9.8 VULNERABILITY OF WATER RESOURCES IN EASTERN MEDITERRANEAN ECOSYSTEMS DUE TO CLIMATE CHANGE - AN INTEGRATED APPROACH TO SUSTAINABLE MANAGEMENT

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1. GLOWA JORDAN RIVER

GLOWA Jordan River is part of a larger GLOWA project (www.glowa.org) to study critical drainage basins around the world. Current study areas besides the Jordan River are the Elbe, Volta, and Danube River basins, the Draa catchment, Morocco and Benin, Africa. The GLOWA Jordan River project focuses on one of the most critical regions with respect to sustainable water supply. The area has one of the lowest per capita water availabilities worldwide. The area is experiencing rising water demands, while available water is gradually decreasing. Climate scenarios for the Eastern Mediterranean, based on large-scale climate models, predict further aridification and increasing variability of regional precipitation. Surface water and groundwater resources have been reduced to record lows in the recent past, mostly due to increased usage and a prolonged drought period.

The upper catchment of the Jordan River (UCJR) is characterized by an elongate valley, 80 km long and 15-30 km wide, covering approximately 1600 km^2. The flow in the UCJR is continuous throughout the year. On average, the UCJR yields about 500x10^6 m^3/yr, which is about 25 percent of the total water budget of Israel. GLOWA Jordan River is structured along a north-south transect that covers the full range of regional climate and vegetation. It includes the major landscape units and components of the water management system, in particular the source region for water supply in the North, and the regions receiving water from transfers mostly for agriculture, i.e. the coastal plain in the West and the semi-arid and arid desert regions in the East and South of the country.

The Jordan River and much of the groundwater of the region are transboundary resources, requiring that strategies for sustainable management of the water resources be based on collaboration between the regional stakeholders.

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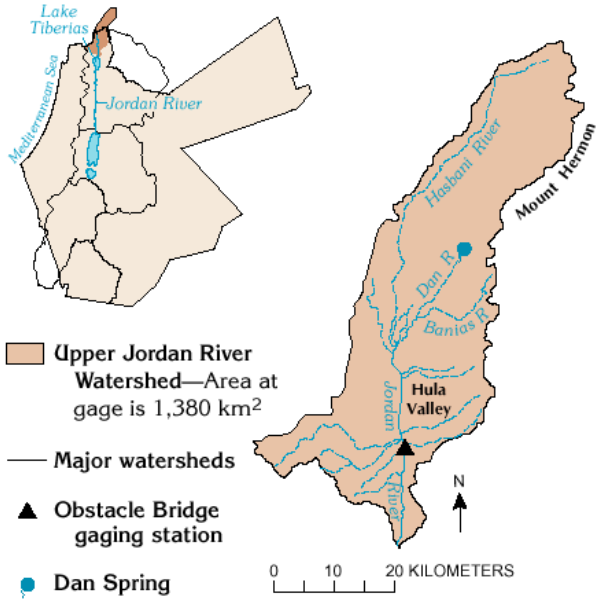


Figure 1 The upper catchment of the Jordan River Basin

1.1 *Objective*

GLOWA Jordan River is an inter- and multi- disciplinary study that addresses the vulnerability of water resources in the upper Jordan River catchment as a case study of eastern Mediterranean ecosystems in response to global change. It employs an integrated research approach, providing the scientific framework for sustainable management practices in the watershed of the Jordan River and other zones in the region. Ultimately results from GLOWA Jordan River should be transferable to other arid and semi-arid regions with transboundary water resources.

A comprehensive vulnerability assessment will be undertaken by the project, taking into account

- the range of environmental stresses and their combined effects

- the resilience of the regional ecosystems, and
- the adaptive capacity of regional socio-economic systems to changes in the hydrological cycle and water resources

1.2 *Scientific Approach*

Partners from a number of scientific institutions contribute information from a variety of sources, such as in-situ and remote sensing measurements, monitoring and manipulative experiments, census, questionnaires, modeling, etc. to a joint knowledge base. An integrated modeling framework is developed, in order to integrate the data, information and methods from a range of participating disciplines.

The project intends to model the complicated interaction among many aspects of the environment to better assess the impacts of change and the use of management policies.

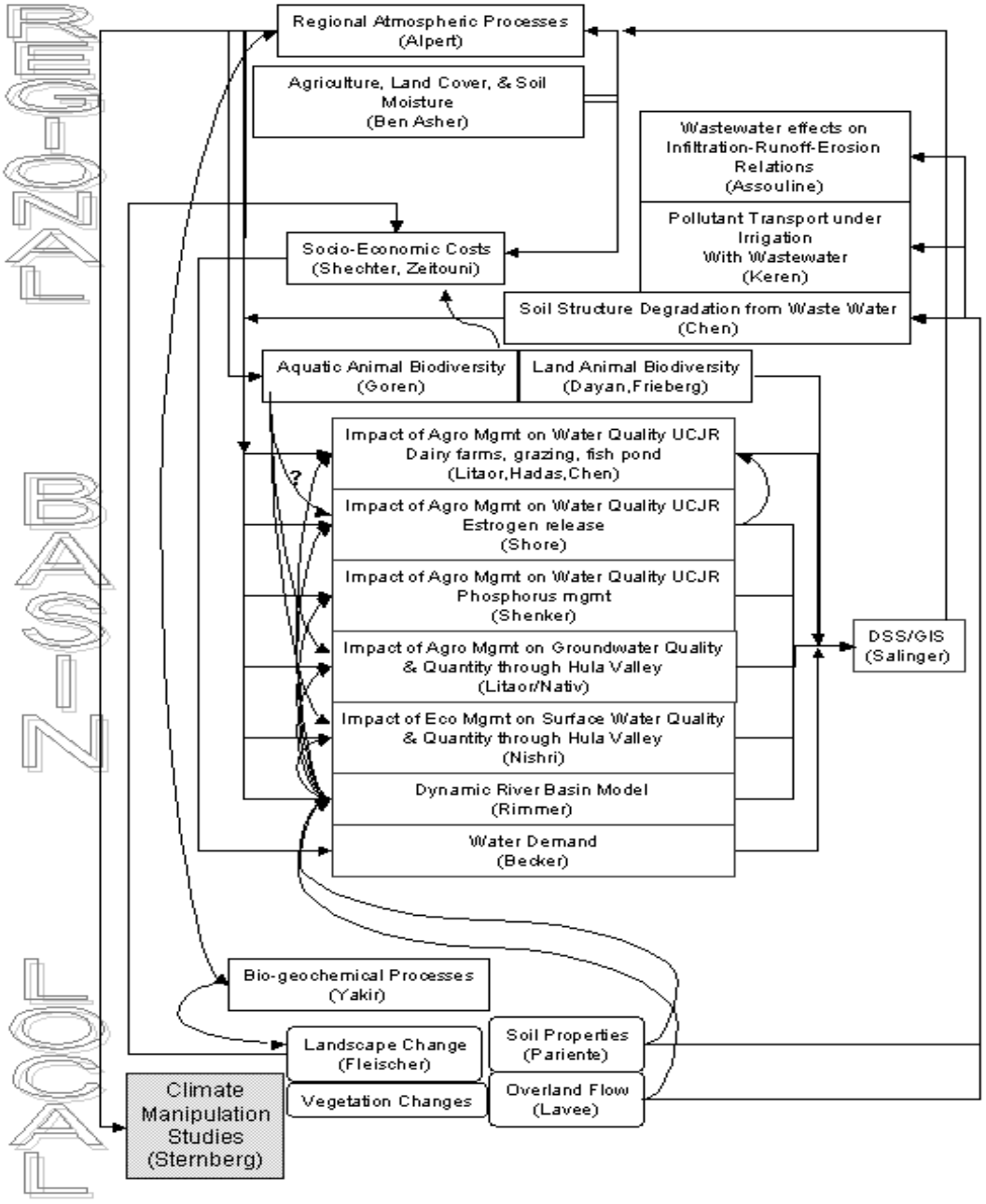


Figure 2 GLOWA Jordan River research project linkages

The main blocks of GLOWA Jordan River are

I. Global change - providing scenarios of how regional climate and land use can develop

II. Water resources - providing information on water availability and water quality under these scenarios

III. Ecosystems - assessing the responses of natural & semi-natural ecosystems with changing water resources and providing management options

IV. Agriculture - assessing the interactions of agriculture and irrigation with water resources and regional atmospheric processes and providing management options

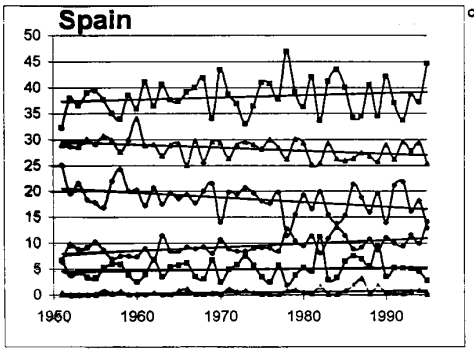
V. Integration and stakeholder participation - assessing the overall water situation of the region and providing decision support for integrated water resources management.

Extreme events, such as further severe drought spells will be a focus of the different simulations within these work packages.

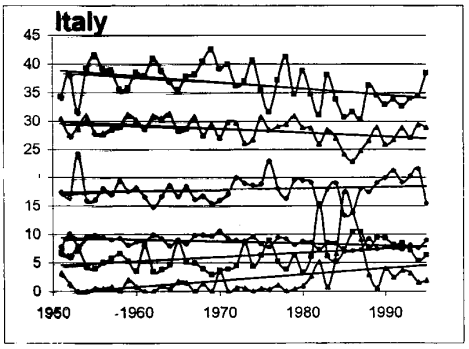
Potential and actual management strategies of water demand and water availability, will be part of the integrated assessment in GLOWA Jordan River, including e.g. seawater desalination, wastewater reuse, water imports, further improvements of water use efficiency in irrigated agriculture, or even substituting irrigated agriculture by other uses.

2. *THE PARADOXICAL INCREASE OF MEDITERRANEAN EXTREME DAILY RAINFALL IN SPITE OF DECREASE IN TOTAL VALUES* (Alpert, et.al., 2002)

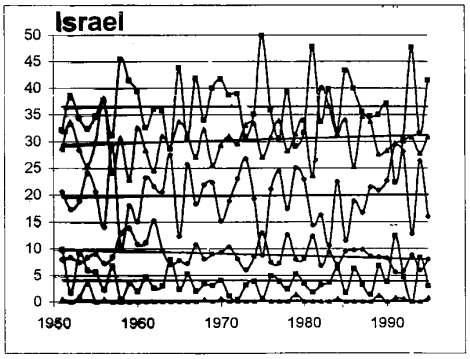
The redistribution of rainfall categories (torrential/heavy versus moderate/light intensities) are of particular interest in semiarid subtropical regions for water management, soil erosion, and flash flooding. A coherent study of the full-scale daily rainfall categories over the Mediterranean region to assess the extent of the paradoxical increase in extreme events while overall rainfall has decreased was performed. Regions around Italy and Spain showed significant increases, while the areas around Israel and Cyprus showed no significant trends (Figures 3 & 4).



CATEGORY	RAINFALL (mm/day)	TREND (SIG.)	SIGNIFICANCE OF MONOTONE TIME TREND
B	4-16	● +0.04 (0.253)	(0.333)
C1	16-32	↓ -0.059 (0.003)	(0.019)
C2	32-64	↓ -0.089 (0.004)	(0.021)
A	0-4	↑ +0.068 (0.000)	(0.0006)
D1	64-128	● +0.019 (0.367)	(0.744)
D2	128-UP	↑ +0.017 (0.017)	(0.0125)



B	4-16	↓ -0.1 (0.002)	(0.0027)
C1	16-32	↓ -0.06 (0.001)	(0.0093)
C2	32-64	● +0.025 (0.335)	(0.101)
A	0-4	↓ -0.035 (0.000)	(0.0008)
D1	64-128	↑ +0.07 (0.006)	(0.0086)
D2	128-UP	↑ +0.11 (0.005)	(0.0013)



B	4-16	● -0.00004 (0.999)	(+)(0.984)
C1	16-32	● +0.043 (0.318)	(0.336)
C2	32-64	● +0.011 (0.857)	(0.793)
A	0-4	● -0.044 (0.076)	(0.161)
D1	64-128	● -0.005 (0.861)	(0.883)
D2	128-UP	● -0.005 (0.501)	(+)(0.763)

Figure 3 The contributions (as a percentage from the total annual amounts) of each of the defined daily rainfall categories for the period 1951-1995. The non-linear time trends were tested for significance using Spearman's rank correlation. A natural separation among the categories contributions for all 3 countries is evident. Class B (light-moderate) is the most common with 34%-39% of the rainfall events, down to class D2 (highly torrential) with less then 5% of the events. In Spain and Italy the D-categories (torrential) increased, while the central C-categories decreased. No significant trends were observed in Cyprus or Israel. The slopes of the trends (%/year) along with their statistical significance level are shown. (Alpert, et.al. 2002)

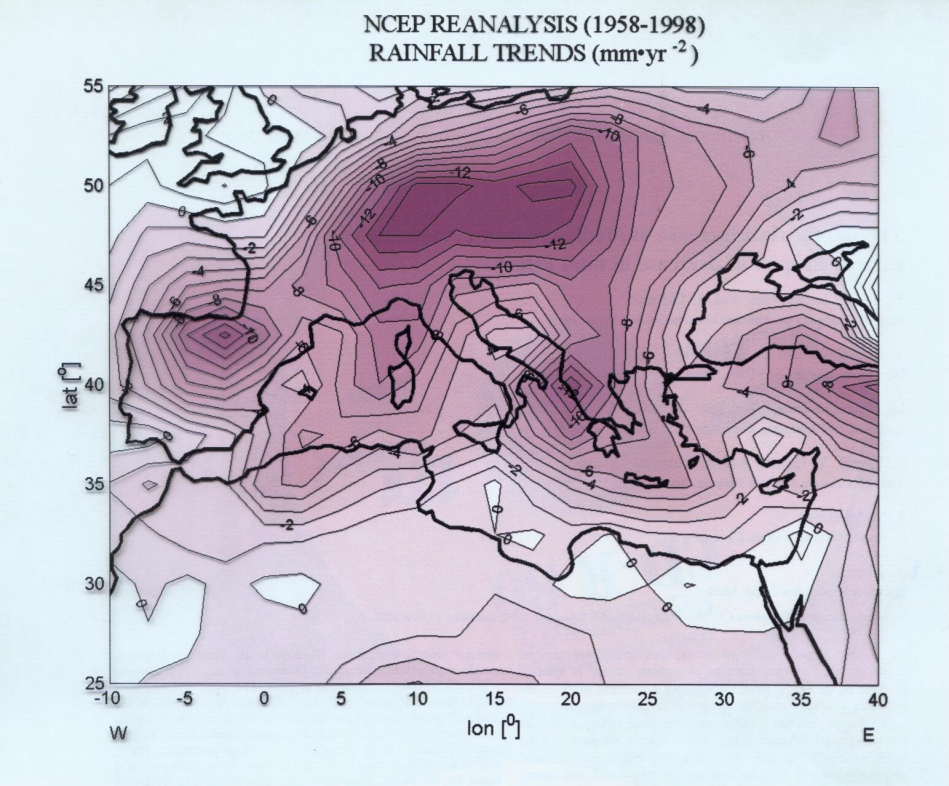


Figure 4 While many global climate models forecast an overall increase in rainfall due to climate change, a study of the rainfall trends over the Mediterranean region shows a generally decreasing trend in the rainfall over the 40 year study period. This difference will have a significant impact in the management practices adopted in the Mediterranean region versus other regions of the world.

3. *Temporal and Spatial Trends in Temperature Patterns in Israel* (Ben-Gai, et.al. 1999)

Recent studies have shown that a small shift in the location of a frequency distribution of a climatic variable can result in a relatively large change in the probability of extreme events. An analysis of 40 stations in Israel revealed a complex, changing pattern. A decreasing trend in both the daily maximum and minimum temperature during the cold season, and an increasing trend during the warm season was observed. A significant decline of the air temperature diurnal range was also observed in both seasons. The frequency of occurrence of extreme temperature events, with lower winter and higher summer temperatures, has increased (Figure 5).

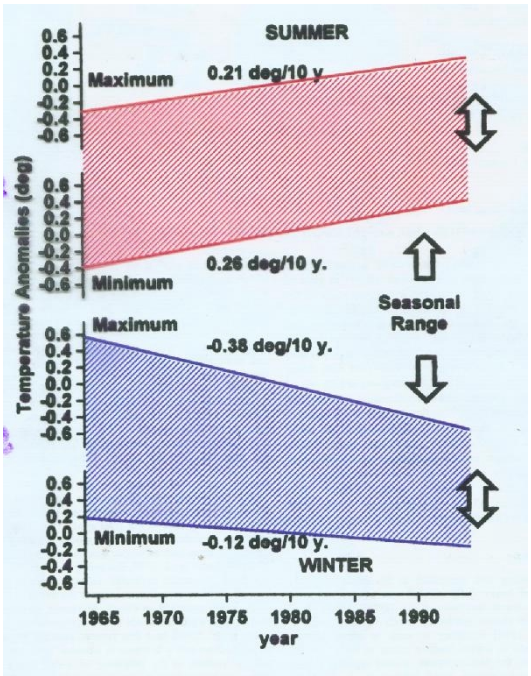


Figure 5 Fitted serial regression for the median Tmax and Tmin for the cool and warm seasons 1964-1994

4. Trends in Objectively-Classified E. Mediterranean Synoptic Systems, 1948-2000

Objective classification of daily 1200 UTC synoptic situations was carried out by employing a discriminant-like analysis of the NCEP reanalysis data over the Eastern Mediterranean (EM) for the period 1948-2000. The annual number of the mostly dry Red-Sea Trough synoptic system was found to significantly increase since the 1960s from 50 to about 100 days per year. This can explain a dominant decreasing trend of rainfall in many of the EM countries along with an increase over S. Israel region. Also, the increasing tendency towards heavier daily rainfall in spite of the general decrease in the totals, may be explained by the increase in the active and stormy Red Sea Trough situations. The annual frequency of Cyprus Low system was also noticed slightly dropping in 1983-1998 to 26 as compared to about 30 during 1967-1982. These tendencies seem to fit the high positive correlation between the recent increase in the North Atlantic Oscillation (NAO) index and the pressure over Israel (Figure 6).

5. Quantitative Assessment of Land-Use Modifications on Convection and Rainfall
(The following section is a short summary of Perlin and Alpert (2001))

To quantitatively evaluate the effects of different land-surface conditions in semi-arid and arid central-southern Israel on convection and convective precipitation. During the fall transition period, monthly October rainfall was found to increase in the last few decades, and was attributed to the anthropogenic land-use changes that had taken place over the same area. Three different surface conditions are modeled to examine the relative influence of land-use changes:

- present-time land-use, "REAL",
- pre-irrigation time, "DRY", and
- progressive irrigated agriculture "AGRI" case.

Numerical mesoscale atmospheric model (MM5/PLACE) simulations of the convective rain case studies, focused over the investigated part of Israel, showed good agreement with the surface observations including the precipitation values and timing. Advanced detailed analysis of the rainfall field and the associated convective properties of the atmosphere (as CAPE) resulted with the following conclusions. Modifying surface parameters from semi-arid land surface conditions toward the cultivated lands tend to consistently increase the potential for moist convection during the daytime heating hours. This, in turn, can lead to the convective precipitation amplification in the noon and the afternoon (08-17 LST), as have resulted in model experiments, upon the favorable weather conditions. In the evening and at night larger scale features seem to be responsible for the rainfall variation. Moreover, 2-dimensional spectral analysis was employed to examine the model-resolved precipitation. This method revealed the recurrent structure of the rain spells primarily in the northeast-southwest direction. As appears from the power spectra plots, replacement of the natural vegetation by the CULTIVATED lands was featured in greater contribution of the rain spells with smaller periods into the total variance. This suggests the increase of convective rainfall driven by local surface forcing during the day, independently of the larger-scale rainfall.

Another interesting result is that as soon as more irrigated agricultural areas are introduced into the simulated domain, the 2-d autocorrelation function for the 24-h accumulated rainfall becomes more stretched in the prevailing wind direction. At the same time the shape of the same function for the 9-hour daytime precipitation not differ much for the "DRY" and "AGRI". The important implication of this autocorrelation analysis is the reduced spottiness of the total rainfall field, while the clear increase in precipitation is detected only for the daytime rainfall.

6. REFERENCES

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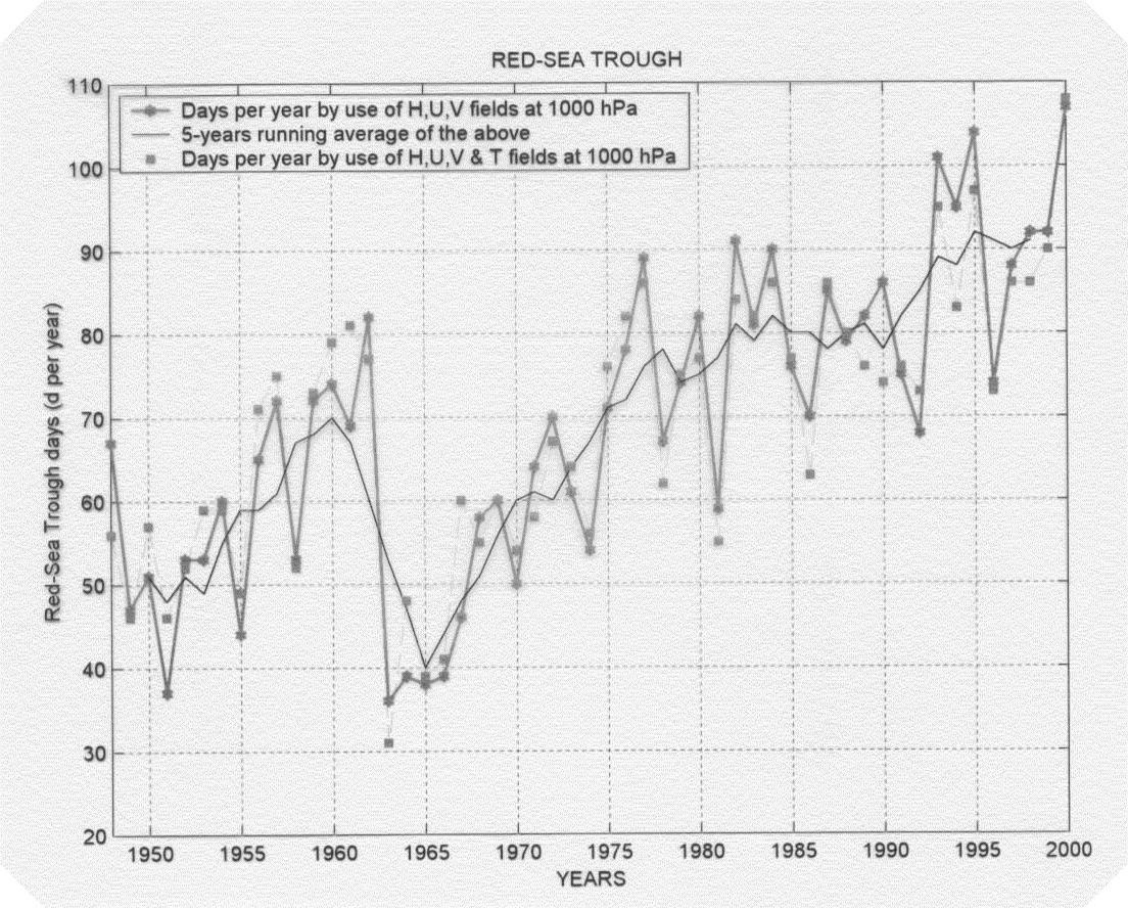

Figure 6 The occurrences of the Red-Sea trough is generally increasing, corresponding to the decreasing trend of rainfall over many eastern Mediterranean countries and an increase over southern Israel. The increase in heavier daily rainfall in spite of the overall decrease in totals may be explained by the increased frequency of the Red Sea trough.