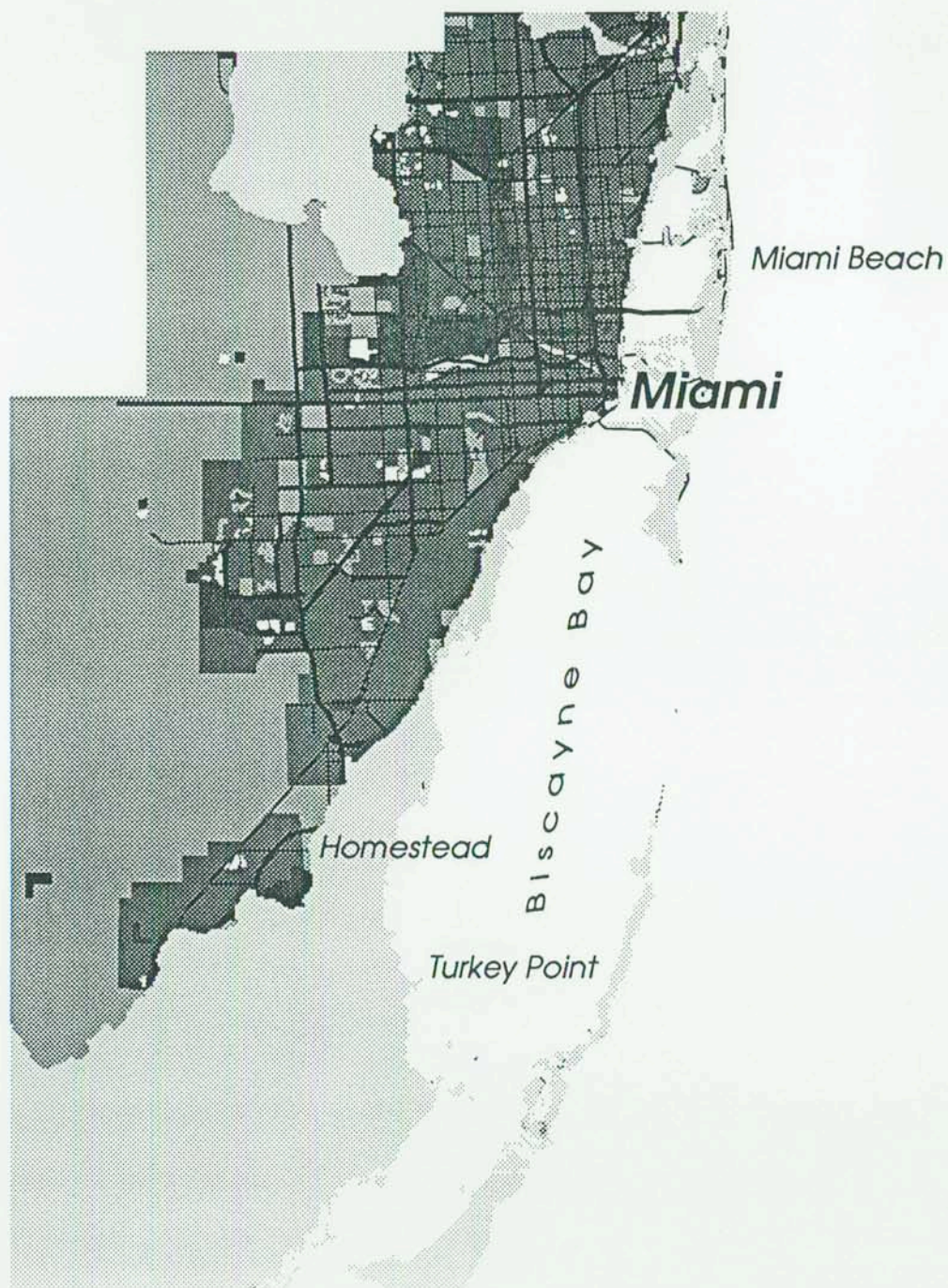
Miami Beach

Miami

Biscayne Bay

Homestead

Turkey Point

- Residential
- Industrial, Business
- Agriculture, Open
- Water
- Sea-level rise

N

scale

0 2 4 miles

0 2 4 6 kilometers

Miami

Sea-Level + 150 cm

Miami Beach

Miami

Biscayne Bay

Homestead

Turkey Point

- Residential
- Industrial, Business
- Agriculture, Open
- Water
- Sea-level rise

N

scale

| 0 | 2 | 4 miles |

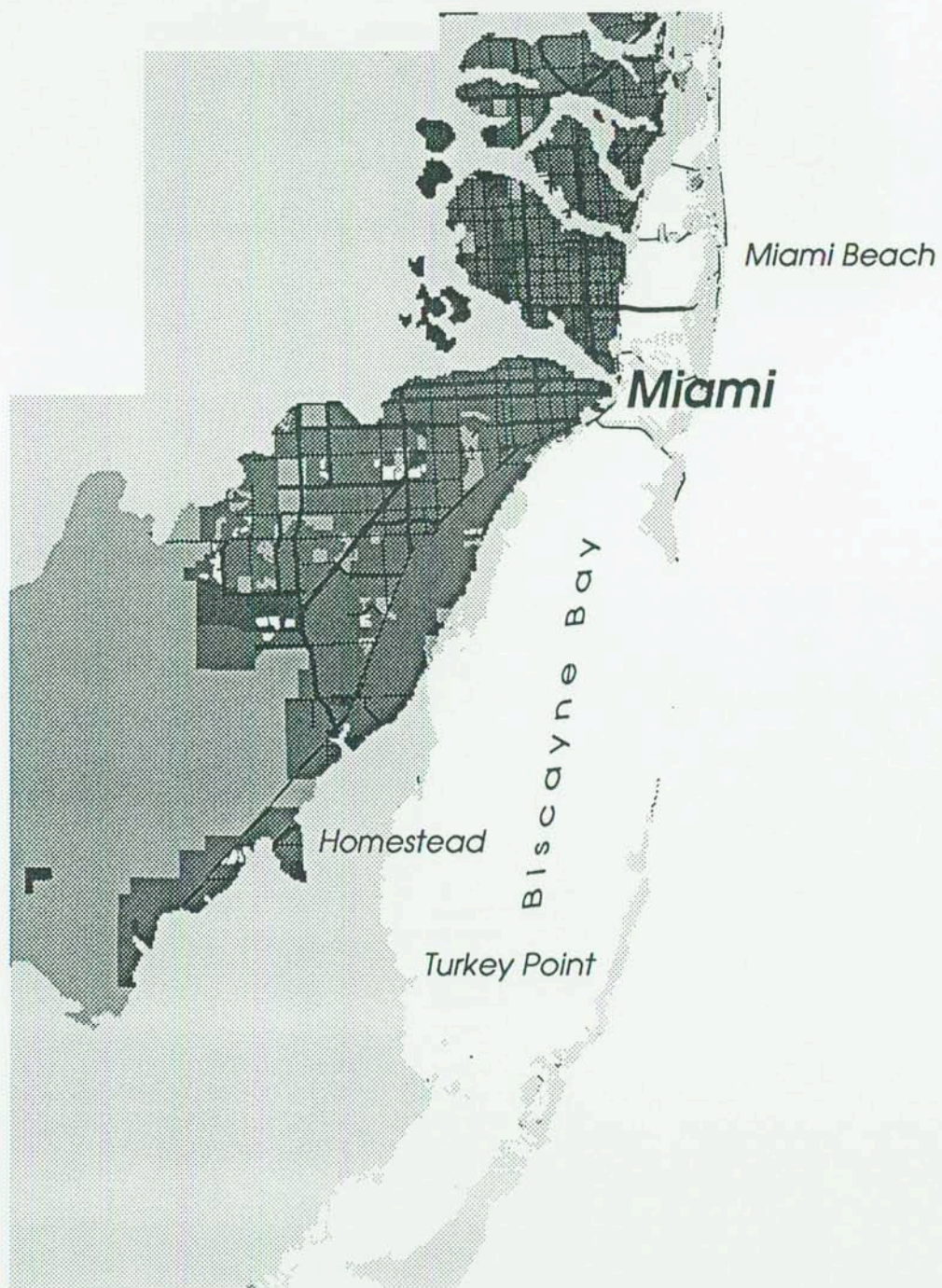| 0 | 2 | 4 | 6 kilometers |

Miami

Sea-Level + 200 cm

Miami Beach

Miami

Biscayne Bay

Homestead

Turkey Point

Residential

Industrial, Business

Agriculture, Open

Water

Sea-level rise

N

scale

0   2   4 miles

0   2   4   6 kilometers
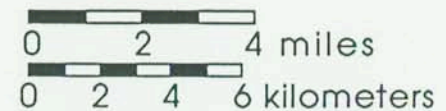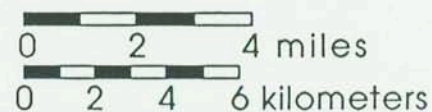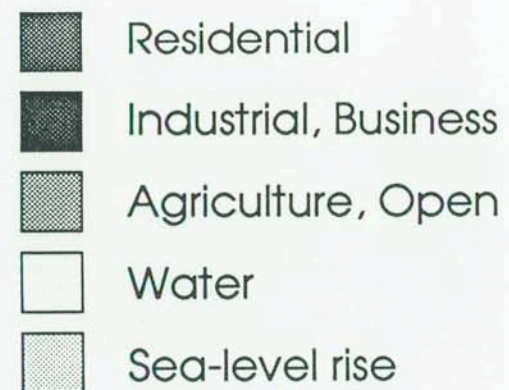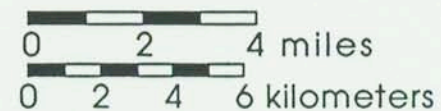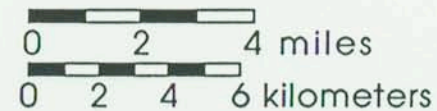
Crop Suitability: Uganda and Kenya

As stated above, the results of our case studies on climatic change impacts on crop suitablitiy can be only indicative.

In **Uganda**, the total area suitable for growing Robusta coffee would be dramatically reduced with a temperature increase of 2° Celsius (Fig. 6). Only higher areas, the Ruwenzoris, Southwestern Uganda and Mount Elgon would remain, the rest would become too hot to grow coffee according to our model. For a country depending on coffee as the main foreign exchange earner (Table 5), such a reduction would be fatal.

The overall area suitable for tea in **Kenya** would not be reduced by a warming of 2° Celsius, but existing plantations around Mount Kenya and the Aberdares would lie outside the tea-growing range (Fig. 7). In these areas, the tea belt would move upwards, where there are forests today, which indicates another potential future conflict. Kenya's main tea zone around Kericho would fortunately not be affected very seriously by the warming implied in our model.

What these case studies clearly show is the vulnerability of developing countries, whose economies rely heavily on one or two agricultural products. In the table below, export value figures for Kenya and Uganda are shown, just to indicate the level of dependency:

| country	total	agriculture	tea & coffee
Kenya	959 (100 %)	675 (70 %)	515 (54 %)
Uganda	470 (100 %)	434 (92 %)	422 (90 %)

in million US$
source: FAO 1986

Table 5: Value of Exports for Kenya and Uganda, 1985

One question to be taken into consideration in conjunction with climatic change impacts on crop suitability is the human ability of adaptation. Since the temperature increase takes place over a long period, crops might well be changed to resist the new conditions. However, human adaptation always has a certain cost and catastrophic meteorological events as a result of climatic change might cause unpredictable damages.

Today:
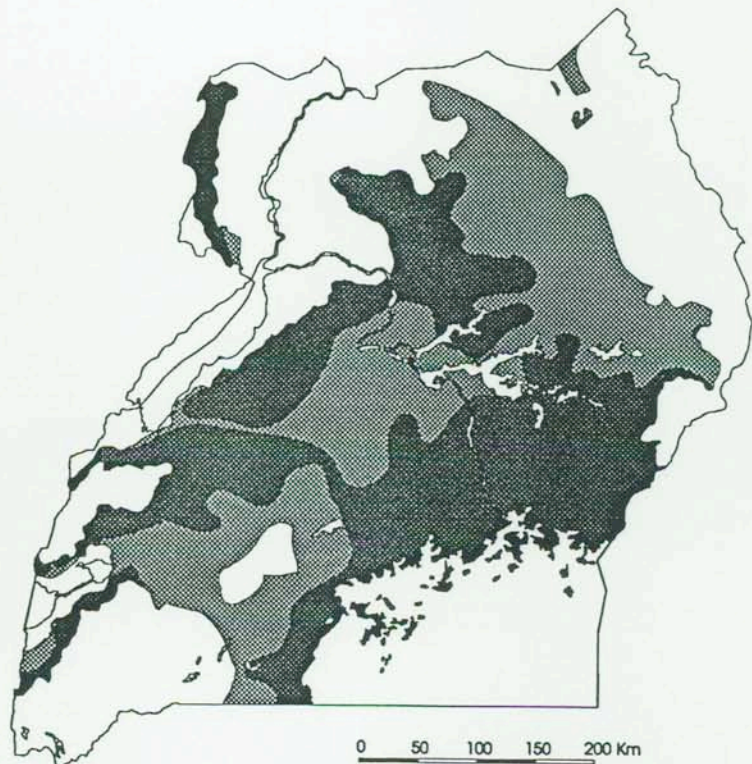
2 ° Celsius warmer

Ecological Suitability
ROBUSTA COFFEE

fair

good

0   50   100   150   200 Km

0   50   100   150   200 Km
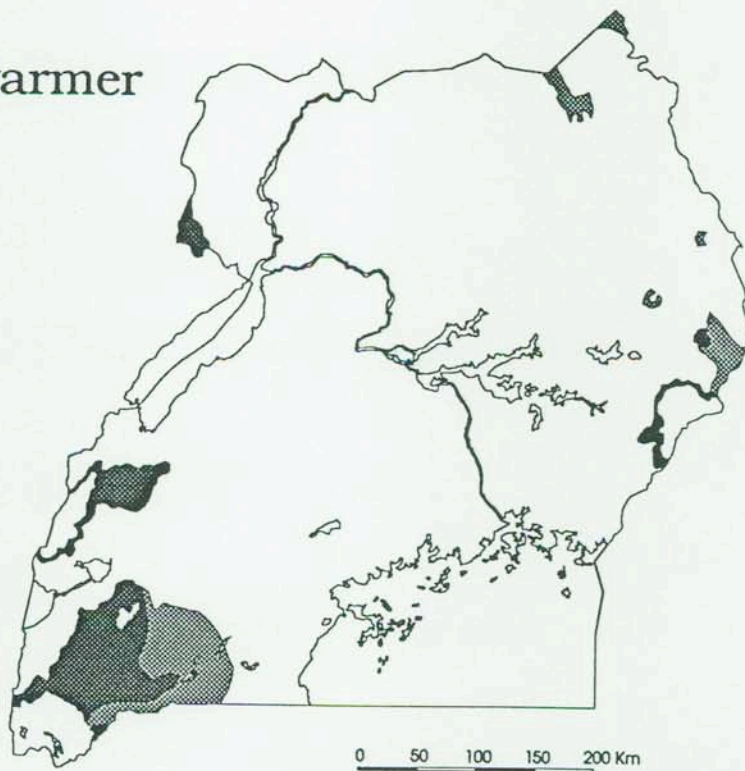
Fig. 5: Climatic Change Impact on Robusta coffee in Uganda

Tea: Today

Suitability
- fair
- good
- Plantation

Tea: + 2° C
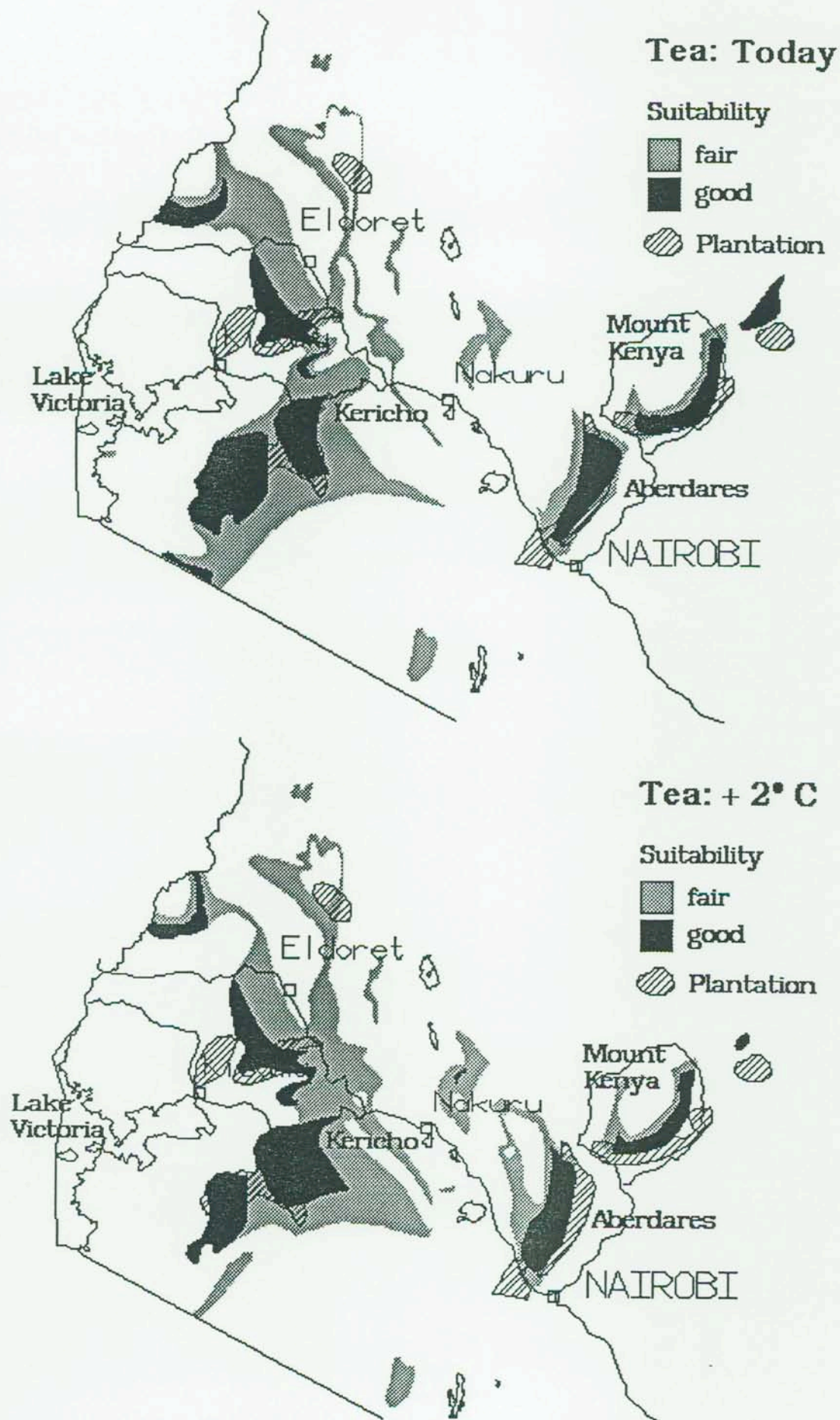
Suitability
- fair
- good
- Plantation

Fig. 6: Climatic Change Impact on Tea in Kenya

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CONCLUSIONS

The GRID case studies on climatic change clearly demonstrate that global warming can have very serious impacts, both on human settlements in coastal areas and on agricultural systems. They also clearly show the potential of Geographic Information Systems to conduct impact studies and, in particular, how such systems can be used to visualize scientific results. At the moment it's particularly important to create awareness amongst decision-makers as well as the public on the fact that with the on-going pollution we will create environmental problems for generations to come. Action is required now and we believe that the more people are aware of the problem, the better are the chances of it being solved.

However, these case studies also reveal a need for research. Our models, particularly the ones on crop suitability are too simplistic to give more than just a hint on what might happen to our environment. In order to be able to make more accurate predictions, far more variables have to be taken into account. A more interdisciplinary scientific approach to create models on climatic change impacts is required,with Geographic Information Systems, the technology to handle complex analysis is there.

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