ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/312119863

Animal Biodiversity, In: Katja Tielbörger, Cornelia Claus, Daniela Schloz (Editors) GLOWA Jordan River – An integrated approach to sustainable management of water resources under g...

Book · January 2013

CITATIONS
0

READS
36

3 authors, including:

Mohammed saleem Ali-shtayeh
Biodiversity and Environmental Research Center

273 PUBLICATIONS **3,078** CITATIONS

SEE PROFILE

Tamar Dayan
Tel Aviv University

208 PUBLICATIONS **7,644** CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:

Project Arab Society for Fungal Conservation View project

Project The micromammal fauna and paleoenvironment of Manot Cave, Israel View project

All content following this page was uploaded by Mohammed saleem Ali-shtayeh on 06 January 2017.

The user has requested enhancement of the downloaded file.

Final Report

Phase III

Jordan River

GLOWA

GLOWA Jordan River

An integrated approach to sustainable management of water resources under global change

Eberhard-Karls-University of Tübingen, Germany, in collaboration with:

Karlsruhe Institute for Technology (IMK-IFU Garmisch-Partenkirchen), Stockholm Environment Institute, University of Bochum, University of Freiburg, University of Hannover, University of Heidelberg, University of Kassel, University of Potsdam, Leibniz Centre for Agricultural Landscape Research (ZALF) Müncheberg

Arava Institute for Environmental Studies, Ben-Gurion University, Haifa University, Hebrew University of Jerusalem, Israel-Palestine Center for Research and Information (IPCRI), Kinneret Limnological Laboratories, Mekorot, STAV-GIS, Tahal, Tel Aviv University, Tel-Hai College, Volcani Center, Weizman Institute

Arab Technologist for Economical and Environmental Consultations (ATEEC), Ministry of Water and Irrigation, Mu'tah University

Al-Quds University, An-Najah National University, Association for Integrated Rural Development, University of Bethlehem, Biodiversity & Environmental Research Center, House of Water and Environment, Ministry of Agriculture, Palestinian Hydrology Group, Palestinian Water Authority

Project period
01.01.2009 – 31.12.2012

Support code (FKZ)
01LW0501A1

Editors
Prof. Dr. Katja Tielbörger, Dr. Cornelia Claus, Daniela Schloz

The GLOWA Jordan River project is part of a larger research initiative launched by the German Federal Ministry of Education and Research under the title "Global Change and the Hydrological Cycle".

www.glowa-jordan-river.de
coordination@glowa.uni-tuebingen.de

SPONSORED BY THE
Federal Ministry of Education and Research

Index of content

Abbreviations

A	An arid site near Sde Boqer, Israel
AOGCM	Atmospheric-Ocean Global Climate Model
AVHRR	Advanced Very High Resolution Radiometer
D	Drainage below the root zone
DJF	December, January, February
E_I	Canopy interception
EM	Eastern Mediterranean
EOF	Empirical Orthogonal Function
E_S	Soil evaporation
E_T	Transpiration
ET	Evapotranspiration
F	Subsurface flow
FAO	Food and Agriculture Organization of the United Nations
FW	freshwater
GCM	Global Climate Model
GHG	Greenhouse Gases
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GLOWA	Globaler Wandel im Wasserkreislauf
ICTP	International Centre of Theoretical Physics
IMK-IFU	Institute of Meteorology and Climate Research - Atmospheric Environmental Research
IPCC	International Panel of Climate Change
IWD	Irrigation Water Demand
JJA	June, July, August
JRR	Jordan River Region
JRSP	Jordan Red Sea Project
LAI	Leaf Area Index
LJRB	Lower Jordan River Basin
LSU	Life Stock Unit
M	a Mediterranean site near Matta, Israel
MAM	March, April, May
MAP	Mean annual precipitation
MAR	Managed Aquifer Recharge
MCM	Million cubic meter
MH	Modest Hopes (SAS Scenario)
MM	a mesic Mediterranean site near Ein Ya'akov, Israel
MWI	Jordanian Ministry of Water and Irrigation
NDVI	Normalized Differenced Vegetation Index
NGO	Non Governmental Organization
NPA	Israeli National Parcs Authority
ORN	Observed Rainfall Niche - the observed distribution of a species with respect to rainfall conditions, also called rainfall preference group in this report
P	Precipitation
PDI	Palmer Drought Index
PET	Potential Evapo-Transpiration
PHG	Palestinan Hydrology Group
PP	Poverty & Peace (SAS Scenario)
PWA	Palestinan Water Authority
Q	Runoff
R	Correlation coefficient
RC	Runoff Coefficients

RCM	Regional Climate Model
RSDSC	Red Sea-Dead Sea canal
RWH	Rain Water Harvesting
SA	a semi-arid site near Lahav, Israel
SAS	“Story and Simulation” scenario approach/method
SEB	Sustaining Environmental Baseflow
SON	September, October, November
SPI	Standardized Precipitation Index
SRI	Standardized Runoff Index
SWE	Suffering of the Weak and the Environment (SAS Scenario)
T	Transpiration
TWW	Treated wastewater
UJV	Upper Jordan Valley
USLE	Universal Soil Loss Equation
WA	Willingness & Ability (SAS Scenario)
WEAP	The “Water Evaluation and Planning” tool
WUEE	Water use efficiency of the ecosystem
θ	Soil moisture

1 Introduction

GLOWA Jordan River (GLOWA JR) is an international, interdisciplinary and transdisciplinary project which is part of a larger research initiative launched by the German Federal Ministry of Education and Research (BMBF, www.bmbf.de) under the title "Global Change and the Hydrological Cycle" (GLOWA) (www.glowa.org). GLOWA JR began in 2001 with its first phase; the second phase started in 2005; the third in 2009. The project ended in 2012. This document presents the results of the third and last phase of GLOWA JR but is strongly based on the findings of the preceding phases.

1.1 Overall goal

According to the BMBF guidelines the GLOWA projects provide "simulation tools and instruments to develop and realize strategies for sustainable water management" under global change. Apart from that, GLOWA JR provides scientific support for improved water and land management in the highly water stressed Jordan River region. Its central question is: How can the benefits from the region's water be maximized for humans and ecosystems, under global and climate change?

Phase I of GLOWA JR mainly focused on experiments, data collection and therefore provided new process understanding and a wealth of new water and land related data and information for specific locations (see Final Report of phase I at http://dx.doi.org/10.2314/GBV:513241132).

Phase II relied more strongly on modeling for improving scenarios of global change impacts on social and natural systems, for upscaling results from field measurements to basin scale. It built a framework for analyzing region-wide questions about global change and water resources. This framework consisted of two main components/integration tools:

- A scenario building process in which experts from the region and Germany interacted with stakeholders from the region. This interaction produced four "regional development" scenarios describing how global change could affect development in the Jordan River region up to 2050.
- Regional and sub-regional versions of the WEAP (Water evaluation and planning tool) model were developed which describe the current water resource situation in the region. These model versions were co-developed with experts in the region and are now being used for further analyses.

In addition, several other subprojects in Phase II elaborated the green-blue water concept which integrates land and water management. In contrast to phase I, these studies relied more heavily on modeling than on site-specific data collection and mostly applied a region-wide approach. They addressed different aspects of land use and water use in the region in a manner compatible with the integration tools. Information from these subprojects contributed directly and indirectly to the scenario-building exercise and the development of the regional and sub-regional WEAP models. (See Final Report of phase II at http://dx.doi.org/10.2314/GBV:61187508X).

Phase III was devoted to further developing and applying the two integration tools and to filling gaps in the scientific knowledge. Its main goal was to develop new, science-based strategies and adaptation options for coping with the impact of global and regional change on regional water and land resources, and to communicate these to the key stakeholders in the region. The main product of Phase III is an integrated assessment of global change effects on the regional water resources and, based on this assessment, recommendations for adaptation options and strategies for sustainable water management under change, as well as decision-support tools.

Phase III was steered by the overarching question: Under expected global change - to what extent can conjunctive blue and green water resources contribute to future water needs in the region?

To make the overarching question tractable we divided it into three guiding sub-questions:

- The "New Water" Question – Under expected global change – How can various "new" (blue) water sources contribute to future water resource needs of the region?

- The “Land Use” Question – Under expected global change – To what extent can land use planning, i.e. green water management, contribute to sustainable water management under different scenarios?
- The “Climate Extreme” Question. – What will be the effect of climatic extremes on the regional water balance and sustainable management of water resources in the region?

1.2 Structure

GLOWA JR phase III consisted of different subprojects which were explicitly designed to interact with the scenario building integration tool (see chapter 2) and to deliver data to WEAP and/or produce data in GIS format (see chapter 3 and 1.5). Several subprojects were merged under four thematic projects, each addressing a different aspect of water management under global change or integrating these aspects to answer three central questions (see Figure 1.1).

The four themes are as follows:

- **Integration, application and dissemination**, dealing with the integration of scientific results of all phases, with developing integrated strategies for sustainable water and land management under global change, and with dissemination of the results to stakeholders and the scientific community.
- **‘New’ (blue) water sources**, where existing information on the most important sources of blue water have been collected to be systematically analyzed within the other themes to alleviate water scarcity and their side effects and attain sustainability, e.g. in WEAP or SAS. The data was obtained from phase II results and from existing results of other water-related scientific and applied projects in the region.
- **Green water management**, where we have continued our successful focus on the role of land management in sustainable water management under global change. As pointed out above, this theme is unique within the regional IWRM context in that the explicit role of open space (‘nature’) and other land uses in water management is addressed systematically, and services produced by water in ecosystems and agriculture are traded-off against each other.
- **Regional water balance**, where we have finalized our regional climate scenarios and subsequent effects on the regional water balance by means of existing models. Consistent with the needs of the stakeholders, refinement of models was done with a focus on extreme climatic events, in particular, series of drought years.

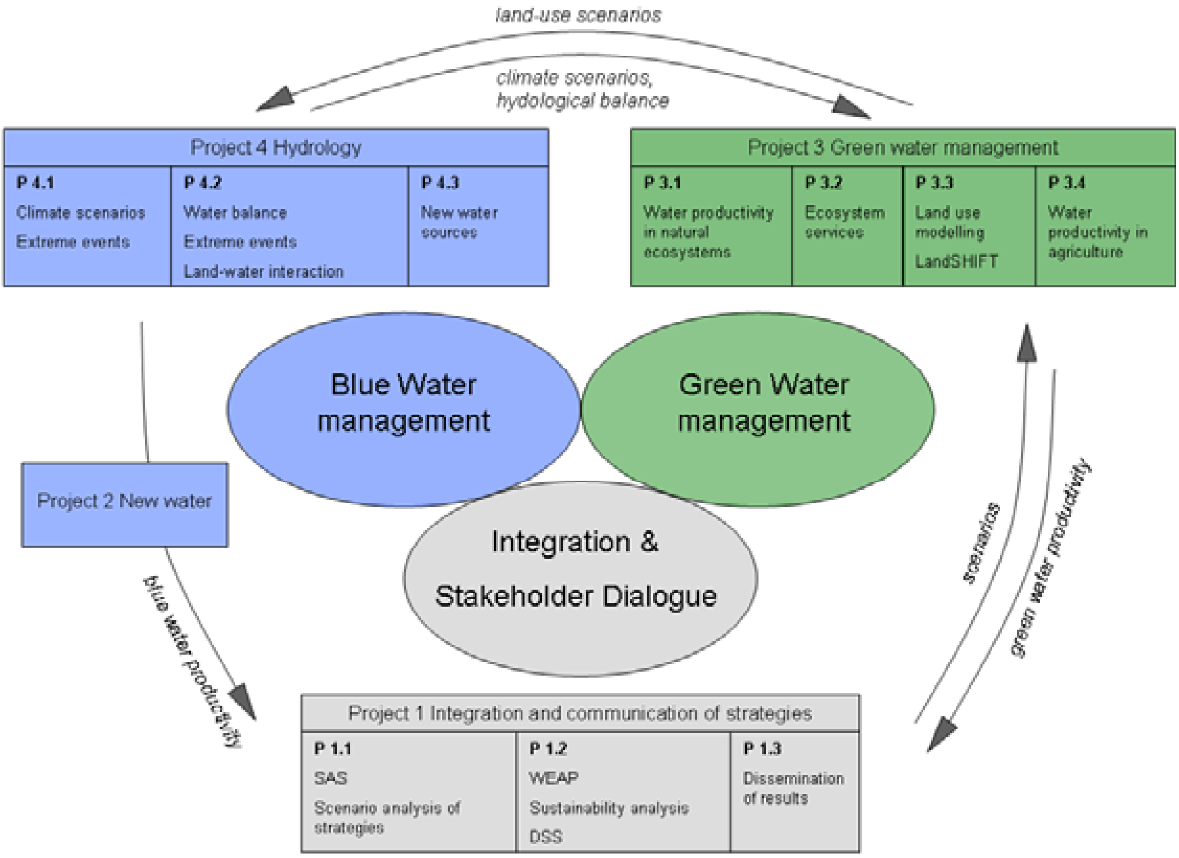


Figure 1.1: GLOWA JR phase III project structure (only main links shown) with the four themes feeding into three central tasks. The numbers of the projects refer to the proposal of phase III. The three core questions are addressed by the main integration tools (see chapter 2 and 3, project 1): The so-called New Water Question is addressed by the projects described in chapter 2, 3, 9 and 13, projects 1, 2, 4.3, 3.4); the Land Use Question is mainly addressed by chapter 5, 6, 7, (project 3); the Climate Extreme Question is mainly addressed by chapter 11 and 12 (projects 4.1 and 4.2).

1.3 Project Partners, their roles and activities

In Table 1.1 the principal investigators of phase III are listed according to their research activities and specific overall project tasks/roles like project leader, project coordination, scientific coordination and steering committee. In addition, the most important stakeholders that were involved in phase III are listed in Annex 6.

The scientific coordination was responsible for the integration of information from all subprojects into the integration tools, and led the continuous interaction with stakeholders on the regional adaptation and application of these tools and the overall project results for bridging between science and water / land management and policy making. The scientific coordination was in charge of the internal project structure and the research direction. Furthermore, they were responsible for building a network with other activities in the region and beyond.

The steering committee's mandate was to take major decisions about overall direction and structure of the project, as well as for the flow of information within the project in the partner countries. In addition the extended steering committee (not listed in the table) consisted of the steering committee and selected stakeholders from German (GIZ), Israel (Water Authority, Ministry of Environment), Jordan (MWI, Ministry of Agriculture), and the Palestinian Authority (PWA, PHG, Ministry of Agriculture, Ministry of Planning).

Table 1.1: Principal investigators within GLOWA JR phase III according to their roles and activities.

	Principal Investigators
Project leader & Project coordination	K. Tielbörger, Univ. of Tübingen, Dept. of Plant Ecology
Scientific coordination	Prof. Dr. Katja Tielbörger, Univ. of Tübingen, Dept. of Plant Ecology Prof. Dr. Pinhas Alpert, Tel Aviv Univ., Dept. of Geophysics and Planetary Science Prof. Dr. Anan Jayyousi, An-Najah National Univ., Water and Environmental Studies Inst. (WESI), Nablus Prof. Dr. Amer Salman, Univ. of Jordan, Dept. of Agricultural Economics and Agribusiness, Amman
Steering Committee	Tielbörger K, Univ. of Tübingen, Dept. of Plant Ecology Alpert P, Tel Aviv Univ., Dept. of Geophysics and Planetary Science Dayan T, Tel Aviv Univ., Dept. of Zoology Hoff H, Stockholm Environment Inst. (SEI), Stockholm Jayyousi A, An-Najah National Univ., Water and Environmental Studies Inst. (WESI), Nablus Lange J, Univ. of Freiburg, Inst. of Hydrology Salman A & Karablieh E, Arab Technologist for Economical and Environmental Consultation (ATEEC), Amman Shechter M, Univ. of Haifa, Natural Resource & Environmental Research Center (NRERC) Simon K-H, Univ. of Kassel, Center for Environmental Systems Research (CESR) Twite R, Israel/Palestine Center for Research and Information (IPCRI), Environment and Water Dept., Jerusalem
Scenario analysis, SAS – Story and Simulation Approach	Simon K-H & Onigkeit J, University of Kassel, Center for Environmental Systems Research (CESR), Kassel Aliewi A, House of Water and Environment, Ramallah Alpert P, Tel Aviv University, Dept. of Geophysics and Planetary Science Dayan T, Tel Aviv University, Dept. of Zoology Dreizin J, Consultant to the Water Authority, Tel Aviv Jarrar A, Palestinian Water Authority, Ramallah Jayyousi A, An-Najah National University, Water and Environmental Studies Inst. (WESI), Nablus Nofal I, Ministry of Agriculture, Ramallah Salman A, Arab Technologist for Economical and Environmental Consultation (ATEEC), Amman Schwarz J, TAHAL Consultants, Tel Aviv Subah A, Ministry of Water and Irrigation, Amman Tamimi A-R, Palestine Hydrology Group (PHG), Jerusalem Twite R; Israel/Palestine Center for Research and Information (IPCRI), Environment and Water Dept., Jerusalem

WEAP - Water Evaluation and Planning Tool	Bonzi Ch, Univ. of Tübingen, Dept. of Plant Ecology Hoff H, Stockholm Environment Inst. (SEI), Stockholm Abu Saada M, Palestine Hydrology Group (PHG), Jerusalem Aliewi A, House of Water and Environment, Ramallah Dreizin J, Consultant to the Water Authority, Tel Aviv Jarrar A, Palestinian Water Authority, Ramallah Jayyousi A, An-Najah National Univ., Water and Environmental Studies Inst. (WESI), Nablus Joyce B., Stockholm Environment Inst. (SEI), Boston Lange J, University of Freiburg, Institute of Hydrology Lipchin C, Arava Inst. for Environmental Studies, D.N. Hevel Eilot Litaor I, Tel Hai Academic College, Dept. of Environmental Sciences, Upper Galilee Nofal I, Ministry of Agriculture, Ramallah Rimmer A, Israel Oceanographic and Limnological Research, The Lake Kinneret Limnological Laboratory, Migal Salinger Y, STAV-GIS Ltd., Rakefet Salman A, Arab Technologist for Economical and Environmental Consultation (ATEEC), Amman Schwarz J, TAHAL Consultants, Tel Aviv Seder N, Jordan Valley Authority Subah A, Ministry of Water and Irrigation, Amman
(Eco-) Hydrological modelling, Rainwater harvesting, Managed aquifer recharge, Water productivity in agriculture	Lange J, Univ. of Freiburg, Inst. of Hydrology Menzel L, Univ. of Heidelberg, Professorship for Physical Geography Almasri M, Jayyousi A, Shaheen H, Shadeed S, An-Najah National Univ., Water and Environmental Studies Inst. (WESI), Nablus Berliner P & Ben-Asher J, Ben Gurion Univ. of the Negev, Jacob Blaustein Inst. for Desert Research, Wyler Dept. of Dryland Agriculture, Sede Boqer Campus Grodek T & Morin E, Hebrew Univ. of Jerusalem, Dept. of Geography Oroud I, Mu'tah Univ., Faculty of Social Science, Dept. of Geography, Karak Yakir D, Weizmann Inst. of Science, Dept. of Environmental Sciences and Energy Research (ESER), Rehovot
Land use modelling	Schaldach R & Koch J, Univ. of Kassel, Center for Environmental Systems Research (CESR)
Regional climate scenarios	Smiatek G & Kunstmann H, Karlsruhe Inst. of Technology, Inst. for Meteorology and Climate Research, Atmospheric Environmental Research Divison (IMK-IFU), Garmisch-Partenkirchen Krichak S O & Alpert P, Tel Aviv Univ., Dept. of Geophysics and Planetary Science, Tel Aviv
(Semi-) Natural ecosystem modelling and management Animal & plant biodiversity	Tielbörger K, Univ. of Tübingen, Dept. of Plant Ecology Ali-Shtayeh M S, Biodiversity & Environmental Research Center (BERC), Nablus Dayan T, Tel Aviv Univ., Dept. of Zoology Geissler K & Jeltsch F, Univ. of Potsdam, Research Group Plant Ecology & Nature Conservation, Potsdam Kigel J, Hebrew Univ. of Jerusalem, The Robert H. Smith Inst. of Plant Science and Genetics in Agriculture, Rehovot Malkinson D, Univ. of Haifa, Dept. of Geography and Environmental Studies Prasse R, Univ. of Hannover, Inst. of Environmental Planning Saleh A, Al-Quds Univ. Abu Deis, Dept. of Biology, Jerusalem Sternberg M, Tel Aviv Univ., Dept. of Molecular Biology and Ecology of Plants

Ecosystem services and socio economy	DiSegni D & Shechter M, Univ. of Haifa, Natural Resource & Environmental Research Center (NRERC) Fleischer A & Kan I Hebrew Univ. of Jerusalem Dept. of Agricultural Economics and Management, Rehovot Hijawi T, Association for Integrated Rural Development (ARID), Ramallah Salman A, Karablieh E, Majdalawi M, Arab Technologist for Economical and Environmental Consultation (ATEEC), Amman
Land evaluation for effluent reuse	Marschner B, Ruhr-Univ. Bochum, Dept. of Soil Science and Soil Ecology Abed Rabbo A, Univ. of Bethlehem, Water & Soil Environmental Research Unit (WSERU) Almasri M, An-Najah National Univ., Water and Environmental Studies Inst. (WESI), Nablus Chen Y & Tarchitzky J, Hebrew Univ. of Jerusalem Dept. of Soil and Water Sciences, Rehovot Salman A & Karablieh E, Arab Technologist for Economical and Environmental Consultation (ATEEC), Amman

1.4 Capacity Building

A large number of activities related to building capacity, either technically or scientifically, was implemented in phase III. Table 1.2 lists most of the workshops that were organized by GLOWA JR and some selected workshops where results of the project were presented. The workshops organized by GLOWA JR were not scientific workshops; they were either technical workshop dealing with WEAP or Scenario analysis workshops with scientists and stakeholders.

Table 1.2: Workshops organized by GLOWA JR and other workshops where GLOWA JR results were presented.

Theme of Workshop/Seminar	Location	Date	Type of Audience	No. of Participants
4th GLOWA JR Scenario Panel Meeting	Amman, Jordan	20 June 2009	Decision makers, policy advisors, technicians, NGO representatives, researchers, students	24
4th GLOWA JR Scenario Panel Meeting	Ramallah, West Bank	22 June 2009	Decision makers, policy advisors, technicians, NGO representatives, researchers, students	30
4th GLOWA JR Scenario Panel Meeting	Tel Aviv, Israel	24 June 2009	Decision makers, policy advisors, technicians, NGO representatives, researchers, students	28
5th GLOWA JR Scenario Panel Meeting	Weilburg, Germany	26-28 October 2010	Decision makers, policy advisors, technicians, NGO representatives, researchers	28
6th GLOWA JR Scenario Panel Meeting	Königstein, Germany	14-16 June 2011	Policy advisors, technicians, NGO representatives, researchers	29
Scientific input meeting	Amman, Jordan	17 January 2010	Researchers, policy advisors, technicians, students	9
Scientific input meeting	Ramallah, West Bank	19 January 2010	Researchers, policy advisors, technicians, students	12
Scientific input meeting	Tel Aviv, Israel	21 January 2010	Researchers, policy advisors, technicians, students	26

Theme of Workshop/Seminar	Location	Date	Type of Audience	No. of Participants
Scientific input meeting	Kassel, Germany	29-30 March 2010	Researchers, students	16
WEAP Training and Application Workshop.	Amman	Nov. 2007	Scientists, authorities	25
Two day WEAP workshop for the Palestinian Water Authority and Ministry of Agriculture.	An Najah University	August 2010	Mainly authorities, some scientist	15
WEAP workshop for Middle Eastern water practitioners.	Arava Institute	June, 2011	Authorities, NGOs and scientists from all three countries	20
WEAP training for students	An Najah University, Nablus	2009/2010 /2011	Students, Scientists	> 100
WEAP training	Arava Institute, Kibbutz Ketura, Israel	2009/2010 /2011	Students, Scientists, and stakeholders from all countries	> 100
WEAP training for students	WERSC, University of Jordan	2009/2010 /2011	Students, Scientists	> 100
WEAP training workshop conducted at the MWI under the supervision of A. Omari (GLOWA) and GIZ	Amman	2009/2010 /2011	Governmental Authorities	10
Mediterranean Climate Change	Tel Aviv	2011	GLOWA JR Scientists and Stakeholders	50
Changes of organic matter in soils irrigated with reclaimed wastewater	ISEEQS, Rehovot	29.5.2005	scientists, stakeholders	65
Effects of effluent irrigation on the carbon dynamics in soils of the Middle East	EM Water, Amman	30.10.2006	scientists, engineers, stakeholders	70
Water and conflicts in the Middle East	RUB, Bochum	annually since 2007	students	150
Water scarcity and irrigation potentials	An Najah National University, Nablus	1.4. 2009	students	25
GIS-gestützte Ableitung der Landnutzungseignung für die Bewässerung mit geklärtem Abwasser in Israel und dem Westjordanland	DBG, Bonn	10.9.2009	scientists	50
Dynamics of soil organic carbon and microbial activity in treated wastewater irrigated agricultural soils along soil profiles	IWRM, Karlsruhe	10.1.2010	scientists	80
Land evaluation for irrigation with treated wastewater	IWRM, Karlsruhe	10.1.2010	scientists	80

Theme of Workshop/Seminar	Location	Date	Type of Audience	No. of Participants
Effects of effluent irrigation on physical, chemical and biological properties of soils in the Middle-East	Galilee Society, Nazareth	7.3.2011	scientists, students	15
Benetzungshemmung nach Abwasserbewässerung in Israel - Bestimmung des Repellency Index mittels Mini-Disk-Infiltrometer	DBG, Berlin	6.9.2011	scientists	80
Risk assessment as a tool in effluent reuse management: Soil suitability for treated wastewater irrigation in the Middle East	IWRM, Dresden	12.10.2011	scientists	20
Soil sensitivity and suitability assessment for wastewater reuse: Case study Middle East	RE Water, Braunschweig	21.11.2011	scientists, stakeholders	30

A major component of this activity was capacity building through which young scientists from the region and Germany were trained in the innovative tools and methodologies used for analyzing global change and water / land resources.

During the three phases of GLOWA JR 52 PhD, 75 MSc, 13 Diploma and 11 BSc Theses have been concluded (see list of theses in Annex 2). The candidates represent a considerable knowledge capacity which is available in the three countries. Many of them are now employed by governmental institutions and thus represent a sustainable legacy of GLOWA JR in the region.

1.5 Outreach / Communication of results

The wealth of scientific and applied results about global change effects and adaptation options in the water and land management sector produced within GLOWA JR were made available to stakeholders and the scientific community. The main dissemination tools were SAS and WEAP, and details can be found there. However, there were many more dissemination activities: the GLOWA JR Atlas, two policy briefings series, the GLOWA JR website, the GLOWA JR portal within the publication server of the University of Tübingen, different radio and television reports about the project direct meetings with stakeholders, the GLOWA JR final conference, scientific publications etc.

The GLOWA JR Atlas

The GLOWA JR Atlas is the first publicly accessible transregional and transdisciplinary end-user GIS for the Jordan River region and it presents the spatial results of the project. Maps about climate change and its impact on water and land resources can be seen as well as the impact of regional change and climate change on ecosystem services, land use and agriculture. Moreover maps about the potential of rainwater harvesting, managed aquifer recharge, irrigation with treated wastewater can be downloaded. The results depicted in some maps are driven by the quantified scenario assumptions of the scenario analysis excersise (e.g. results of the land-use model LandShift) or drive the scenarios such as e.g. the results of the regional climate models and the hydrological model TRAIN.

The atlas is online available at http://www.glowa-jordan-river.de/OurProducts. Here it can be either launched online or the offline version can be downloaded and stored on DVD, USB or hard disc. The atlas will be published at the GLOWA JR portal (http://tobias-lib.uni-tuebingen.de/portal/glowa), where it will get a permanent identifier and be citable. Further information about the atlas is available in the GLOWA JR Atlas Briefing at the GLOWA JR portal.

Briefings and other published products

To give a general idea to the broad public about the project a flyer about GLOWA JR was developed and printed (see http://www.glowa-jordan-river.de/uploads/Main/GLOWA_JR_Flyer.pdf)

There have been two briefings series, a first one in 2009/10 and a second in 2013. The aim of the briefings is to summarize and present in an understandable way the results of the project concerning the effects of climate, global and regional change in the Jordan River basin. The target audience is stakeholders like policy and decision makers, as well as the broad public. The first briefings series was printed and distributed either by mail or handed out. They are available online at http://www.glowa-jordan-river.de/OurProducts/Briefings. In Table 1.3 the briefings of the first series are listed.

Table 1.3: First GLOWA JR Briefings Series (2009/2010) (first edition), see www.glowa-jordan-river.de/OurProducts/Briefings.

No.	Authors	Title of briefing
1	J. Onigkeit	Scenarios of regional development under global change for the Jordan River basin
2	H. Hoff	WEAP – A decision Support Tool for the Jordan River
3	A. Heckl, H. Kunstmann	Climate change in the Jordan River region
4	P. Alpert	The atmospheric moisture budget over the Eastern Mediterranean- past and future
5	F. Wimmer, J. Koch, R. Schaldach.	What about land-use change?
6	J. Lange	A basin-wide view on the variability of water resources
7	A. Rimmer	Hydrological modelling of the Upper Jordan River and Lake Kinneret
8	A. Fleischer	The economic impact of climate on Israeli agriculture: Will warming be harmful?
9	A. Salman, E. Al-Karablieh	Socio-economics of water allocation in Jordan
10	I. Kan	Economic analysis of global and climate change impacts on agriculture in Israel
11	B. Marschner	Land suitability for irrigation with treated wastewater
12	R. Prasse	Intercropping arable land with perennial plants is economically rewarding
13	K. Tielbörger	Allocation of more water for nature is economically rewarding
14	M Köchy	Climate and grazing impacts on natural grasslands
15	S. Bangerter	Grazing cessation-Restoring rangelands in the face of climate change
16	I. Sivan, Y. Salingar, A. Rimmer, R. Sade	Water Evaluation and Planning Tool (WEAP) for Lake Kinneret (Tiberias) Basin
17	P. Alpert	Climate modelling of the Eastern Mediterranean at Tel Aviv University
18	L. Menzel	Impact of environmental change on the water resources
19	M.N. Almasri, M. Abu-Baker	Assessment of the effects of irrigation using untreated wastewater on soil properties
20	S. Shadeed, A. Jayyousi, H. Shaheen	Hydrological modeling in a typical arid catchment: Wadi Faria, West Bank, Palestine

The second GLOWA JR Briefings series is a re-edition of the first one actualizing the first briefings as well as incorporating new briefings. Since follow up activities are taking place new briefings are being still published online at the GLOWA JR portal also after phase III (see http://tobias-lib.uni-tuebingen.de/portal/glowa). In Table 1.4 the already published or planned briefings of the second series are listed. This second edition is a major final product and an important part of this summary report.

Table 1.4: Second GLOWA JR briefings series (2013) (second edition). Since follow up activities are taking place also beyond phase III an actualized list can be seen at http://tobias-lib.uni-tuebingen.de/portal/glowa.

No.	**Authors**	Title of briefing
1.1	J. Onigkeit	Scenarios of Regional Development under Global Change
1.2	J. Onigkeit	Strategic Development of Water Resources for the Jordan River Basin
1.3	G. Smiatek	Predicting climate change in the Jordan River region using Regional Climate Models
1.4	C. Claus, A. Braun, A. Rysavy, K. Tielbörger	The GLOWA Jordan River Atlas
2.1	C. Bonzi	The Water Evaluation and Planning Tool (WEAP): An Overview
2.2	C. Bonzi	A Regional Water Evaluation and Planning (WEAP) application for the Jordan River basin
2.3	R. Sade, Y. Salinger, M. Denisyuk, A. Rimmer	Water management in a complex hydrological basin: Application of WEAP to the Lake Kinneret watershed
2.4	E. Al-Karablieh, A. Salman	Evaluating the impacts of the Red Sea - Dead Sea Canal on the Amman-Zarqa and Jordan River basins: Using WEAP to measure future scenarios under climate change conditions
2.5	A. Jayyousi	The Water Evaluation and Planning Tool (WEAP). Application for the West Bank
2.6	M. Abusaada	Projecting water availability within the Western Aquifer Basin: WEAP-MODFLOW Coupling
2.7	L. Menzel	A view on current and future water resources
2.8	A. Gunkel, J. Lange	Modeling water resources and variability in the Lower Jordan River Basin: Learning from the present for the future
2.9	T. Törnros, L. Menzel	The duration and frequency of drought under a changing climate
2.10	Jens Lange, Anne Gunkel	The Renaissance of an Ancient Technique: Rain Water Harvesting Potentials in the Lower Jordan River Basin
2.11	B. Marschner, K. Schacht	Land suitability for irrigation with treated wastewater
3.1	E. Al-Karablieh, A. Salman	Socio-economy of water allocation in Jordan
3.2	I. Kan, A. Fleischer, M. Rapaport-Rom, M. Shechter	How can land-use be adapted to climate change? An economic analysis for Israel
3.3	W. Siewert	Plant species cannot escape climate change but may be less vulnerable than previously thought
3.4	M. Bilton	Grazing cessation – More supporting evidence for a rangeland management strategy in the face of climate change
3.5	P. Berliner, A. Arazi & J. Ben-Asher.	Future change in irrigation demand for main crops in the Upper Jordan Valley
3.6	A. Arazi	The impact of future climate change on Wheat yields

Moreover an html-document has been developed which gives a detailed overview of the results of the scenario process including the development of water strategies in the region. The document can be accessed via the GLOWA JR portal (http://tobias-lib.uni-tuebingen.de/portal/glowa).

The GLOWA JR website

The GLOWA JR website (www.glowa-jordan-river.de) presents the aims, a short description, the list of scientific publications and the team of the project and its subprojects. Furthermore the presentations and posters presented during the different status conferences as well as the final conference are downloadable (http://download.glowa-jordan-river.com). Besides the different results of the public relations activities are available (http://www.glowa-jordan-river.de/OurProducts), like the first briefings series (see below), the GLOWA JR Atlas (see below), the GLOWA JR ecosystem management expert system (see below) etc. Moreover links were made to radio and television reports about the project (http://www.glowa-jordan-river.de/News), like the documentary about GLOWA JR by the German Television (ZDF) entitled "Kampf ums Wasser" (www.zdf.de/ZDFmediathek/#/beitrag/video/1698974), which was broadcasted on August 12, 2012 (http://www.glowa-jordan-river.de/News/2012-07-26-PlanetE).

The GLOWA JR portal

The library of the University of Tübingen offers to publish electronically generated and qualified documents on its online publication system. After publication, the texts and tools are available open access worldwide on the internet and will be archived permanently by the library. The documents are indexed and made accessible in library catalogues and web search engines. Therefore a GLOWA JR portal (http://tobias-lib.uni-tuebingen.de/portal/glowa) was setup where the transdisciplinary publications of the project are published as well as other information about the project. With the GLOWA JR portal we make sure, that the results of the project are publicly available and easily searchable also beyond the GLOWA JR website. Apart, the GLOWA JR portal publications have permanent identifiers and can be easily cited what is not the case with documents presented on the GLOWA JR website. The fact, that the transdisciplinary GLOWA JR results can be cited is very important for the authors of these.

The GLOWA JR Atlas, the second edition of the GLOWA JR briefings, the GLOWA JR ecosystem management expert system, the GLOWA JR scenario homepage etc. are or will be published at the GLOWA JR portal.

The GLOWA JR Final Conference

From 5 to 8 September 2011 the Final Conference took place in Limassol, Cyprus. More than 100 persons attended and there was active participation of high-ranking stakeholders from Israel, Jordan and the Palestinian Authority, and representatives form the GIZ and the EU. The results of the project were presented in different ways either via oral presentations, poster trains or within a "tools marketplace", were each tool had a stand where the participants could get the needed information. The program, list of participants, the posters and presentations as well as pictures are available on http://www.glowa-jordan-river.de/Conference.

Scientific publications

The scientific publications of the three phases of GLOWA JR can be seen in Annex 1. 312 articles in peer reviewed journals and 27 books or book chapters with results of the project were written.

Direct meetings with stakeholders

Direct meetings between the project scientists of the region and the stakeholders are an efficient way of disseminating detailed policy relevant information to stakeholders. This direct contact ensures scientifically sound recommendations, and continuation of dissemination of project results and further development of information beyond the duration of the project. Apart of presenting project results within the Scenario Panel Meetings (see Table 1.2) the project scientists organized a series of one-on-one meetings with key stakeholders in the region like the following:

- High level workshop to discuss the use of WEAP as a central planning tool with the Jordanian Ministry of Water and Irrigation, 2009.
- The West bank WEAP for the four scenarios has been prepared and tested and results were

presented to the Palestinian Water Authority and the Palestinian Ministry of Agriculture, 2009, 2010, 2011.

- Discussion with the Planning Department of the Israeli Water Authority on the potential and use of WEAP in water planning by means of the regional WEAP, 2010, 2011.
- Presentation and discussion of Jordan Valley WEAP model and results with the Jordanian Ministry of Water and Irrigation and the Jordan Valley Authority. Institutional implementation of the model, 2011.
- Several presentations and discussions of the results and models to analyze the effects of climate and land use change on natural ecosystems and to develop guidelines for land use management with the Israeli Nature Parks Authority (Y. Shkedy, Chief Scientist) and the Israeli Ministry of Environment (Y. Bar-Or, S. Netanyahu; Chief Scientists), 2009-2012.
- Many discussions about different items concerning the project with Prof. Uri Shani, Water Commissioner, and with Dr. Amir Givati, Israeli Hydrological Service, 2009-1012.
- Presentation of Climate Change data and results at DAWASSA, Damascus, Syria on the 09.01.2010 and at the KfW, Frankfurt, Germany, 10.12.2011.
- Meeting about regionalizing data about water availability and climate variability and the possibility of using this information for decision support with the "Wasserwirtschaftsverband Baden-Württemberg, 11.05.2012.
- Regular meetings with the Jordanian Ministry of Water and Irrigation presenting the results of the rainwater harvesting evaluation, 2010-2012.
- Discussions about the GLOWA JR Atlas with Gabriel Weinberger (Israeli Hydrological Service), Karen Assaf (Water consultant in the Palestinian Authority), Issam Nofal (Palestinian Ministry of Agriculture), Ali Subah (Jordanian Ministry of Water and Irrigation), 2011-2013.
- Several discussions about evidence-based decision making in policy and strategy and policy making while integrating ecosystem services and biodiversity conservation. Discussions about linking applied agricultural research on biodiversity with agricultural extension programmes, with the Ministry of Agriculture, National Agriculture Research Center (NARC), Policy Department, Agriculture Extension Department, Plant Protection Department of the Palestinian Authority, 2011-2012.
- Several presentations of GLOWA JR results in a forum held with a cooperation between the World Bank and the Ministry of Agriculture (Jordan) regarding blue water availability in Jordan following climate change.
- Land use changes in the Jordan Valley and its impacts were addressed and discussed with policy makers. Relative impacts of climate change on water resources and stress in Jordan between 2030-2050 was discussed with the Jordanian Ministry of Water and Irrigation and Ministry of Agriculture; 2011.

Distribution of the WEAP model and its data

Within GLOWA JR a series of WEAP applications were implemented on different levels. These implementations were developed in cooperation with stakeholders and results were presented in stakeholder-workshops or in the scientific community. The WEAP applications implemented exclusively within the GLOWA JR project were:

- **Regional level**: Transboundary WEAP application covering resources and demands connected to the Jordan River Basin in Israel, Jordan and West Bank Palestine.
- **Israel**: (1) WEAP simulations for the upper catchments of the Jordan River under various precipitation and evaporation scenarios. (2) WEAP simulations of evaporation and salinity for Lake Kinneret. (3) Water balance model for the Lower Jordan.
- **Jordan**: WEAP implementation for the Jordan Valley and Amman-Zarka basin addressing climate change and large scale water management options.
- **Palestinian Authority**: Three constantly updated implantations using 11, 25 and 89 demand

nodes for the West Bank. Additional WEAP implementation in Tulkarem and for the Jerusalem Water Undertaking.

The regional and national WEAP models will help decision makers in the region to understand the water (management) system and will provide important results to water managers. This will be on the topic of water management issues and adaption options in general, as well as on water available from the RSDSC project, on environmental impacts, on aquifer management in the West Bank, on the efficiency of green and blue water management and on the restoration of the lower Jordan River.

Other ways of disseminating results

The findings of the research dealing with assessing the effects of climate change and land use change on natural ecosystems as well as the simulations for ecosystem management resulted in the development of an online version of an ecosystem management expert system tool comprising a Bayesian Network of summarized simulations. This preliminary tool is temporarily available at http://www.hed.cc/webQ.jsp?a=glowap&n=NPA4.neta and can also be accessed via the GLOWA JR homepage (http://www.glowa-jordan-river.de/OurProducts). It is planned to publish this tool at the GLOWA JR portal.

Furthermore the findings within ecosystem response to climate and land use change and the contacts with stakeholders yielded a research proposal that was co-designed with stakeholders from the environmental sector in Israel, Jordan, and the Palestinian Autonomy, and that dealt with ecosystem service evaluations and applications in an era of land use change. Though the proposal was not funded, it serves as the basis for future common research activities with stakeholder buy-in. Due to the GLOWA JR findings there is a potential for other projects between the Tel Aviv University with Ministry of Environment and the Water Authority, were some seed money became available.

The results of the project were presented in a lot of international and national conferences, meetings and seminars.

In addition most of the GLOWA JR researchers present their results in their personal homepages or in the homepages of their institutions. Examples are the homepage of Prof. Pinhas Alpert, http://www.tau.ac.il/~pinhas/ or the one of Prof. Lucas Menzel, as well as the Homepages of the Center for Environmental Systems Research and the Department of Geography at Heidelberg University, where individual project homepages, including links to the official GLOWA Jordan project pages, have been installed and maintained.

1.6 Synthesis of scientific key results

Regional climate change scenarios

The RCM runs are the first of their kind for the Eastern Mediterranean. The simulations of climate change yielded in four highly resolved RCM simulations and five ensembles of RCMs with different climate scenarios. Most scenarios yielded a decrease in rainfall and an increase in temperatures, and a possible increase in the frequency of extreme events. The elevation dependency of the climate change signal was illustrated.

Furthermore an important aspect of all findings regarding climate change impacts is that all impact studies in GLOWA JR were able to utilize downscaled climate scenarios instead of uncertain large-scale GCMs. This is a unique feature of this project and enhances the credibility and robustness of all climate impact studies conducted within the GLOWA JR project compared to most other climate impact studies world-wide.

Integration and application

The WEAP analysis has reached a new consensus database and a basin-wide WEAP tool. This regional WEAP application has been used to identify and present the influence of projected climate change on the water management system. It was also used to visualize the four SAS scenarios resulting from the scenario analysis and the respective changes in and challenges for water management.

Further the five main sub-regional WEAP applications in GLOWA JR have led to a better understanding of local and regional elements of the water cycle, in particular:

- the hydrological system of the upper and lower Jordan River basin,
- the modeling of lake salinity and evaporation in Lake Kinneret with WEAP,
- future irrigation management in the Jordan Valley under climate change,
- the development of water use and water sources until 2050 in the West Bank,
- groundwater management under climate change for the Western Mountain Aquifer.

Green water and land management

The simulations about the **response of vegetation** to climate change and different management options showed that overgrazing is a major risk, since resilience of vegetation to climate change breaks down before the stocking capacity is reached. There are no changes in structure and composition of the vegetation expected due to the future increase in extreme climatic events if the systems are not grazed.

Another issue of concern was a potential change in the frequency of wildfires under climate change. Daily temperature and wind speed are the critical parameters dictating wildfire spread. Since their current annual distributions are not significantly different from predicted future distributions, wildfire hazards are not expected to alter due to climate change.

A key result from both a scientific as well as applied point of view is the apparently high resistance of the plant communities inhabiting semi natural ecosystems to climate change. In addition to this finding on a system level, we have developed a novel scheme of classifying species into those more responsive to climate change and species less responsive, so-called ORN (observed rainfall niche) groups that are based on the current distribution pattern with respect to rainfall. This scheme is remarkable because it is both very effective and very simple. Namely, we could show that species currently inhabiting drier regions will increase in abundance in currently wetter regions when climate changes. Though this may seem intuitive at a first glance, this finding is important because models that suggested such a response have been heavily criticized. An intriguing finding in that context was also that when looking at the response of the ORN groups to grazing, the dry-adapted species were most sensitive to grazing; indicating that a combination of grazing and climate change may be fatal for those species that would be most resistant to climate change. These findings also have an important applied aspect in that through the classification of species into groups of different vulnerability, managers and stakeholders will be able to set conservation priorities, and they will need to think carefully about future stocking rates.

Another important finding that emerged only due to the long study period provided by GLOWA JR is that different approaches to studying climate change effects on natural ecosystems yielded different and even contradictory results. The most relevant approach through experiments yielded a relatively large resistance of the systems to change, where correlative approaches (e.g. comparisons of ecosystem properties along the climate gradient or through time) would suggest a high responsiveness of the systems to changes in rainfall. When going into more detail but looking at longer time scales by using plant demographic rates for parameterizing demographic models, the suggestion of 'high resistance' was supported in that extinction probabilities of many component species appeared rather small, albeit more so in the wetter sites and, surprisingly, in the most arid site. Thus, modeling approaches, when based on robust field data, can complement experiments for studying climate change effects on ecosystems. Our most detailed approach was to study evolutionary response in main component species to our experiments. Here, the findings are equivocal in that some species appeared to have evolved into 'better' adapted types during only ten years of manipulations, while other species showed no response or an opposite pattern. Our findings are very important because correlative approaches (e.g. spatial gradients) account for the vast majority of climate impact studies in ecology, and have thus had large impact on the IPCC reports. Our results indicate that these approaches may not even provide a rough approximation of climate change effects on natural ecosystems. In the case of Eastern Mediterranean to arid ecosystems, these approaches (e.g. adopted by the IPCC) greatly overestimate the vulnerability of these highly diverse ecosystems to climate change, and thus may lead to potentially costly and unnecessary management efforts.

The socio-economic results of the project show that in Israel long-term losses stem from increases in crops' input requirements and changes in the inter and intra-annual distribution of precipitation. Therefore, these vulnerable points were identified as the main potential targets of further research and development efforts. Apart from that, a regional scale model named VALUE (Vegetative Agricultural Land Use Economic) to effectively estimate the impacts of changes in vegetative agriculture was developed. The objective of VALUE was to simulate the behavior of farmers under changes of climate conditions (precipitations), the availability of irrigation water and different prices and limitations of water. Such changes can be attributed to processes of climate change, global change (like trade conditions), technological improvements, and others. The VALUE model was developed and calibrated for Israel's 21 "ecological" regions. In each region the model incorporated 45 crops and calculated the allocation of land among those 45 crops, as well as the allocation of freshwater, treated waste-water and brackish water. In the first stage, the model was calibrated in order to represent the land and water allocations observed in 2002 (the base year of the analysis). It was assumed that these allocations maximized the farming profit. In a second stage, the VALUE model was updated for assessing climate change impacts on vegetative agriculture based on farmers' adaptations through water and land-use management strategies.

In Israel, the value of supporting services was carried out using a simple macroeconomic growth model that was extended to include the impact of climate change on the natural stocks within the system. The model (MEVES model) integrates into a specific growth model the impact of changes in natural stocks that are associated with non-market services. Within this model, the average value of marketed ecosystem services (like grazing, tourism) was fixed, and mainly associated with its market values. The value of non-market goods provided by natural stocks (like green biomass, soil deposition, and plants' seeds) was associated with the impact of the stock on the optimal path of social growth.

In Israel, the value of the ecosystem services was carried out using two main models: the first model used the reintroduction costs in order to calculate the value of the damaged caused by climate change and human interference and the other model used characteristic valuation methods of biodiversity loss. Based on data of the Water Authority and NPA, we concluded that since there were over-extraction of water from different wells, especially Ein Izrael well (part of Harod river), different plant species had been extinct.

For Jordan, the water demand from agriculture likely responds to increasing water prices in a quite inelastic manner over a long interval, as long as the planning of cropping patterns is based on the expectation of average results only. If planners consider risk, however, even marginal increases of the water price will change the production structure, reduce agricultural production and initiate negative impacts on the supply situation and the living standards of the local rural population. It may be expected that raising water prices under the existing cropping pattern would lead to a mixture of effects from both scenarios. Discussions on the allocation of water between the different sectors of society on the basis of pricing mechanisms will have to consider the substantial impacts on market supply in terms of quantity and variety of agricultural products.

For Jordan, the impact of climate change on the optimal growth path has been evaluated to be about 0.35% of GNI along the period 2000-2010. This estimation is based on an average impact of climate change effect on natural stocks that are considered to provide a large range of ecosystem services. These include (i) Plant seed number and diversity; (ii) Extinction risk of certain species; (iii) Stocking capacity as function of climate change; (iv) Green biomass production; (v) Plant cover. Also, from the biodiversity assessments, we conclude that climate change and human interference damage the biodiversity and the ecosystem services flow. There is a need for social planner intervention for sustainable and adapted development.

The activities resulting from **the modeling of land use change** identified that LandSHIFT.JR is a tool suitable for supporting the development and testing of land-management strategies in the Jordan River region. According to the GLOWA JR scenario assumptions one can expect considerable expansion of urban and built-up areas (44-59%) as well as cropland (rainfed: 96-255%; irrigated: 36 – 157%). Climate change may increase the area demand for irrigated agriculture by about one quarter. Socio-economy might have even stronger impacts: according to the GLOWA JR scenarios irrigation area is likely to expand between 36 and

98%, not considering any adverse effects of climate change. Future livestock production, as projected by the GLOWA JR scenarios, might push the land-use system to its limits. Hence, livestock production is likely to be limited by a shortage of land resources.

The results of the research dealing with **water productivity in agriculture** showed that the simulations of the RCMs and GCMs differ not only by their simulated periods, but also on other parameters like initial conditions and assumptions. Therefore the resultant calculations of the future change in irrigation demand were strongly affected by the climatic simulations. In the cases tested in this sub project the irrigation water demand for different crops may change by a factor of 2-3 according to the different climatic simulations.

According to climatic simulations tested within this sub-project (see chapter 9 water productivity of agriculture), the increase in PET during the irrigation period in UJV (summer) is approx. 60 mm (for the years 2020-2050) & 100 mm (2070-2099), causing an increase in water for irrigation of 10-40 mm & 40-110 mm, respectively, depending on the crop type. Note that such increase in PET will consequently also cause water stress for natural forests and non-irrigated crops.

The regional based land evaluation for **effluent irrigation** highlighted that long-term irrigation with treated wastewater (TWW) can stimulate microbial activity in subsoils to such a degree that soil organic carbon pools are depleted to a greater degree than being replenished through the wastewater-borne organic matter. In irrigated topsoils such priming effects were not observed because microbial activity was not limited by substrates. Even short-term irrigation with TWW induces water repellent soil surfaces that reduce infiltration rates and promote seepage along preferential flow-paths. This can be attributed to hydrophobic organic compounds introduced with the TWW. During winter rains, these effects subside, either due to leaching or microbial degradation.

Regional water balance

The research about the impact of environmental change on water resources showed that the water balance components could be determined both on the point scale (e.g. Yatir forest) and on the large scale covering the entire JRR and neighboring regions. Data from field observations, climate stations, radars and remote sensors have been used in combination with hydrological models. The results give an extensive overview of the vertical and horizontal hydrological fluxes over a variety of land-uses/vegetations and bare soils during normal as well as abnormally dry and wet years. Based on climate projections it is shown that the water availability is expected to decrease and the irrigation water demand to increase by the middle of this century. Several drought indices have been applied and it was shown that the Standardized Precipitation Index (SPI) correlates with vegetation data received from remote sensing. Since SPI can reproduce the vegetation phenology of different land-uses both during average wet seasons, as well as during abnormally dry and wet seasons, the drought index was identified as suitable for characterizing droughts in the region.

In the arid to semi-arid study region, a high percentage of the rainfall evaporates into the atmosphere without providing any real benefits to the human or the nature. In chapter 13 (RWH), we illustrate that a combination of several methods (data collection in the field, questionnaires and hydrological models) were applied and the potential of rain water harvesting (RWH) was addressed both in rural and urban environments, where the rainfall can be collected along hill slopes and on rooftops, respectively. In rural areas, it was shown how the amount of water collecting trenches along the hill slope is dependent on the soil characteristics and soil depth. In urban areas (city of Ramallah), the runoff coefficient (RC) was estimated to be 75% during drought seasons (250 mm) and 87% during average season (550 mm). This corresponds to a roof top runoff of 190mm and 480 mm in a drought and average years, respectively. Questionnaires indicated that water collected from the roof has good quality and can be used for various purposes.

A regional map on the potential for managed aquifer recharge (MAR) was derived by considering the parameters surface lithology, topography, urban areas and availability of water resources. A high potential for MAR via surface infiltration was given to areas where an aquifer was combined with a slope smaller than 5 %. To address the potential benefits of MAR, a variety of simple models were applied to a karst spring and it was shown that the declining spring discharge that has been observed the last years, is mainly due to water pumping, and not due to a changing climate. This has to be considered for water resources management and MAR, SEB implementations.

1.7 Synthesis of applied key results

Regional climate change scenarios

The Regional climate models show a high probability for

- A mean increase of the annual mean temperature of approximately 2.1°C for the period 2031–2060 and 3.7°C in for the period 2070–2099.
- A mean decrease of the annual mean precipitation by approximately −11.5% in 2031-2060 and −20% in 2070-2099. All values are in relation to the 1961-1990 mean
- Increase of 1.5-2.5ºC in the summer temperature for the 21st century.
- Decrease of 15% in the annual rainfall for the 21st century.
- Increase in frequency of extreme events.

Integration and application

The objective of the GLOWA JR scenario process was to integrate the results of the scientific sub-projects in a way useful for the development and valuation of water and land management strategies in the region. Here, the stakeholder-driven and moderated scenario process served as an essential approach for several aspects of integration in the project: The dialogue between stakeholders from Israel, Jordan and the Palestinian Authority was continued and intensified during the scenario process. This included an intensive discussion between representatives of different water-using and partly competing sectors as well as the dialogue between project scientists and stakeholders.

A second result of the scenario project consists of four comprehensive water management strategies which cover quantifiable aspects as well as non-quantifiable aspects which are relevant when developing a future long-term strategy for the handling of water resources in the region. The resulting overall water supply under these management strategies varies widely depending on future financial resources and degree of cooperation in the region. Consequently, under future scenarios with poor economic development a management of the demand including the respective governance measures is of utmost importance to alleviate the increasing water scarcity.

Next to WEAP applications which have been developed within GLOWA JR and which will, at least in parts, be used to address water management beyond the lifetime of the project, there were many WEAP applications which are the result of the support offered by the project and the communication of the project models and results:

- WEAP applications for 15 hydrological basins in Jordan have been implemented as a basis for planning at the Ministry of Water and Irrigation. This is part of the ongoing work for Jordan's National Water Plan
- WEAP is being implemented as a tool for planning at the Palestinian Water Authority
- WEAP-MYWAZ coupling activities are planned for Jordan, West Bank Palestine and maybe Israel
- Ongoing WEAP-MODFLOW couplings are planned at the Palestinian Water Authority
- A WEAP application on rehabilitation of the lower Jordan River is conducted by Friends of the Earth Middle East
- Many smaller WEAP-applications, e.g. for Wadi Nar wastewater pollution study, have been implemented

Green water and land management

Guidelines for managing uncultivated rangelands resulted in the awareness that productivity and thus stocking capacity will be relatively little affected by climate change. The risk of a great fire is reduced by either regular prescribed fires or cutting of shrubs/trees, while grazing and climate change have a low impact. Shrub encroachment is more sensitive to decreased grazing intensity than to fire management; it is promoted by tree cutting. Erosion risk is more sensitive to annual precipitation and grazing intensity and less sensitive to other management options (prescribed fire, tree cutting). Only small regions of Israel are prone to intensive soil erosion, namely the Poleg basin and the Ayalon basin.

Furthermore it could be demonstrated that while overall response of semi-natural ecosystems to climate change is rather small, indicating a potentially high resistance to climate change, the response to grazing is immediate and large, and important interactions between climate and land use effects have emerged. Namely, the systems maintain their inherently high level of biodiversity and exhibit no or little change in productivity and species composition under climate change, but only when they are not grazed or experience low levels of grazing. However, not only do productivity and species richness decrease with grazing if it is applied at current stocking rates, but the sensitivity of these highly diverse ecosystems to climate change increases dramatically when they experience medium-to high stocking rates.

On the one hand, this points to an interesting manner in which these systems can be managed, because a reduction in grazing pressure will render them less sensitive to climate change. On the other hand, current stocking rates in many regions in Jordan and the West Bank are beyond the threshold that will enable maintaining the services and diversity of these systems under climate change.

A clear recommendation can be drawn from these findings: a reduction in grazing pressure in regions with very high stocking rates will greatly help maintaining the function of these ecosystems for the future. *Vice-versa*, maintaining current stocking rates will lead to the irreversible loss of these ecosystems both for nature conservation and for the farmers and nomads using the land. A sustainable future where grazing is still possible and biodiversity is protected requires the reduction of stocking rates in many parts of the region, especially in Jordan and the West Bank.

The GLOWA Jordan River project provided us with the unique opportunity of integrating our findings with those from other disciplines. For example, one main conclusion could only be derived when combining our findings with those from the agricultural and socio-economic sciences: Namely, we may conclude that in terms of revenue from ecosystem services, rainfed land-use is superior to irrigated agriculture: it is more sustainable and may yield, on the long-run, higher returns. Rainfed land use includes rangeland, open space for recreation and nature conservation as well as rainfed agriculture. Protecting open space may maximize the benefit of society, because non-market values can be much larger than profit from agriculture. At the same time, natural and semi-natural ecosystems are relatively resistant to climate change and thus the maintenance of their services for society requires little additional input. In combination with findings from previous phases, where intercropping with wild plants in rainfed fields was shown to yield high revenues, we can indeed conclude that an expansion of rainfed land use at the expense of irrigated land use may help to meet the challenges of the water crisis in the region in an era of global change. Such a shift in land use patterns will require fundamental decisions about priorities in land allocation and management.

The socio economic research in Israel showed that by applying the model to Israeli data and a simulated future climate scenario, it was possible to derive potential research and development directions for adjusting agricultural production technology so as to mitigate possible adverse effects of climate change on agricultural profits. The Israeli simulations indicate a reduction of about 15% in the cultivated land and of 5-7% in the profits of the vegetative agricultural sector. Although the use of freshwater is sensitive to changes in freshwater quotas and prices, land-use and profits are quite robust to these changes. We have evaluated the impact of climate change on optimal growth to be about 0.11% of Israel GNI along the period 2000-2010 and 0.35% of Jordan GNI. This estimation is based on an average impact of climate change effect on natural stocks that are considered to provide a large range of ecosystem services. These include (i) Plant seeds volume and diversity; (ii) Biodiversity (resp. extinction risk of certain species); (iii) Stocking capacity as function of climate change; (iv) Green biomass production; (v) Plant cover; (vi) Soil deposition and runon; (vii) Leaf area index.

For Jordan, the suggested mathematical models proved to be relatively easy to handle, and have a sufficient level of generality that would allow their use as a decision aid and prognostic tool in other locations of the region, too. In addition, the results can serve as a decision support device suggesting to a planner what crop patterns are likely to prove optimal under different water policies and under the risk of market price variations.

The developed modelling system, LandSHIFT.JR can be applied to produce results relevant for (1) analyzing the water demands and deficits for irrigation under different socio-economic and climate scenarios and (2) analyzing the development potential for agriculture in the Jordan River region. The information is relevant for stakeholders and decision makers involved in sustainable land and water resources management and especially for the members of the GLOWA Jordan River Scenario Panel and for MWI, JVA and MOA.

The applied key results of the activities within the assessment of water productivity in agriculture (see chapter 9 water productivity) illustrate that the spatial distribution of vegetation within of the Upper Jordan Valley based on the land-use maps, produced within this sub project shown that 60% of the area is occupied by natural forests & open area, 20% by field crops (mainly rain-fed wheat), 5% olive groves, 8% irrigated orchards. Due to the predicted increase in water stress and in order to minimize damage to the natural forests, thinning actions should be considered. Measures to reduce evapotranspiration, like shading mesh, should be taken within irrigated orchards.

The irrigation with TWW (see chapter 10 TWW) can pose various risks to soil fertility and groundwater quality. This depends on TWW quality and site parameters. The overall suitability of land for sustainable irrigation with TWW was evaluated based on soil properties, geology and depth to groundwater table. A GIS-based land suitability evaluation system was developed and implemented for the region in the GLOWA Jordan River Atlas to enable easy access to data and maps for land-use planners and other stakeholders.

Regional water balance

Regional co-operations and data sharing have resulted in an improved understanding of the hydrological conditions of the region. The quantified water fluxes of different land-uses and under different climate conditions, as well as on the point and large scale, are highly valuable for regional water planning and the estimation of available water and irrigation water demand under current and future climatic conditions. Furthermore, the extensive drought analyses are valuable regarding the water allocation within and between sectors during extended periods with rainfall deficits. They can be used to take informed decisions about the location of irrigated agriculture and its overall share in future agricultural activities.

The developed methodology for runoff harvesting system at a slope scale can be used for a better planning of runoff harvesting system and soil/water conservation. Results on rainwater harvesting in Jordan are highly relevant, because there is a widespread acceptance and implementation of water harvesting in Jordan. The RWH suitability map for the entire West Bank may give valuable information for decision makers to develop and implement a strategy that guides the sustainable wide scale adoption of RWH in the West Bank. Numbers of urban RWH potential are highly relevant for water management, and the suitability map was considered of top interest by the regional stakeholders.

1.8 Outlook and implementation

GLOWA JR has many achievements to its credit, the most important being:

- **Regional cooperation in applied environmental science** on water and land-use, with unprecedented success. Working together over this period has created relationships between the scientists and stakeholders involved which have transcended political boundaries and are highly unusual in this region.
- **Highly significant scientific results** produced by the multilateral teams on climate change that are of regional and global relevance and whose creation has helped significantly in capacity building.
- **The development of regional environmental management tools** such as the WEAP tool which is

being used by Governments in the region to enable them to deal effectively with the challenges posed for sustainably managing their limited water resources under climate change.

- **Regional awareness of governments and different stakeholders of challenges of climate change** and the means for adaptation was significantly increased by the scientific insights produced by GLOWA JR, and current decisions in water management are taken on the basis of GLOWA climate scenarios.

This success is based on ten years of confidence building combined with excellent science. It is remarkable in a region with great political complexity where the studied resources -water and land- are among the most contentious and volatile. Working together over a decade has fostered a genuine atmosphere of mutual trust among scientists and stakeholders concerned with a sustainable future. In particular, we have learned that:

- The German Government can play a lead role in promoting the dialogue in the Middle East via sustainability science. Namely, natural resources know no borders, and they are needed for economic and social welfare in all countries. Therefore, sustainability research is an ideal focus for collaborative work between German and Israeli, Palestinian and Jordanian scientists and stakeholders, enabling to address the challenges of managing scarce and diminishing resources in a transboundary manner.
- Educating a future generation for taking responsibility in regional Governments and in Academy is a cornerstone for ensuring that future decisions in resource management will be taken on a scientific basis. Continuous capacity building can ensure that the benefits of sustainability research are shared between the countries of the Jordan River Basin and Germany as an emerging leader in developing the scientific basis for environmental sustainability.
- Prioritizing on the establishment of a regional environmental and adaptive management database that is accessible for all partners in the region will be a major step towards an informed national and regional resource management. The credibility of Germany as a host of such a database will considerably facilitate future dialogue among the partner countries both in science and policy.
- Ongoing scientific support of WEAP in all three countries and developing similar decision support tools in land management is an explicit wish of stakeholders from all three Governments in the region. Regional decision support tools and technology transfer are required for finding transboundary solutions.

The outstanding achievements have created a **unique momentum** for commitment to regional cooperation. This was utilized to create a **Regional Centre** dedicated to supporting the regional dialogue for resource management under global change. Two workshops have taken place one in September 2012 and another in March 2013 with key scientists and stakeholders of the region. The September Workshop yielded amongst other in an Expression of Intent of all participants (see Annex 3). The common goals of the platform were defined, the structure and organization, the commitments and it was discussed what is needed for establishing and sustaining such a platform. The participants of the March Workshop gave to the centre the following name: Sustainable Adaptation to Global Change in the Middle East –The SAGE Centre. A concept for SAGE was developed (see one page Info about SAGE in Annex 4)

2 Scenario Analysis of strategies

Authors: Onigkeit, Janina, Center for Environmental Systems Research (CESR), University of Kassel, Kassel

2.1 Aim

In GLOWA JR a scenario process was initiated as an integrating element. During the third phase of the project three Scenario Panel meetings were organized involving project scientists and stakeholders from Israel, Jordan and The Palestinian Authority in order to develop regional scenarios of water and land management. The overall aim was to explore possible future developments of the water and land sector in the Jordan River basin under conditions of regional and global change and to do this in a way that allows for an integration of the research results of the project in a form which makes them useful for planners and stakeholders in the region. The Regional Development Scenarios worked out during GLOWA JR phase II were available as framing conditions for the development of water management strategies in order to cover changes in socio-economic and political conditions as well as cultural aspects in the region[1].

The development of long-term water strategies up to the year 2050 is a very complex issue. We therefore focused on three aspects: (1) The potentials of so-called "New Water" or unconventional water sources, (2) the potentials and impacts of changing land management to deal with the increasing gap between water availability and demand, and (3) the development of strategies to cope with the anticipated increased number and severity of extreme climate situations. The information generated during the scenario process served as input to the WEAP and other models in order to perform a more in depth analysis to estimate e.g. the degree of fulfillment of water demand in different water-using sectors at different times of the year and different sub-regions of the Jordan River basin.

2.2 Description of research

2.2.1 Material and methods

In light of an increasingly fast changing world uncertainty of future development increases (1) with respect to the impacts of climate change and (2) with respect to future global and regional socio-economic development. In this situation scenario development is a useful method to work out strategic development pathways in a systematic and creative way in order to gather information about the extent of this uncertainty and to prepare for it. In GLOWA JR phase III the scenario process focused on the development of strategies to manage water and land resources taking up and integrating (if possible) the scientific insights provided by the different sub-projects. Stakeholders and other experts from the region and from a variety of different water related sectors met with scientists in order to identify the major water related issues and challenges in the future and to formulate different strategies suitable to cope with these challenges. In a final step robust actions could be identified which should be taken in the short term in order to keep flexibility to cope with the different challenges a highly uncertain future might bring.

[1] Definition: Scenarios are a sequence of "if-then" statements. They describe possible developments of the future which are plausible, relevant and challenging (nevertheless simplified). They are based on a coherent and internally consistent set of assumptions about key driving forces of change and their relationships (MA, 2005).

In order to obtain a profound picture of the future development of the water situation in the Jordan River Basin, we applied the so-called "Story and Simulation" (SAS) approach. A characteristic of this approach is that it integrates quantifiable scientific information and qualitative region-specific information in a balanced way. Numerical information such as the results of climate models or hydrological models is enriched with information on the future development of the political situation or changing habits and attitudes of the population which is difficult or non-quantifiable at all. Another characteristic of the SAS methodology is that a scenario process is organized as an iterative process which allows for an intensive interaction and feedback between project scientists and stakeholders. These discussions took place at the three Scenario Panel Meetings (however, at these meetings the focus was on the development of strategies) and at specific sessions on the second Status Conference of the project in 2010.

Participants

The four Regional Development Scenarios and the corresponding strategies of managing water resources strongly differ with respect to the assumptions about the future socio-economic and political situation. Consequently, they provide the opportunity for very different perspectives and strategies to develop the future (regional) water sector. We therefore invited stakeholders who potentially represented a large range of different perspectives on the water issue. The participants who accepted our invitation came from the following countries and ministries or organizations:

Israel

Israel Water Authority
Tahal-Consulting Engineers
Israel Meteorological Service
Arava Institute for Environmental Studies

Jordan

Ministry of Water and Irrigation
Ministry of Agriculture
Jordan Valley Authority
Water User Association
Meteorological Department of Jordan

Palestinian Authority

Palestinian Water Authority
Ministry of Agriculture
Environment Quality Authority
Ministry of Planning
Ministry of Local Government
Palestinian Hydrology Group
House of Water and Environment

Regional and other organizations

Palestinian Agricultural Relief Committees (P.A.R.C)
Israel Palestine Center for Research and Information (IPCRI)
Friends of the Earth Middle East (FOEME)
EU Water Initiative – Mediterranean countries (MED EUWI)
Gesellschaft für International Zusammenarbeit (GIZ, formerly GTZ)

Three Scenario Panel Meetings were organized as follow-ups of the three Scenario Panel Meetings of phase II and took place in the Jordan River region and in Germany between 2009 and 2011.

Fourth Scenario Panel Meeting

We started the scenario process in phase III with three sub-regional one-day meetings which took place in Amman, Ramallah, and Tel Aviv in June 2009 and which were used to familiarize new participants with the scenario process. The outcome of the meeting included a list of the most promising sub-regional and regional water management options which were discussed, and prioritized from the perspective of each of the involved countries in order to further elaborate them at the following regional meetings.

Fifth Scenario Panel Meeting

The fifth meeting started with a session providing the most recent scientific background information and continued with short sub-regional meetings again to outline sub-regional water strategies and agree on water options for regional discussion. Most of the time of the meeting was spent to develop four scenario-specific visions for a future regional water regime in 2050 and then to work out the necessary measures and actions to bring the vision to reality. This was done by applying a back-casting method, i.e. by going backward step by step and identifying the necessary activities but also constraints to realize the vision. This process resulted in a draft/outline of four regional water management regimes which were subsequently quantified by the scenario team.

Sixth Scenario Panel Meeting

At this final meeting the participants were asked to further enrich the regional water strategies, to specify measures to adapt to an increasing frequency and severity of droughts and other climate extremes and to discuss the environmental impacts of the different water options. Then, those options were identified that are robust (with adaptations) which means applicable under all scenarios. The concluding step of the scenario process led the participants from the future perspective and their visions under the scenarios back to the present time: They were asked to agree on and elaborate a small number of measures which they considered as feasible to facilitate a region-wide cooperation for a sustainable and efficient management of water resources in the very near future. This step resulted in the so-called "Cross-cutting strategic options".

2.2.2 Results

One major result of the scenario process in GLOWA JR phase III is the continuation of a region-wide and cross-sectoral dialogue between stakeholders engaged in water, environmental and other related issues. Besides, the main outcome of the scenario process consists of four strategies for the management of water resources corresponding with the Regional Development Scenarios resulting from phase II. The scenarios as well as the water management strategies were developed along two dimensions which are expected to shape the future water situation: The first one can be described as the future degree of cooperation on water issues including the degree of sharing regional water resources. The second dimension takes into account the future economic development in the region and its implications for the use of existing and the development of new water resources. The resulting qualitative scenario descriptions including the water management strategies are summarized below. Quantitative estimates for major "New Water" options can be found in the following section.

2.2.2.1 Four scenarios of regional development and resulting water management strategies

Scenario Willingness & Ability (WA)

The "Willingness & Ability" scenario reflects the most optimistic perspective of the future in which peace and economic prosperity rein. *In the beginning* of the scenario period a strong growth of the population (see Table 2.1) and the tourist industry together with a climate induced reduction of precipitation lead to a growing pressure on water (and land-) resources. Foreseeing a fast growing gap between water demand and supply, governments take first cooperative steps very soon. A comprehensive regional water master plan is developed in parallel with a regional environmental protection plan. These two plans build on an agreement which introduces new rules for the sharing of regional water resources and costs of infrastructure measures, as well as monitoring and control measures to protect biodiversity and the environment in the region in general. It also stipulates a regular evaluation and, if necessary adaptation of the master plan. Measures to respond to the adverse impacts of climate extremes such as groundwater recharge and adaptation of crop types are implemented and taken early and in a cooperative way so that substantial damages can be avoided region-wide. *In the medium term* the overall water availability can be increased sufficiently through a fast and region-wide spread of water and environment related technical know-how (which, under this scenario largely contributes to the generation of wealth in the region) and large scale high-tech solutions, such as desalination plants, infrastructure for waste water treatment and re-use and the realization of the Red Sea - Dead Sea canal. In parallel, awareness campaigns inform the broad public about the limitation of water resources but also of the environmental impacts of the high-tech solutions for water production, especially the tremendous amounts of brine but also sludge from waste water treatment. As a result, conservation of resources through repair and maintenance of pipeline systems and an increasing efficiency of water use in households and agriculture gain more and more acceptance. *In the long term* a sustainable agriculture and land-use is realized region-wide and overgrazing is successfully avoided. The availability of sufficient water and a growing awareness of the impacts of overuse of environmental resources results in the allocation of water for nature. The availability of financial resources and an increasing level of public awareness together guarantee a sustainable development of the region. Solar energy for seawater desalination partly replaces fossil fuels although at a very slow rate since prices for energy are rather low due to the development of a recently discovered large natural gas field near the Mediterranean coast.

Table 2.1: Development of regional key driving forces under the four scenarios.

	Population (Million persons)				GDP (Billion 2000US$)			
	WA	PP	MH	SWE	WA	PP	MH	SWE
2000	14.2	14.2	14.2	14.2	133.6	133.6	133.6	133.6
2010	17.7	17.7	17.7	17.7	180.6	176.8	179.8	176.8
2030	28.4	24.5	23.5	24.5	439.5	278.2	311.4	271.1
2050	39.0	32.7	37.0	31.7	1064.3	396.4	863.8	306.9

Scenario Poverty & Peace (PP)

The “Poverty & Peace” scenario constitutes a combination of peaceful development in the region without economic prosperity. Although water resources are being shared, water stress problems, caused by climate change which occurs over the coming decades, remain an important issue because of the poor economic development. In the short term awareness campaigns with a clear regional perspective are organized which are accompanied by an upgrading and enforcement of water-saving rules and regulations and thus help to conserve water resources. "Make peace an economic value" is the guiding principle of the water strategy under this scenario. Modest economic development is achieved through development of region-wide ecotourism. It is realized by re-allocating sufficient water mainly from agriculture to this sector and by taking care of and expanding of nature reserves. First steps in tri-lateral water management can be realized very soon but requires third party involvement in the beginning. In the medium term water resources can be augmented through cooperation on the basis of small scale projects. Political stability leads to a slow but steady spread of technology throughout the region. However, the cooperative projects remain small-scale and continue to be dependent on financial support from outside the region. Consequently, measures to motivate the establishment of water saving measures prove to be of equal importance as the development of additional water resources. Awareness of water scarcity and the availability of cheap conservation technologies together result in a slow-down of domestic water demand (see Figure 2.1). In the long term full regional cooperation leads to an equitable sharing of water and the economic situation in the region is perceived as more equitable since unemployment is successfully reduced. However, the continued shortage of water resources combined with a lack of financial means requires a high level of environmental and political awareness of the regional population and economy in order to at least fulfill their minimum water demand.

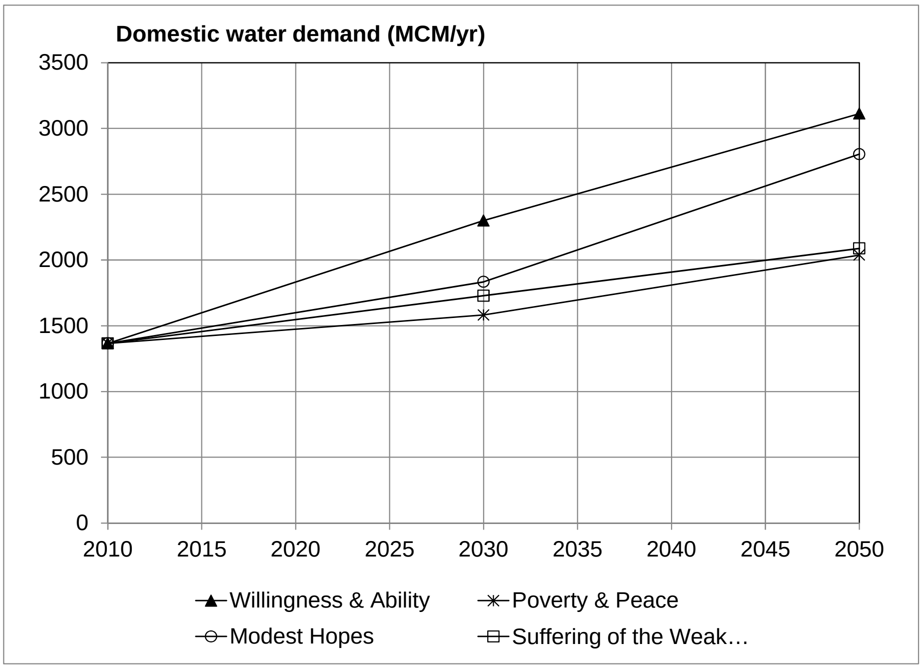


Figure 2.1: Future development of domestic water demand 2010 – 2050 under four scenarios.

Scenario Modest Hopes (MH)

The "Modest Hopes" scenario assumes that no peace agreement can be reached but that economic prosperity prevails, kindled by international donors. This results in fairly stable conditions in the region with limited informal cooperation in form of e.g. an exchange of knowledge and technologies. *In the short term* water master plans are developed in each of the countries, separately. The focus of water management is on increasing the supply of water by large scale desalination, expansion of sewage networks, building of waste water treatments plants and the re-use of the properly treated waste water in agriculture in order to expand irrigated agriculture. Comprehensive education, training and capacity development programs allow for the realization and maintenance of water production facilities on a high technical and efficient level in all three countries. Large investments are made in research and development to replace fossil energy by solar energy for the desalination of seawater. *In the medium term* projects are initiated and started to restore natural rivers. The efficiency of water use for irrigation is increasing fast. Additional desalination capacity and rainwater harvesting help to make up for the climate induced decreasing reliability of natural water resources. In Jordan the storage capacity of dams is increased to adapt to climate extremes in form of floods and droughts. In addition, farmers adapt their production schemes and are compensated for income losses in case of droughts. However, the economic prospects of those who depend on rainfall (herders/Bedouins) deteriorate. *In the long term* household and industrial water demands are fulfilled and agriculture becomes profitable in general since enough water is available at the right time. However, this strategy increases the pressure on open land. The increasing desalination of seawater which is ongoing for years now produces considerable amounts of brine with impacts on coastal environments.

Scenario Suffering of the Weak & the Environment (SWE)

The "Suffering of the Weak & the Environment" scenario is a worst case scenario in which neither peace nor economic growth can be reached. It represents the most vulnerable future with respect to climate change and the non-reliability of future water resources. It is perceived as critical to take actions in the very near future. *In the short term*, the development and implementation of emergency measures are regarded as essential to be prepared for future climate extremes. A combination of small-scale water options and traditional measures are considered as most adequate strategies to develop additional water resources. The introduction and enforcement of governance options such as regulations & laws to make full use of available technologies and techniques to save water and protect resources from pollution are fully used to alleviate water scarcity. The implementation of new and but also the maintenance of existing infrastructure becomes increasingly difficult due to the lack of funding by international donors who are unwilling to invest money in a politically instable region. Only in the case of extreme water crisis international financing is available. Cooperation on water issues remains possible only to a limited extent on an informal and technical level. *In the medium term* in Israel increasing water prices lead to sinking water use in households. However, population growth requires a region-wide and increasing allocation of water in favor of the household sector. Since the replacement of fresh water by treated waste water is very limited due to the lack of treatment plants and a functioning infrastructure, agriculture is particularly confronted with dwindling water resources. In the North of Israel a shift to supplemental irrigation helps to conserve water resources. In Jordan, summer irrigation in the Jordan Valley is stopped and cultivated area in the Highlands is reduced in order to prevent groundwater abstraction by agriculture. In all three countries high water (and fertilizer) demanding crops are replaced by low water demand crops. In rural areas small earth dams are built and cisterns are used wherever possible in order to collect flood- and rain water. *In the long term* donor-funded rural projects fall away and many small farmers give up and move to the growing cities. The majority of the remaining farmers grow basic/subsistence crops relying on rain or they use more brackish water e.g. to irrigate olive trees. The poor suffer the consequences of a deteriorating environment most, but also the middle class is coming under increasing pressure.

2.2.2.2 New water sources

Developing new unconventional water resources is regarded as the most important strategy to alleviate water scarcity in the region. Five major options to augment water resources were discussed during the scenario process for four different scenarios and quantified[1]:

Seawater desalination: In Israel the desalination of seawater from the Mediterranean Sea is already realized on a large scale reaching 275 MCM per year in 2010. Preparations are in an advanced stage to provide 600 MCM by 2015. In the long term, Israel aims at the production of up to 1750 MCM of potable water by desalination of seawater by 2050. For Jordan two options of desalinating seawater from the Red Sea are in the planning or already in the development phase: A Jordanian project (Jordan Red Sea Project, JRSP) is expected to finally generate about 930 MCM of potable water by the year 2055. From a second project, the Red Sea - Dead Sea Project which is currently still under review by the World Bank all three parties would benefit. This project aims at a final production of 850 MCM/yr to be shared between Israel, Jordan and the Palestinian Authority with a major share of 550 MCM for Jordan. In the West Bank and the Gaza Strip currently no considerable desalination capacities for seawater exist. For the year 2020 a desalination project in the Gaza Strip is planned in order to produce about 100 MCM/yr to supply the population with potable water and to protect the overused Coastal Aquifer. Additionally, it is planned to allocate 30 MCM of water from the Red Sea - Dead Sea project to low lying cities in the West Bank.

Under the four GLOWA JR scenarios the assumptions on the further development of desalination capacities differ. Considering the current situation and existing plans for the future projects are assumed to be realized depending on the availability of financial resources and the degree of cooperation between the three parties. Under the WA scenario already in 2030 considerable amounts of water are expected to be available from seawater desalination: In the Gaza Strip 150 MCM of water are produced, the desalination capacity in Israel reaches 600 MCM per year and the Red Sea - Dead Sea Canal (RSDSC) supported by international donors and the World Bank provides desalinated water for Jordan (230 MCM) and a smaller

[1] This is only a rough overview of major water sources to estimate their potentials under the different scenarios. Small scale, traditional, and uncertain water generating options such as dew harvesting or water from cloud seeding were considered as options in the water strategies but were not quantified.

amount for Israel and the Palestinian Authority. The regional desalination capacity amounts to 1420 MCM already in 2030 (see Figure 2.2) thus covering 62% of the domestic water demand in the region. The optimistic expectations under this scenario lead to a further rise of the regional desalination capacity to 2880 MCM by 2050, from which 830 MCM are expected to come from the RSDSC as a source under regional management. Together this technology is expected to cover 93% of the regional domestic water demand in 2050. In contrast to the WA scenario, under the SWE scenario considerable desalination capacity is realized solely by the capacity increase in Israel reaching a production of 600 MCM per year via the new projects and expansion of existing plants envisaged for 2015. No more projects are realized after 2030 reflecting the economic decline in the region. This additional water can contribute 35% and 29% of the regional domestic water demand by 2030 and 2050, respectively.

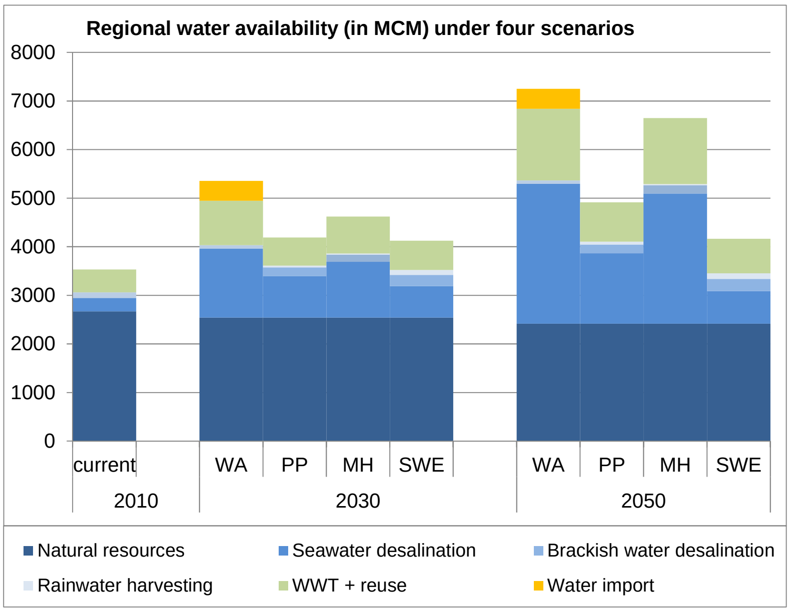


Figure 2.2: Development of the regional water availability up to the year 2050 considering natural resources and five major "New Water" options. For natural resources we assumed a climate induced decrease of 10 % in 2050 relative to 2010.

The ***reuse of treated wastewater (TWW)*** is regarded as an unconventional water source of increasing importance in the Jordan River basin. The treatment of wastewater which is mainly produced in the domestic sector has two advantages. Firstly, adequate treatment helps to protect the health of the population and aquifers from contamination. Secondly, treated wastewater can act as a considerable source of water especially for agriculture when properly treated and can thus protect freshwater resources in order to fulfill the increasing domestic water demand.

The current situation regarding the treatment and reuse of wastewater is very heterogeneous. In Israel 96 % of the population is connected to the sewage system (DREIZIN, 2007). About 500 wastewater treatment plants produced 416 MCM of treated effluent in 2010, which is 51% of the water allocated for domestic and industrial use (CBS, 2011). It is intended to increase this share to a maximum of 60% of the water allocated for domestic purposes (SCHWARZ, 2011). The treated effluent is used for irrigation and the recharge of groundwater in the coastal area of the Mediterranean. TAHAL (2011) estimates for the future use of TWW in the agricultural sector assume up to 673 and 929 MCM by 2030 and 2050, respectively. This equals 52% and 61% of the projected allocation to the agricultural sector in 2030 and 2050, respectively.

In the West Bank, out of the five existing wastewater treatment plants currently only the one in Al Bireh is properly functioning. About 69% of the population in the West Bank relies on septic tanks. The remaining 31 % of households are connected to a sewage system (WORLD BANK, 2009) but the treatment level is poor and a reuse scheme is virtually not existent. In Gaza 60% of the households are connected to a sewage system but the capacities of the three existing treatment plants are incrementally exceeded. Missing or insufficient treatment and distribution of the treated effluent currently allows for the reuse in the Palestinian territories only to a very limited extent. Long term plans of the Palestinian Water Authority

(PWA) estimate that 80% and 95% of the population will be connected to a sewage network by the 2030s and the year 2050, respectively (HWE, 2009). According to these plans, the treatment and reuse in agriculture and for groundwater recharge will increase to 275 MCM in 2050.

In Jordan, currently 22 centralized governmental wastewater treatment plants are operating which produced about 110 MCM of treated wastewater in 2010 which was blended with fresh water and then used for irrigation mainly in the Jordan Valley. These 110 MCM are 34% of water allocated to the domestic sector (SEDER & ABDEL-JABBAR, 2011). The two main reasons for this relatively low share are (1) that only about 64% of the households are connected to the sewage system and (2) relatively high conveyance losses of between 25% and 40%. For the future it is planned to intensify the reuse of grey water and to more than double the capacity of treatment plants to 256 MCM by 2022. This would cover 39% of irrigation water to be allocated for agriculture in the Jordan Valley in 2022 (661 MCM) (MWI, 2009).

The regional availability of treated waste water available for reuse in agriculture currently amounts to about 467 MCM. For this water the infrastructure for treatment and transport to agricultural area is already in place. Under the four scenarios it is assumed that on a regional scale infrastructure can be build up to provide treated water for reuse which is twice of the current amount by 2030 and trifold by 2050 (1473 MCM) under the most optimistic WA Scenario. This is equal to an increase of 34 % to 47 % of the water allocated for domestic purposes in 2050. At the other end of the range of the scenarios, under the SWE scenario a maximum amount of 711 MCM of treated effluent could regionally be provided for irrigation purposes by 2050. The regional treatment capacity is enlarged by 60 MCM per decade under the SWE scenario and by an optimistic increase of 250 MCM per decade under the cooperative and prosperous WA scenario. For comparison: Jordan plans to increase treatment and reuse capacities by 150 MCM during the coming decade up to 2022 (MWI, 2009). In Palestine for the West Bank an increase of treatment capacities by 67 MCM accelerating to 100 MCM per decade between 2030 and 2050 are considered as plausible under the optimistic conditions of the WA scenario (HWE, 2009). In Israel an increase of treatment capacities by about 125 MCM per decade are considered to be feasible (TAHAL, 2011). These plans to increase wastewater treatment capacities sum up on a regional scale to a potential rate of increase of 330-375 MCM per decade, an assumption which exceeds estimates for the optimistic WA scenario.

Brackish water desalination is of medium importance in the future regional water budget but depending on its origin and location it is advantageous to use it e.g. for local supply. It is generally defined in the region as water having a chloride concentration greater than 400 mg/l and originates from natural processes such as the mixing of deep fossil and highly saline water with higher groundwater bodies through the fault system of the Rift valley which is the case for the Eastern Mountain Aquifer and for springs near Lake Tiberias (MARIE & VENGOSH, 2001)). Other sources of saline water which become increasingly important are directly or indirectly the result of human activities: The application of untreated or not sufficiently treated wastewater to soils can contribute to the increasing salinity of aquifers as well as the leaching of fertilizer as a result of over-fertilization in agriculture. In addition, an over abstraction of water from groundwater can result in seawater intrusion into the groundwater body and deteriorate the water quality (e.g. Coastal Aquifer in Gaza). However, depending on its salinity brackish water can be used directly or blended with fresh water in industry or for the irrigation of salinity-resistant crops. Another way to increase the quality and number of options for its use is desalination. This option is used in Israel and Jordan (120 MCM/yr) with small options to increase the amount of water to be produced this way (see scenario assumptions). In Gaza the water quality of the Coastal Aquifer is so poor that small-scale desalination of water from wells is necessary and common practice (if fuels and required chemicals are available and affordable) in order to get water of drinking quality (WORLD BANK, 2009).

Under the GLOWA JR scenarios the maximum of water to be developed by 2050 amounts to 181 - 251 MCM of (natural) brackish water under the PP and the SWE scenario, respectively. Under these scenarios economic development is poor so that this option is fully used since no financial resources are available for the large scale and more expensive water and desalination projects. Consequently, brackish water desalination sums up to only 70 MCM and 170 MCM by 2050 under the WA and the MH scenario, respectively. The major resources of brackish groundwater are available in Jordan (about 110 MCM) followed by the West Bank (about 70 MCM) (not taking into account the necessity in the Gaza Strip and

Israel to desalinate water from the Coastal Aquifer because of increasing seawater intrusion caused by future sea level rise).

Water imports from Turkey are officially discussed since the middle of the 1980s e.g. as the “Peace Pipeline” plan. According to this plan about 2000 MCM of water per year from the Seyhan and Ceyhan Rivers in Turkey would be available and could be transported via a 700 km pipeline to Syria, Jordan, Palestine, and the Gulf States (IPCRI, 2010). Another, partly realized plan is to import yearly about 50 MCM of water from the Manavgat River in Turkey via the Mediterranean Sea to Israel using tankers or “Spragg” bags for transport to the Israeli coast.

Since both water import options require region-wide cooperation the “Peace Pipeline” was discussed as an option to provide about 360 MCM of potable water per year to Jordan under the WA scenario only. This was considered by the Scenario Panel as a possibility to ease the water situation in Jordan before water can be provided via the Red Sea - Dead Sea project. To import water via the Mediterranean was also considered feasible under the WA scenario to provide 50 MCM of water for Israel for the coming 20 years. However, options of importing water from Turkey are uncertain because agricultural water demand in Turkey is considerably rising and water supply is reported to become increasingly insecure during summer months (ALLAN et al., 2012).

Rural or urban rain water harvesting (RWH) does not generate additional water but is a reasonable measure to make water available at the right time and at the right place (if decentralized) by creating reservoir capacities to capture rainfall. In urban areas in Jordan, the West Bank and the Gaza Strip rooftop cisterns are already widely used to collect water during winter rainfalls for basic needs or water supplemental to that supplied by the water distribution system. The water is available almost at the price of constructing the cisterns. In the context of national water management an expansion of urban areas could be used to integrate rainwater harvesting facilities as a standard in the design of new private and public buildings. In rural areas rainwater harvesting is a common practice to collect water for irrigation and livestock. A disadvantage of the techniques is that water availability for potential downstream users or groundwater recharge is decreased. Rainwater harvesting is a flexible water option which can be realized either as a small-scale relatively inexpensive and decentralized option or as a large scale and centrally controlled measure.

Rural and urban rainwater harvesting play an important role in the future development of the water sector under the scenarios with poor economic development (the PP and the SWE scenario). In the long term it contributes about 115 MCM under the SWE scenario and 55 MCM under the PP scenario, which amounts to about 6 % of the “New Water” supply under SWE and about 2 % under the PP scenario.

2.2.2.3 Land management

An integration of the land management aspect in a sustainable water strategy will have a considerable impact on the overall water balance in the region since agriculture is one of the major water users. Moreover, the use of land, both for housing and agriculture, can have an impact on existing natural ecosystems and their biodiversity. Simulation results of the land-use model LandSHIFT.JR indicate that population growth can increase the demand for housing area by 44 % up to 56 % under the SWE and the WA scenario, respectively (see results of Chapter 8). The agricultural sector in the future has to supply an increasing population with agricultural goods and has to do this with a limited supply of fresh water for irrigation. In addition, rain-fed agriculture as well as livestock grazing are highly vulnerable to the anticipated climate induced decrease of the amount and reliability of rainfall.

In order to cope with these challenges several options were discussed and quantified during the scenario process:

- the water saving potentials of increasing irrigation efficiencies,
- the availability and use of treated waste water,
- limitation of water allocation to agriculture (via regulation or price signal as incentive),
- extension and intensity of livestock grazing.

In Table 2.2 the non-quantifiable measures such as e.g. governance aspects or changing cropping patterns that were discussed during the scenario workshops under the four scenarios are summarized.

Table 2.2: Future development of the agricultural sector and the related environment.

Willingness & Ability	Poverty & Peace	Modest Hopes	Suffering of the Weak…
Short term Standards for agricultural inputs, soil conservation Regulations for safe disposal of waste Action plan for nature reserves & regional corridors Regional institution for environmental research & conservation Medium term Regular revision of action plan incl. financial analysis (→ adaptive management) Long term Sustainable use of natural resources on regional basis	Short-term Awareness campaigns for environmental protection Scientific survey: Areas of high conservation priority identified Medium term Optimization of cropping patterns ($/m³ of water) Ecotourism: Network of nature reserves implemented, staff adequately trained Tax incentives for environmental friendly infrastructure Long term Establishment of peace parks	Short term Small enlargement of irrigated area Medium term Individual projects for stream restoration Further enlargement of irrigated area Long term Natural water resources rehabilitated (with exception of Dead Sea due to lack of cooperation) Further enlargement of irrigated area	Short & medium term Increased use of brackish water Adjustment of cropping patterns to changing (climate-) conditions (dates, olives) Long term More water saving in agricultural sector where possible

2.2.2.4 Adaptation to climate extremes

Beside the water sector, rain-fed agriculture and pasture farming are directly affected by and especially vulnerable to the occurrence of extreme climate events. According to simulation results of TÖRNROS & MENZEL (2011) the frequency, length and severity of droughts are projected to increase. Consequently, irrigation water requirements during longest drought periods in the future period 2031-60 are about 40 % higher than for longest drought periods in the reference period 1961-90. Coping with extreme fluctuations in precipitation is therefore one of the key issues of future water management. Heavy rainfall events have been seen as an opportunity to generate extra water by increasing storage capacities in wadis especially in Palestine and Jordan as can be seen from the overview in Table 2.3.

In general, the scenarios with the economic capability to provide large amounts of extra water (either on regional or on national level) will suffer less. Building and protecting water reservoirs (e.g. groundwater or dams), planning of extra water resources (e.g. extra desalination capacity) and limiting water supply to agriculture (with financial compensation for farmers where this is economically possible) are among the options open for coping with extremes especially in drought periods.

Table 3.3: Options for adapting to climate extremes (droughts & floods).

Willingness & Ability	Poverty & Peace	Modest Hopes	Suffering of the Weak…
Budget for extra waste water treatment & desalination capacity as permanent and secure sources Focus on regional drought anticipation & cooperation Phase out crops w high water demand, introduce drought tolerant crops Aquifer recharge using treated waste water & desalinated water	More efficient use of rain water harvesting during rain periods Adapt cropping periods in agriculture Reinforce optimal (minimum requirement) crops Optimize agricultural practice (e.g. irrigation) Be prepared for (virtual) water import Restructure water pricing in all sectors Grey water for garden watering in large buildings	Quicker expansion of desalination capacity Drought in agriculture: compensation for farmers, alternative production schemes Rain water harvesting to generate drought reserves	Awareness raising & increase of water prices in case of drought periods Jordan: prevent groundwater abstraction by farmers, cut summer irrigation in JV Israel: abandon agric. areas in the south, supplemental irrigation in the North, minimum water for agriculture, Small earth dams for flood water harvesting Use full potential of urban water harvesting & cisterns for rural water harvesting Drought tolerant crop varieties

2.2.2.5 Cross-cutting strategic options

In order to focus and identify those results of the scenario process and strategy development which are robust i.e. applicable under all scenarios, the participating stakeholders worked out a list of so-called “cross-cutting strategic options“. Out of this list three options have been discussed in more detail. These three options are from the perspective of the stakeholders the ones which are necessary and at the same time – considering the present political development – feasible in order to realize first steps of a regional water management:

(1) Implementation of a Regional Center for Water & Environmental Research

- Research
- Education, training, public awareness campaigns
- Technology development & transfer, pilot studies

(2) Towards harmonized planning

- “Prepare for cooperation” → identify regional management issues
- Share information, national plans, solutions
- Joint technical committee to discuss specific issues

(3) Regional projects

- Red Sea / Dead Sea Project
- Sea water desalination (JRSP, Gaza, Med. Coast)
- [Jordan River restoration]
- Waste water treatment

Especially option (1) has been seen as a feasible and promising option which would address several requirements. Such a regional research center would be a suitable frame in order to

- provide continuity for the dialogue between representatives of the three countries and other organizations working in the region which was started in the Glowa JR project and continuously intensified during the project’s lifetime;

- integrate young scientists in a dialogue with stakeholders and decision makers in order to practice communication of scientific results at an early stage of their scientific career. The communication and utilization of scientific results was often perceived as difficult but considered necessary and would considerably increase the relevance of scientific work for decision making and planning in the region;
- continue regional climate modeling, maintain, enable or intensify applications of the regional WEAP model e.g. by adding an economic module and including the continuous updating of databases as an indispensable prerequisite for a scientifically sound regional water management.

2.3 Applied value of results

The three scenario panel meetings provided opportunities for a structured and target-oriented discussion of water and land management issues with a strong focus on the regional (transnational) level between participants from all three countries. The same is valid from the perspective of different sometimes competing water using sectors: Here, the scenario panel meetings provided the opportunities to get to know in more detail and discuss the perspective of different persons from relevant water-using sectors which could improve the coordination between sectors within countries.

2.4 References

Allan JA, Malkawi AIH & Tsur Y 2012. Red Sea–Dead Sea Water Conveyance Study Program. Study of Alternatives, Preliminary Draft Report. URL: http://go.worldbank.org/9BEGALRN40 (viewed 02/2013)

CBS 2011: Israeli Central Bureau of Statistics. Israel in Figures - 2011. Available at http://www1.cbs.gov.il/reader/publications/israel_fig_e.htm (viewed 02/2012).

Dreizin Y 2007. Waste water reuse in Israel – Risk Assessment. In: Zaidi, MK (ed.): Wastewater Reuse – Risk Assessment, Decision-Making and Environmental Security. Springer. 297-303.

HWE 2009. House of Water and Environment: The “New Water” Question. Studying desalination, wastewater reuse and water transfer options in the future of the Palestinian water sector. Report GLOWA JR project - Phase III, 37 pp.

IPCRI (Israel/Palestine Center for Research and Information) 2010. Fact Sheet #2 Water Imports – An Alternative Solution to Water Scarcity in Israel, Palestine, and Jordan? http://www.ipcri.org/files/waterimports.pdf (viewed 03/2012)

MA 2005. Millenium Ecosystem Assessment, URL: www.maweb.org

Marie A & Vengosh A 2001. Sources of Salinity in Ground Water from Jericho Area, Jordan Valley. Ground Water, 39, 240-248.

MWI 2009. Ministry of Water and Irrigation. Water for Life, Jordan’s Water Strategy (2008-2022), 70 pp.

Schwarz, J 2011. Personal communication.

Seder N & Abdel-Jabbar S 2011. Safe Use of Treated Wastewater in Agriculture.

Jordan Case Study. Arab Countries Water Utilities Association (ACWUA). Available at

http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/110/Jordan_-_Case_Study(new).pdf (09/2012)

Törnros T & Menzel L 2011. GLOWA Jordan River Annual Report 2011, Hydrological drought analysis, pp 117-122.

World Bank 2009. West Bank and Gaza. Assessment of restrictions on Palestinian water sector development. World Bank Report No. 47657-GZ. 136 pp.

3 WEAP analysis

The report was assembled by: C. Bonzi, University of Tübingen, Germany
Based on work and publications by:
H. Hoff, Stockholm Environment Institute, Sweden
B. Joyce, Stockholm Environment Institute, Boston, USA
C. Bonzi, University of Tübingen, Germany
A. Rimmer, KLL, Israel
Y. Salinger, R. Sade, STAV-GIS, Israel
C. Lipchin, Arava Institute, Israel
A. Salman, ATEEC, Jordan
A. Omari , ATEEC, Jordan
A.R. Tamimi & M. Abu Saada, Palestinian Hydrology Group, PA
A. Jayyousi, An-Najah Universit, PA
M. Haddad, An-Najah University, PA

3.1 Aim

Refine WEAP models and current water balances for Israel, Jordan and the Palestinian Authority as well as the region-wide model, based on updated information from various GLOWA Jordan River subprojects. Analyze and compare a series of regional scenarios and water-management options and prepare a decision support tool for stakeholders in the region which will be used post-GLOWA.

3.2 Description of research

GLOWA scientists together with stakeholders from Palestine, Jordan and Israel have developed conceptual WEAP models and initial WEAP representations of the regional and sub-basin water systems (Upper Jordan River WEAP, Western and Eastern Lower Jordan River WEAP). The WEAP development in the Jordan River Basin can be described as a nested approach, accommodating data of variable resolution and facilitating data sharing between different institutions. The WEAP applications start from sub-catchments, addressing very specific local management options. Sub-basin models have been developed by the respective national partners e.g. for the upper Jordan River (Sivan et al 2007. Sade et al, 2011), the West Bank (Almasri et al 2009, Haddad et al 2007), Jordan Valley and the Amman-Zarqa basin (Al Omari et al 2011). Applications at higher level up to basin scale (Hoff et al, 2011) use aggregate information from sub-regional WEAP simulations. The sub basin WEAP applications addressed the following research questions:

- The regional WEAP
- WEAP implementation for the Jordan Valley and Amman-Zarka basin addressing climate change and large scale water management options.
- WEAP-MODFLOW Coupling for the Western Mountain Aquifer addressing the question of aquifer management under climate change
- West Bank WEAP model using for the four developed story and simulation scenarios for estimating “New Water” options.
- WEAP simulations for the upper catchments of the Jordan River under various precipitation and evaporation scenarios using 4 different climate scenarios.

3.2.1 Material and methods

WEAP is a water resources management tool, based on water balance accounting principles. It allows testing sets of scenario conditions of supply, demand and quality, in order to develop adaptive management strategies. WEAP is used to develop and assess a variety of scenarios that explore the physical changes to the system, such as transfers or desalination, as well as socio-economic changes, such as policies affecting water allocations or population growth. The implications of these policies can be evaluated with WEAP's graphical display of results.

3.2.2 Results

3.2.2.1 Regional WEAP

We have reached a new consensus database and a basin-wide WEAP tool. This regional WEAP application can - as currently done in the GLOWA Jordan River project by using this tool for integration - be used for future research and basin approaches to assess how blue or green water resources can contribute to future water needs in the region.

To verify input data, harmonize data and chosen assumption we have validated some of the key system components (see Figure 3.1)

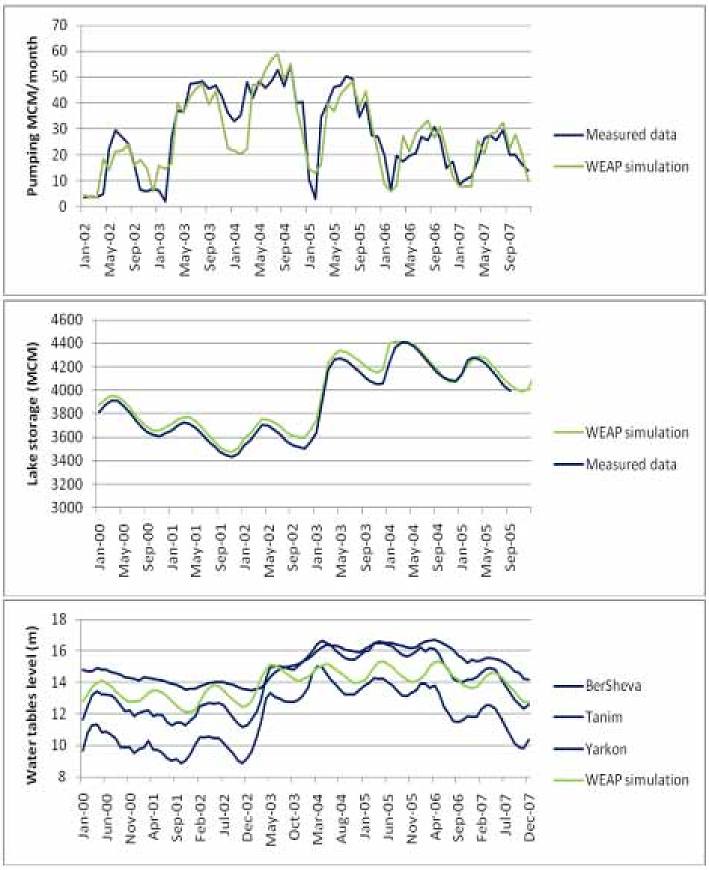


Figure 3.1: Simulated Vs. measured values for a) the Israeli National Water Carrier, b) volume of Lake Kinneret, c) aquifer levels in parts of Western Mountain Aquifer.

In the GLOWA JR project a range of subprojects model and describe the effect of climate change and regional change on water availability and on water use throughout the Jordan River basin. The Regional WEAP tool integrates scientific results from these different subprojects and links them together into a consistent framework of supply and demand (Figure 3.2).

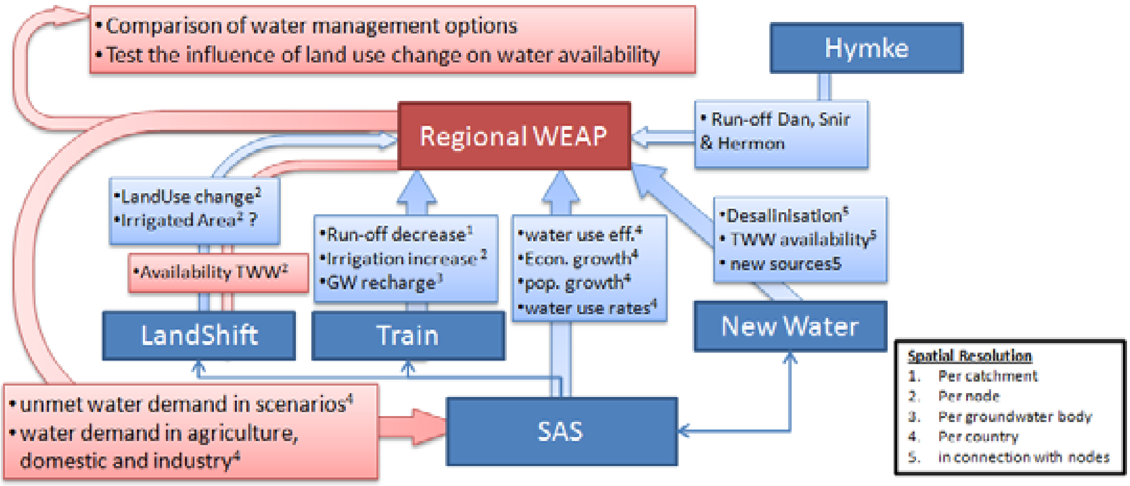


Figure 3.2: Flow chart illustrating data Exchange between GLOWA JR sub-projects and the Regional WEAP.

This input includes projecting population, land use, and climate trends as well as considering planned interventions to mitigate increasing demand.

Using the WEAP scenario analysis we have made the following analysis and presented them at conferences and discussed them with stakeholders (Figure 3.3):

- Evaluation of 4 different socio-economic futures based on the GLOWA SAS scenarios
- Comparing and evaluation of the development of unmet demands on a regional level for a set of water management interventions (rainwater harvesting, desalination of brackish water, water imports and more wastewater reuse) to the effects of one large scale, all under current socio-economic conditions. The model showed that the political and physical constraints inhibit the impact of large scale solutions on regional water scarcity, compared to decentralized approaches.
- Compares regional unmet demands from socio-economic scenarios (using drivers from the SAS subproject) with climate change driven scenarios (based on the eco-hydrological TRAIN model). The results show that the potential impact of climate change is high (it could double unmet water demands), the socio-economic impact however have a far greater potential.

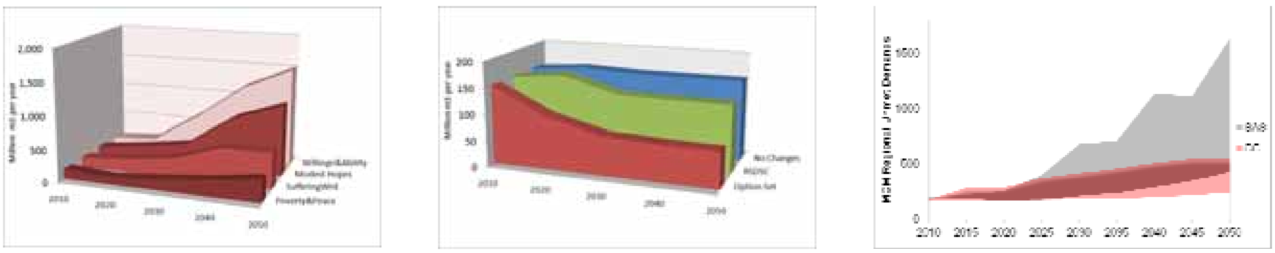


Figure 3.3: Simulated unmet water demands for
a) the 4 SAS scenarios,
b) a scenario assuming no socio-economic change compared to a set of water management options and the implementation of the RSDS and
c) the comparison of regional unmet demands of a "pure" socio-economic scenario (SAS, gray) with a scenario only regarding climate change (TRAIN, red).

A focus was on the integration of water balance data under climate change. In GLOWA JR a first time overview of the current and possible future water conditions of the Jordan River basin have been calculated using a hydrologic model, TRAIN, with spatially explicit projections on the level of small catchments (1x1km^2). Changes in water supply and demand as a result of Climate change were extracted from these outputs and introduced into the regional WEAP model (Figure 3.4).

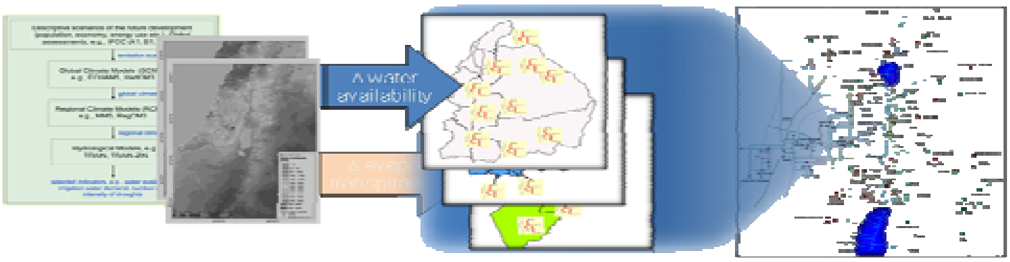


Figure 3.4: Model flow TRAIN -> WEAP: The TRAIN model used downscaled climate data from regional climate models to estimate future water availability, evapotranspiration, and irrigation. Gridded TRAIN outputs were used to estimate changes in supply and demand throughout the Jordan River Basin.

An initial assessment of climate change impacts on water management using the regional WEAP model can be seen in Figure 3.5, where one baseline and two climate change scenarios were each run under 14 sequences of the historical hydrology. These results suggest that increasing demand and decreasing supplies with climate change may further constrain operations and lead to a doubling of total unmet demands in the Jordan River Basin by the middle of the century.

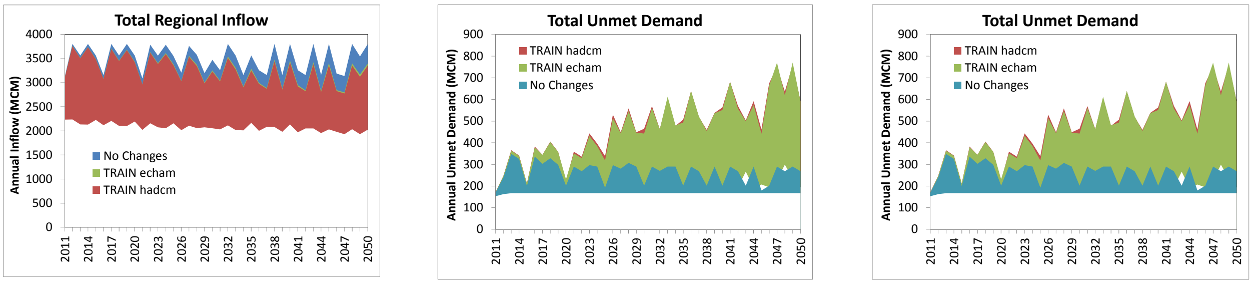


Figure 3.5: Changes in regional water availability, 2010-2050, for 3 scenarios run under 14 hydrological sequences.

3.2.2.2 Jordan Valley WEAP

Figure 3.6 shows domestic demands for the main cities in AZB and the JV as well as agricultural demand in the Jordan Valley. Figure 3.7 shows rapid increase in the domestic demand as a result of the high population growth and the projected increase in the per capita water demand due to the socio economic development. Figure 3.6 shows that the agricultural demand in the Jordan Valley was about 321 MCM for the year 2010 which is expected to drop slightly for the year 2025 to reach about 306 MCM which will remain steady until the year 2050. Figure 3.7 shows the projected deficiency in the irrigation demand in the JV for the planning period for the different scenarios considered in this paper. This Figure shows that the RDC project is expected to help reduce the increasing deficiency in the irrigation demand in the Jordan Valley due to climate change significantly. The deficit in the agricultural demand in the JV for the year 2050 will drop from about 195 MCM for the climate change scenario to about 85 MCM for the RDC scenario.

Figure 3.8 shows the projected deficiency in the domestic demand in Amman for the three scenarios for the planning period. This Figure shows that the unmet domestic demand is expected to grow for the BAU scenario which will be even more under the climate change scenario. This Fig. shows that the RDC scenario will bring the unmet domestic demand from about 186 MCM for the climate change scenario to Zero for Amman city for the year 2050. The unmet demand in Zarqa city showed similar trend.

Figure 3.9 shows pumping form AZB groundwater for the three scenarios. This Figure shows that the implementation of the RDC project will save AZB groundwater which can be used to satisfy other growing demands in the basin i.e. industrial demand or demands outside the basin i.e. domestic demand in Irbed governorate. Figure 3.10 shows that the groundwater resources from south of Jordan are no longer needed to satisfy domestic demands in Amman and Zarqa cities, they rather can be saved to satisfy the increasing domestic demands south of Jordan.

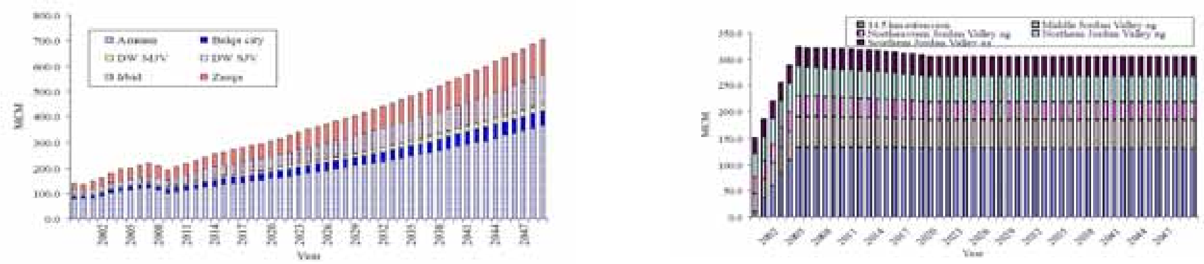


Figure 3.6: Projected demand in the study are (a) domestic (b) agricultural.

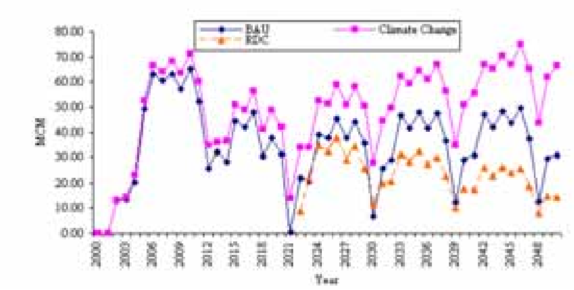


Figure 3.7: Projected unmet demand in the Jordan Valley for three different scenarios.

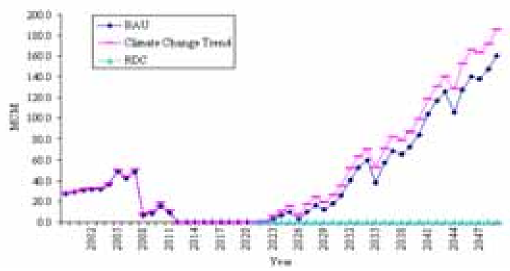


Figure 3.8: Projected unmet domestic demand in Amman for three different scenarios.

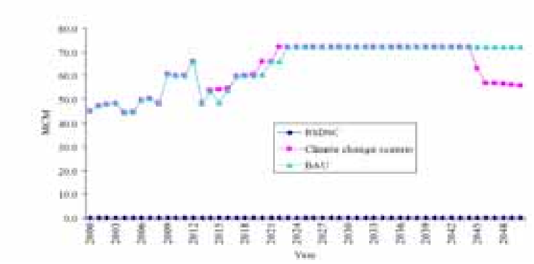


Figure 3.9: Projected pumping from AZB for three scenarios for the planning period.

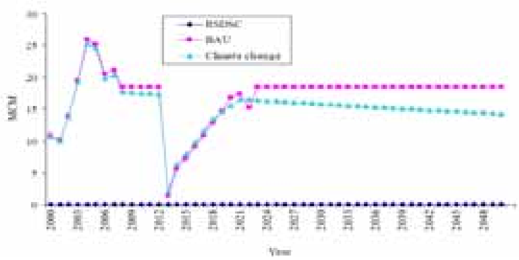


Figure 3.10: Projected pumping from groundwater sources south of Jordan.

3.2.2.3 WEAP-MODOFLOW Coupling

The MODFLOW model for the Western Aquifer Basin (WAB) was linked to the WEAP. The WAB is divided into 8 management zones based on the confinement line, Figure 3.11.

- Using the coupled model for the WAB, the water budget for each zone was calculated.
- Developing two rainfall scenarios based on the historical rainfall records and from the regional climate model developed by Glowa III, Climate project, Figures 3.12 and 3.13.

Figure 3.11: Schematic diagram of WEAP-MODFLOW of the WAB.

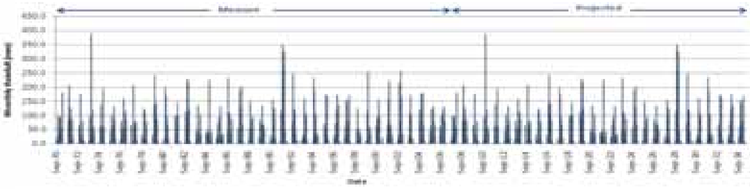


Figure 3.12: Normal rainfall scenario (no climate change).

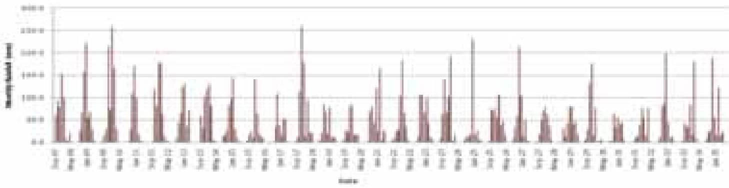


Figure 3.13: Reduced rainfall scenario due to Climate change[1].

Figure 3.11: Schematic diagram of WEAP-MODFLOW of the WAB.

- Developing three pumping schemes taking into consideration the sustainability of the aquifer and the demand. These schemas are:
- Moving average pumping scheme, pump 85% from the 7 years moving average of estimated annual recharge.
- Aquifer yield pumping scheme, where pumping rate is constant (85% from the sustainable yield of the aquifer)
- Related pumping scheme, which relate the annual pumping rate to annual rainfall (i.e. increase pumping rate in dry years).
- Develop one management scenario. This scenario assumed the part of the storm water in the main watersheds in the WAB will be artificially reached to the aquifer.
- The climate, pumping and management scenarios were used to generate 24 management options for managing the WAB. These 24 management options were analyzed using the coupled MODFLOW-WEAP model. Some obtained results are shown in Fig. 3.14.

[1] Climate simulations produced at TAU for the BMBF project GLOWA Jordan River (http://www.glowa-jordan-river.de) with RegCM3 in 2009-2010 (Krichak S. O., Alpert P (2010) Projection of climate change during first half of twenty-first century over the Eastern Mediterranean region according to results of a transient RCM experiment with 25 km resolution. Geophysical Research Abstracts, EGU2010)

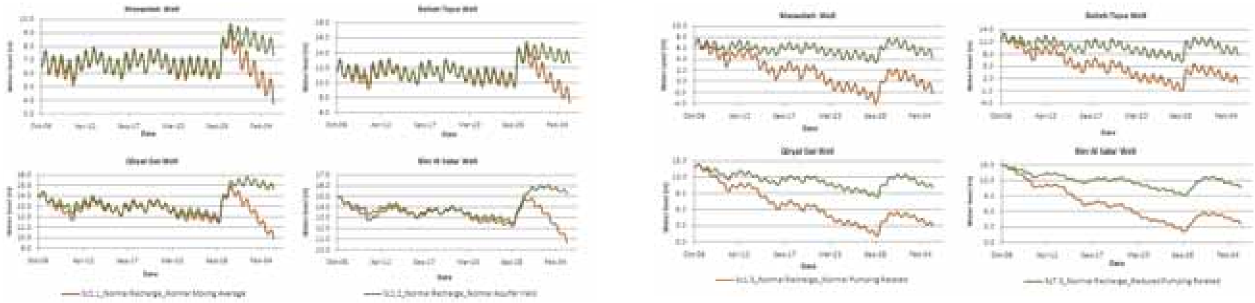


Figure 3.14: Exemplary graphs showing water levels for 4 of the 24 scenarios.

3.2.2.4 Westbank WEAP

New Water Model

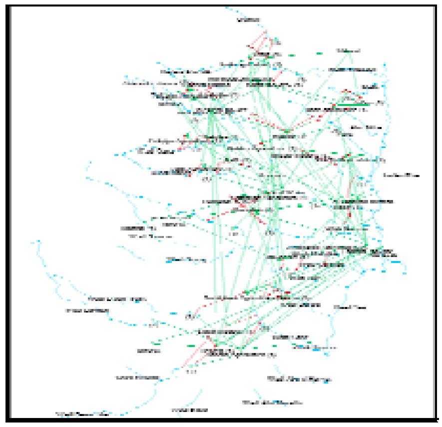


Figure 3.15: Schematic of WEAP West Bank Model.

The West Bank WEAP – new water model was run under the following new water options:

- Water Transfers – preliminary evaluation of different water transfer schemes including Red Sea-Dead Sea Canal (including side-impacts), water transfers from Turkey, and other proposals
- Desalination – evaluation of its potential, costs and side-effects.
- Wastewater reuse - the volume and quality of usable wastewater, costs and side-effects are estimated.
- Water demand and demand management – future water use in the domestic, irrigation, livestock and other sectors.

Summary of results of the West Bank WEAP - New Water model run

- Desalination: it is introduced as a new supply source of water next to Jericho called Al-Fashkha with a start year of 2015 and amounts of 20, 50, 70 MCM/year by the 2030, 2050 respectively.
- RSDSC: Supplies water to domestic and agricultural use in Hebron and Bethlehem with the start year of 2015 and amounts of 30, 40, 70 MCM/year for years 2030, 2050 respectively with 0.7$/m^3.
- Waste water reuse: it is introduced as amounts of daily capacity total (30, 70, 274) MCM/year (2015, 2030, 2050) for 12 waste water treatment plants in Ramallah, Jenin, Tubas, Jericho, Jerusalem, Bethlehem, Hebron, Tulkarm, Qalqilia, Salfit, Western Nablus, Eastern Nablus. It was distributed based on the agricultural area in each district 33% from the water transferred was lost into the ground water recharge, with cost 0.6$/m^3.

3.2.2.5 Upper Jordan River Catchment WEAP

The main focus was to understand how the available water in different parts of the Watershed is expected to change under future scenarios. This was achieved by running LK WEAP with four different climatic scenarios:

- SC1 - Real rain series for the years 1996-2005.
- SC2 - Similar to SC1,except rain X 0.8, ET X 1.05.
- SC3 - Artificial rain series taken from Samuels et al. (2009).
- SC4 - Similar to SC3, except rain X 0.8, ET X 1.05.

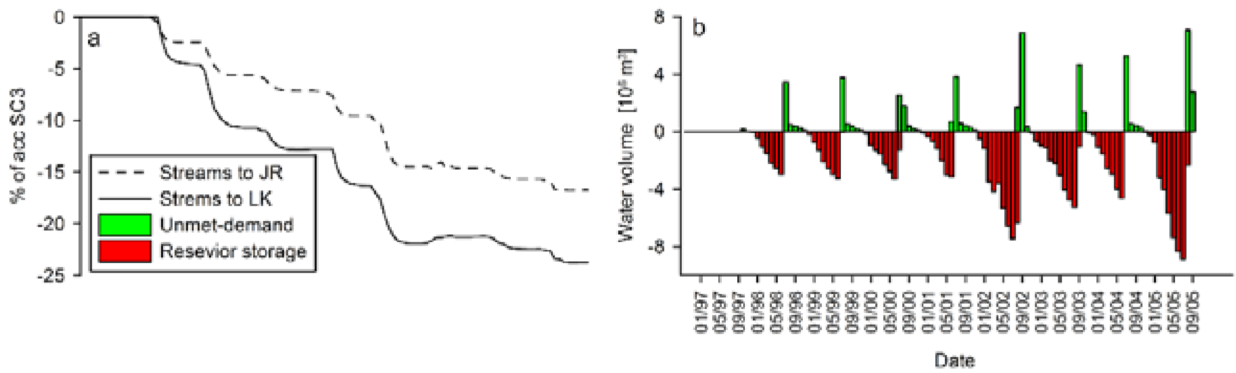


Figure 3.16: The relative accumulated flow from the Golan in SC4 as percentage from accumulated flow in SC3 (a); The change in unmet demand and storage volume in the Golan The difference in calculated results between SC3 and SC4 (b).

3.2.3 Discussion and conclusion of scientific highlights and outlook

The GLOWA JR project has led to WEAP applications and specialist knowledge in the working groups of the project and in related research, governmental and non-governmental institutions. Whereas the implementations of WEAP do not lead to new scientific findings, the benefit of the implementations lies in a better understanding of the water (management) system and the possibility to integrate scientific findings into a water management tool. This can be seen in the different applications presented under 3.2.2.

3.3 Applied value of results

The existing applications make WEAP a de-facto standard IWRM tool in the region. The proficiency that regional scientists and water managers have reached in using WEAP provide an excellent basis for further harmonization of efforts and consolidation of data, and for facilitating consultations and dialogues

Scientific model integration and basin-wide data exchange – a precondition for finding sustainable and politically viable water management solutions – have been fostered by the GLOWA JR project. Stakeholders have continuously stated the importance of an ongoing exchange between scientists and stakeholders.

Current WEAP activities and the GLOWA JR network of researchers and stakeholders provide an excellent basis for transboundary initiatives addressing a sustainable water management and promoting cooperation and eventually supporting e.g. a basin organization.

3.4 References

Al-Omari, A., Salman, A., Karablieh, E. 2011: The RDC Project: An Adaptation Option to CC in Jordan, proc. 1. Water and Env. Intern. Conf., 26-29 Oct., Marrakech, Morocco.

Almasri, M. (2009). Application of WEAP-MODFLOW in the Eocene Aquifer Basin, Palestine. First Arab WEAP conference. Damascus, Syria.

Hoff, H., Bonzi, C., Joyce, B., Tielbörger, K. 2011: A Water Resources Planning Tool for the Jordan River Basin Water 2011, 3(3), 718-736

Sivan I., Salingar Y., Rimmer A. 2007: A WEAP model of the Kinneret basin, Wat Eng 53, 50-58.

Marwan Haddad, Anan Jayousi and Salam Abu Hantash 2007: Applicability Of WEAP As Water Management DSS Tool On Localized Area Of Watershed Scales: Tulkarem Distr. in Palestine, 11th Int. Water Techn. Conf., Sharm El-Sheikh, Egypt.

Rotem Sade, Yigal Salinger, Alon Rimmer, WEAP simulations for Lake Kinneret catchment under various precipitation and evaporation scenarios (2011). Glowa Jordan River, Limasol Cyprus.

4 Simulation based guidelines for management of uncultivated rangelands subject to climate change

Florian Jeltsch, University of Potsdam, Germany
Katja Geissler, University of Potsdam, Germany
Dan Malkinson, University of Haifa, Israel
Martin Köchy, University of Potsdam, Germany

4.1 Aim

We link and use the dynamic, process-based models constructed in phase 1 and 2, including the latest climate change projections, to

- Project the mean and variance of natural vegetation cover and green biomass production for general and specific landscapes for a range of climate change and land-use scenarios, such as grazing, fire and tree/shrub cutting,
- Project further the effect of changes in vegetation on the stocking capacity and on generation of runoff and erosion and indicate the likelihood of results,
- Evaluate the models to test hypotheses regarding the benefit of environmental variability for populations with a seed bank,
- Evaluate the ecohydrological models regarding feedback loops between vegetation and soil hydrology at the sub-watershed scale,
- Assess landscape vulnerability to specific climate change and land-use scenarios and extreme events,
- Scale floristic diversity from plots at field sites to landscapes including effects of climate change, vegetation change, and land-use/management,
- Present results as maps with accompanying reports for means and variance of vegetation productivity, composition, stocking capacity, runoff, and erosion.

Further, we analyzed the relationship between climatic factors and wildfire properties to project future wildfire risk due to climate change, and parallel to that we analyzed the soil erosion risks of the region north of the 200mm precipitation/year. We combined the two analyses in order to estimate which regions may be at greater risk to soil erosion as a result of wildfires.

4.2 Description of research

4.2.1 Material and methods

We conducted simulations of semi-natural vegetation for five climatic regions (arid to mesic Mediterranean). Four of these regions correspond to the ecological field sites of GLOWA in Israel (Holzapfel et al. 2006) from which we obtained data for model parameterization. All sites are located on South-facing slopes with 15° inclination. In the simulations the inclination was varied from 0° to 30° and the stocking rate (animal density) between 0 and 8 animals/ha (1 animal = 10 sheep or goats). Typical stocking rates in the Middle East range between 0.8 and 2.3 animals/ha (Osman et al. 1991). All the different projections that result from the simulations of vegetation dynamics in our idealized wadi landscapes were interpolated by non-linear regression to provide estimates along the whole precipitation gradient. These equations were applied to precipitation maps in a geographical information system to eventually extrapolate the results to other regions with similar precipitation, slope, and temperature characteristics (Figure 4.1). To run our simulations we prepared daily precipitation time series of 5 global/regional model combinations of the GLOWA climate simulations of the A1B IPPC emission scenario (Table 4.1). Time series were provided by IMK-IFU (Smiatek & Kunstmann) and by Tel-Aviv University (Krichak & Alpert).

Table 4.1: Overview of used climate model combinations following the A1B scenario of the IPPC.

Global climate model	Regional climate model	Spatial resolution	Time window	Number of biascorrected time series used
ECHAM5	MM5 3.7	10' (≈18 km)	1961-2060	5-45
ECHAM5	MM5 3.5	10' (≈18 km)	1961-2060	5-122
HadCM3	MM5 3.7	10' (≈18 km)	1961-2060	5-52
HadCM3	MM5 3.5	10' (≈18 km)	1961-2060	5-65
ECHAM5	RegCM3	15' (≈25 km)	1961-2060	5-43

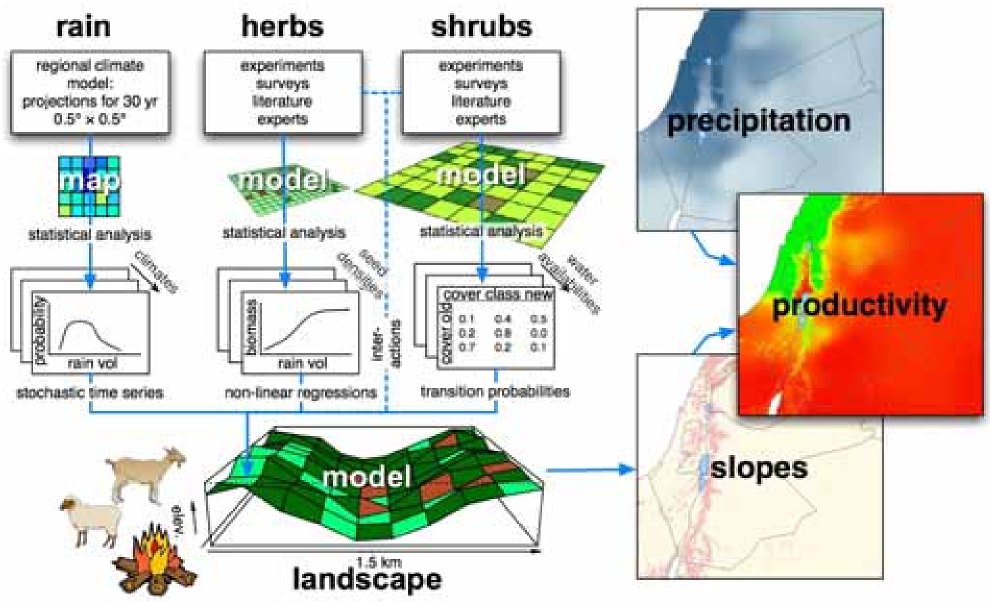


Figure 4.1: Visualization of the WADISCAPE model and our cascading modeling approach. Information from fine-grained models is aggregated to stochastic if-then rules, transition probabilities, or non-linear functions and included in coarse-grained models ensuring a continuous flow of information including variability in the scaling process.

We used an extended version of the spatially explicit landscape model WADISCAPE (Köchy 2008, Matthay 2007) to explore the consequences of climate change, namely those of precipi-tation, grazing by sheep and goats, and management measures such as prescribed fire and tree/shrub cutting on green biomass production of the potential vegetation, its cover, the system's carrying capacity for livestock grazing, tree growth, shrub encroachment and the generation of soil erosion and runoff. We used an average global value for the food demand of goats and sheep of 1 kg dry matter/d/animal. It's the value used by FAO and we think it is more representative of rural breeds than the observed food intake of goats in Israel of 1.35 kg/goat in Perevolotsky et al. (1998). The model simulates the growth of herbs, dwarf shrubs and two tree types (deciduous, evergreen) at a spatial scale of landscapes (1.5×1.5 km² extent) on 6 different topographies. It synthesizes results of two specialized fine-grained models (Figure 4.1) and thus condenses and integrates information obtained from field experiments and literature data. The strong influence of water availability is the main driver of vegetation dynamics. The model uses 1-month time steps. Foraging is restricted to parts of the year according to common practice in Israel (Gutman et al. 2000). If there is a fire, we assume a 50% chance of having it in either May or June, corresponding to the empirically observed peak of fires in Israel. As a management practise to control shrub and tree cover, trees may be cut. The cutting is done in regular intervals. We assume that the trees are cut down to a height of 0.5 m but are not killed by the cutting (Perevolotsky & Haimov 1992).

To systematically explore the relevance and effects of extreme climate events for the GLOWA region on vegetation and soil hydrological processes we used a modified version of another vegetation model (EcoHyD) with a stronger emphasis on ecohydrological processes (TIETJEN et al. 2009). Stochastic time series of daily precipitation that serve to drive this model were generated by the rain generator ReGen of KÖCHY (2006a).

To test whether a shrub effect on soil moisture is sufficient to explain observed pattern of annual herb distribution we used the spatially explicit model AnnuGrow (KÖCHY 2006b) with an added shrub component. The model simulates seed bank dynamics, growth and water dynamics at a resolution of 1cm/1 day and five soil layers. Changes were explored along a simulated precipitation gradient and compared with field data of spatial distribution of soil moisture and biomass of herbs under or between shrubs along the real climate gradient (HOLZAPFEL et al. 2006, METZ 2010, PARIENTE 2002). Stochastic time series of daily precipitation were also generated by the rain generator ReGen of KÖCHY (2006a).

Upscaling of floristic diversity from plots at field sites to landscapes was done with data from subproject 3.1.2 (see Chapter 5) and from the BioGIS data-base (Hebrew University of Jerusalem, 1998-2003). We used the number of annual plant species as a proxy of diversity.

To assess the potential changes in the wildfire regime in the region and considering the claim of LEVIN & SAARONI (1999) that favorable meteorological conditions allow fire development and propagation, we examined the relations between the sizes of the burnt areas to the prevailing weather conditions before and during the fire events and a series of increasingly complex indices which we considered to reasonably represent the mechanistic relationships between the environmental variables. We applied stepwise regression and maximum-likelihood-estimation and compared the results with the output of the predicted climate changes of the GLOWA climate simulations. The climatic factors assessed included wind speed, temperature, precipitation, humidity and wilting days (number of days soil moisture was below wilting point). Data for the period 1991-2007 were obtained from the Israel Meteorological Service, for 14 representative meteorological stations distributed in the regions of > 250 mm. We applied Kriging procedures to spatially interpolate the values of the parameters over the entire study area. The data base on wildfire distribution and properties was received from the KKL-JNF (Keren Kayemet LeIsrael – Jewish National Fund) and the Israeli Nature and Parks Authority.

Hotspots of soil erosion were assessed by considering the spatial physiographic properties. According to the RUSLE approach we used slope length and steepness calculations and lithological properties to estimate initial vulnerability of the landscape to soil loss, using a 33m grid resolution data (HICKEY 2000, WANG et al. 2001, VAN REMORTEL et al 2001). Coupling with the wildfire analysis we identified locations which are more prone to soil degradation following wildfires.

4.2.2 Results

4.2.2.1 Effect of changes in annual precipitation amount on productivity and stocking capacity and effects of grazing

Climate simulations for the A1B scenario projects a decrease of precipitation in the Jordan River Watershed for the future period 2031-2060, regardless of the global/regional model combination used and resolution. Across the more than 100 bias-corrected time series of the global climate model ECHAM5 available for the Jordan River area, mean annual precipitation will decrease by values between 8 and 17 % dependent on the regional model. Among-year variability of precipitation is expected to increase. Annual temperatures are generally projected to increase by 1 K till the 2023-2033 period and by 2 K till the 2031-2060 period.

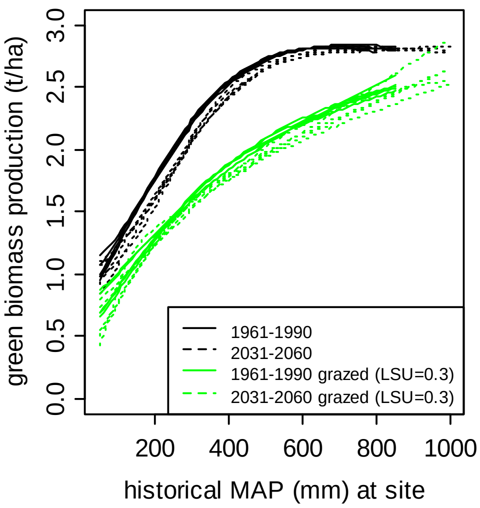


Figure 4.2: Simulated green biomass production averaged across North and South slopes and six wadiscapes (15° slopes) on historic mean annual precipitation for 5 different climate model combinations of the A1B Scenario (see Table 4.1). Continuous lines: historical time period, dashed lines: future time period. Black: ungrazed, Green: grazing with 3 animals/ha.

The relationship between simulated productivity of green biomass (herbs and leaves of dwarf shrubs and tree parts up to 1.5 m height) and mean annual precipitation (MAP) shows similar sigmoid curves for all global/regional climate model combinations of the A1B scenario (Figure 4.2).

Our simulations further indicate that average annual biomass production of both grazed and ungrazed vege-tation is only little affected by projected changes in precipitation in the Jordan River Watershed. Neverthe-less, if vegetation remains ungrazed, green biomass production in the 2031-2060 future period is more reduced in the semiarid and dry Mediterranean regions (Figure 4.2, black lines). The opposite holds for heavily grazed vegetation (Figure 4.2, green lines). Here, future green biomass production is more reduced in the arid and mesic Mediterranean regions. Grazing weakens negative climate change effects in semiarid and amplifies them in Mediterranean regions. Considered separately, grazing reduces productivity mostly in the dry and typical Mediterranean (450 mm < MAP < 600 mm). Overall, grazing reduces the productivity of the vegetation much more than projected climate changes in precipitation.

Similarly, stocking capacity, which is defined as the number of animals per hectare for which the vegetation provides sufficient food in 9 out of 10 years, is only little affected by climate change (Figure 4.3). However, and especially in more humid climates (MAP>400mm) where at first vegetation shows remarkable resilience when grazing intensity increases, production takes a steep downturn before the stocking capacity is reached (at 60-75% of stocking capacity, Figure 4.4). This is another indication of the substantial effects of grazing as compared to climate change in the Middle East. In this situation of greatly reduced productivity, cover is also reduced and additional negative effects of erosion are likely. An increasing area of open soil is thought to facilitate erosion risk, intensity and frequency. However, it is obvious that simulated erosion amount is declining at a specific relative area of open soil (Figure 4.5), probably due to opposing feedbacks between erosion and precipitation amount (Figure 4.5, right) and between precipitation amount and vegetation cover. In fact, grazing can intensify erosion processes in Mediterranean landscapes (Figure 4.5, left).

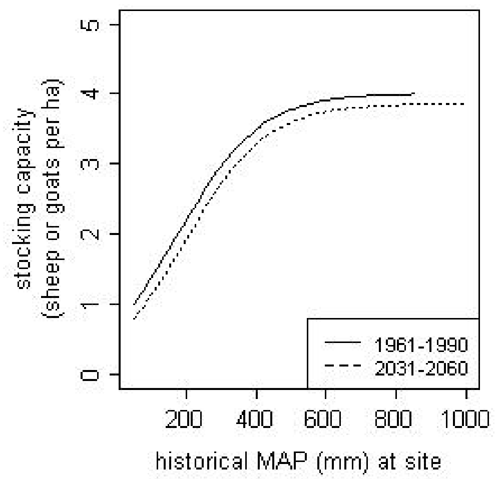


Figure 4.3: Stocking capacity averaged across North and South slopes and six wadiscapes (15° slopes) on historic mean annual precipitation for the A1B climate scenario (ECHAM5/RegCM3).

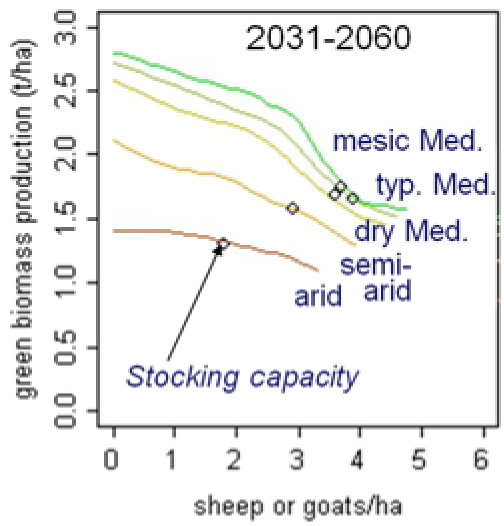


Figure 4.4: Green biomass production of a typical wadi in five climatic regions (means of six wadiscapes 15°) for 2031-2060 as a function of grazing intensity. Circles indicate the stocking capacity for each climate.

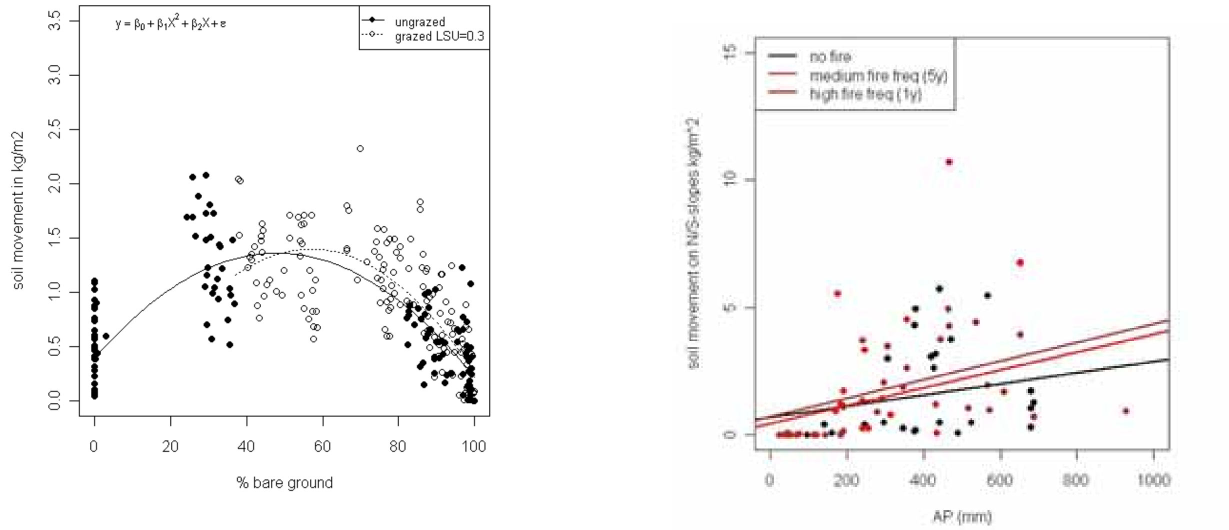


Figure 4.5: Relationship and estimates for regression between yearly soil erosion at northern and southern slopes (15°) and (left): % bare ground (+grazing effect), or (right): yearly rain amount (+fire management).

4.2.2.2 Effects of changing daily patterns of (extreme) precipitation amounts and frequency distributions on soil hydrologic processes and a community of herbs and dwarf shrubs

Up to now, landscape related considerations of possible consequences of climate change in arid regions have mostly focused on changes in the annual precipitation amount. Since these changes will be rather low in the Middle East, it was reasonable to assume that effects on productivity will also be of little importance. Meanwhile, climate scenario simulations have also been analyzed in terms of *distribution* of *daily precipitation amounts* (TÖRNROS 2010). Results show that for the Jordan River region these within-year changes are expected to be more extreme compared to among-year changes. Regarding more extreme rain events (rainstorms), our systematic simulations with EcoHyD indicate that in all climate regions both plant types, shrubs and annuals, are remarkably resilient, their cover showing only little responses. On an annual basis, the same is true for the soil hydrological processes like infiltration rate, groundwater recharge and soil moisture. It seems that in the long run Mediterranean vegetation has the ability to buffer against changes in the extent and distribution of daily precipitation amounts.

4.2.2.3 Investment in seed banks and the use of shrubs as shelters for the establishment of annual herbs

Herb mass and density were not greater under shrubs than between shrubs in the model in any simulated climate. This suggests that the observed higher density of herbs under shrubs in arid field sites is not related to greater soil moisture that is indirectly induced by shrubs but rather to more seeds dispersed to shrubs. Shrubs may simply act physically as a kind of seed trap. Since shrubs did not have a positive hydrological effect on herb performance, they could not replace the function seed bank longevity in arid climates. This is a crucial point if soil erosion will continue to increase in the future.

4.2.2.4 The effect of prescribed fire on grazed Mediterranean landscapes under climatic changes of annual precipitation amount and frequency distribution of daily precipitation amounts

Projections consist of one future period 2030-2060 of the globally moderate A1B climate scenario of the model combination ECHAM5/RegCM3 (Table 1). Simulations show a stimulating effect of fire on herbaceous vegetation, but only in Mediterranean regions. In a landscape without tree growth, average annual green biomass production of both grazed and ungrazed vegetation is reduced by regular prescribed fires, the more humid the regions are, the stronger the effect (Figure 4.6a).

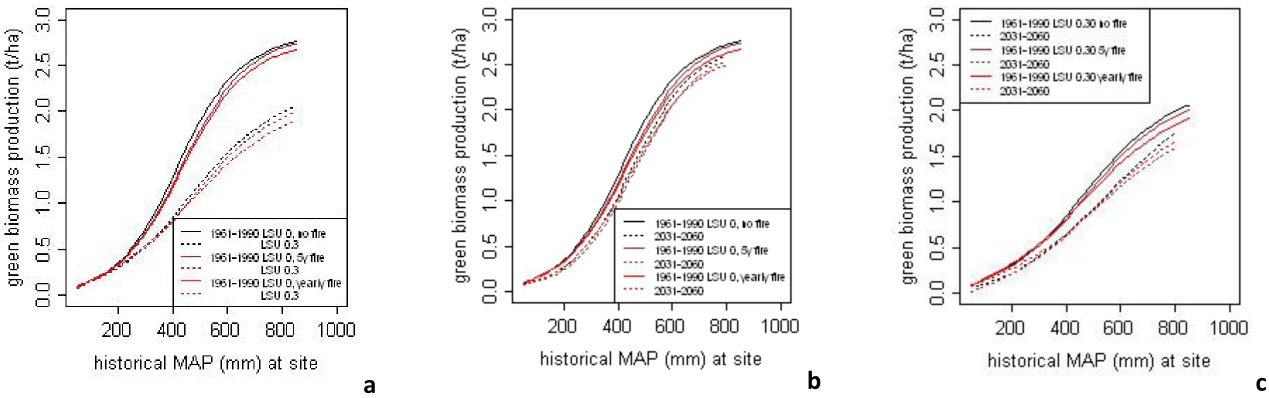


Figure 4.6: Fire effect on simulated palatable green biomass production without tree growth along the gradient of historic mean annual precipitation under grazed (0.3 LSU) and ungrazed conditions and under climate change (A1B scenario, ECHAM5/RegCM3). Averaged across North and South slopes and six wadiscapes (15° slopes).
a) grazing effect; b) climate change effect when ungrazed; c) climate change effect when grazed
Black: no fire, Brown: fire every 5 years, Red: yearly fire. Continuous lines: control (ungrazed or historical time period), dashed lines: effect (grazed or future time period).

Predicted climate change slightly amplifies this fire effect, especially under grazed conditions (Figure 4.6b,c). Compared to grazing, changes remain however low, even if prescribed fire is applied on a yearly basis. In a simulated landscape where trees are allowed to grow in addition to herbs and dwarf shrubs, regular fires start, however, to stimulate annual green biomass production of vegeta-tion when MAP exceeds 400 mm, and this happens regardless of grazing (Figure 4.7, left). Under grazed conditions, this also holds for the future time period (Figure 4.7, right), with grazing reducing future green biomass production anyway. In Mediterranean regions these grazing-based losses account for up to two-thirds of the green biomass production. If, in the humid regions, vegetation remains ungrazed, the stimulating effect of prescribed fire reverses during the next 50 years, and quite clearly so. Although Q.calliprinus saplings are known to produce long branches after a disturbance like fire, a process that is incorporated in the model, the reduction in MAP and thus water availability under climate change seems to alleviate this resprouting under ungrazed conditions. Another reason for decreased productivity is that fire acts as a blocking succession disturbance, since it prevents succession to the very productive forest stage. High fire frequencies are most effective. Moreover, our results indicate that the general risk of a great catastrophic fire is reduced by regular small prescribed fires, while grazing has a low impact. This is because adult tree cover is reduced to very low percentages (Figure 4.8).

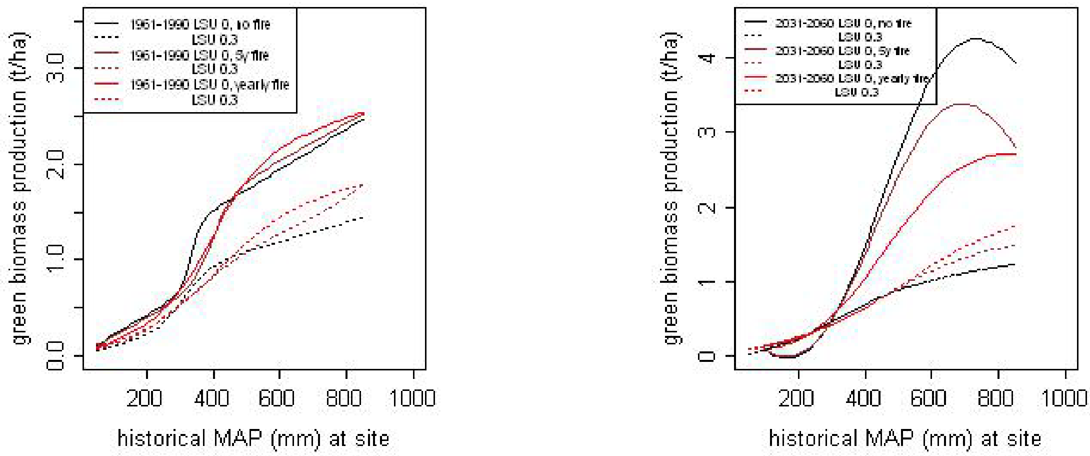


Figure 4.7: Fire and grazing effect (0.3 LSU) on simulated palatable green biomass production with tree growth allowed along the gradient of historic mean annual precipitation under climate change (A1B scenario, ECHAM5/ RegCM3). Averaged across North and South slopes and six wadiscapes (15°slopes).
left: historical period 1961-1990; right: 2031-2060.
(Linetypes and colors as in Figure 4.6)

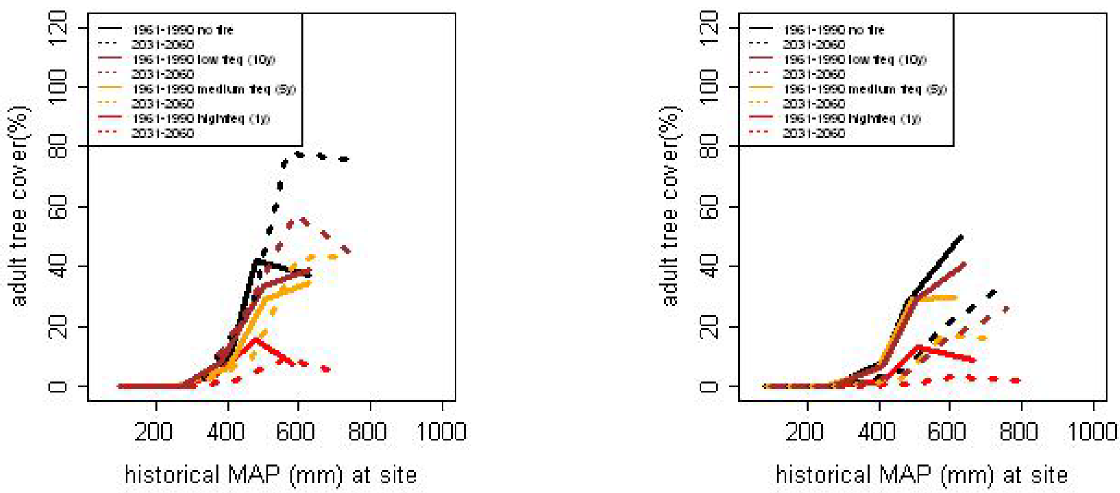


Figure 4.8: Fire and climate change effect on simulated cover of evergreen and deciduous trees along the gradient of historic mean annual precipitation, averaged across North and South slopes and six wadiscapes (15° slopes). A1B scenario, ECHAM5/RegCM3). Left: ungrazed; right: grazed (0.3 LSU)
Black: no fire, Brown: fire every 10 years, Yellow: fire every 5 years, Red: yearly fire. Continuous lines: historical period 1961-1990, dashed lines: future time period 2031-2060.

Sclerophyllous leaves of evergreen trees are regarded as very effective fuel in Mediterranean regions and as to reinforce the high crown fire hazard and fire propagation over wide areas. Crown fires often turn out to be catastrophic fires with direct negative impacts for human life. Erosion risk is however more sensitive to annual precipitation and grazing intensity and less sensitive to fire management (Figure 4.5). Also shrub encroachment (dwarf shrubs), which eventually reduces plant richness, is more sensitive to grazing intensity than to fire management (Figure 4.9), although if trees are growing in the landscape, prescribed fire even favors this encroachment.

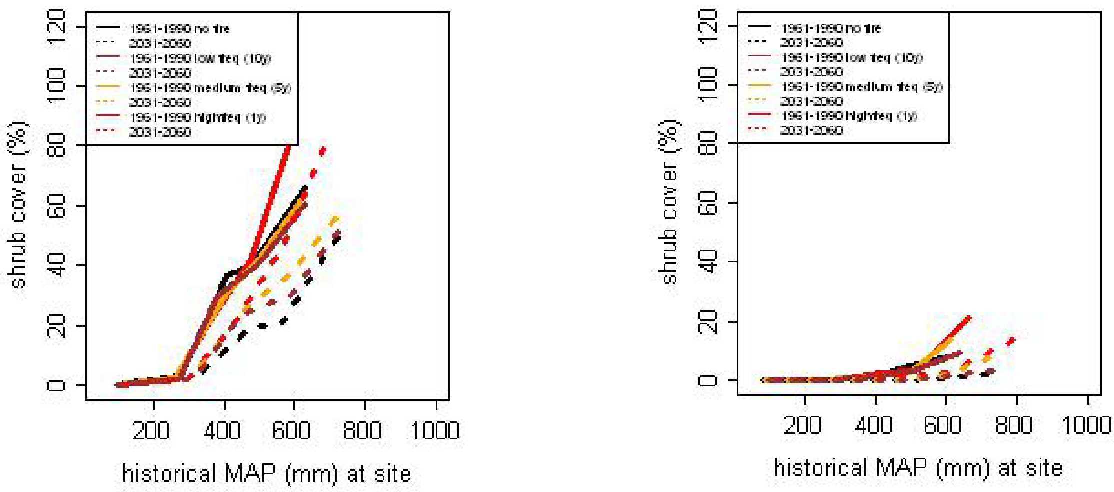


Figure 4.9: Fire and climate change effect on simulated cover of dwarf shrubs along the gradient of historic mean annual precipitation, averaged across North and South slopes and six wadiscapes (15° slopes). A1B scenario, ECHAM5/RegCM3 Left: ungrazed ; right: grazed (0.3 LSU)
(Linetypes/ colors as in Figure)

4.2.2.5 The effect of tree and shrub cutting on grazed Mediterranean landscapes under climatic changes of annual precipitation amount and frequency distribution of daily precipitation amounts

These projections also consist of the future period 2030-2060 of the globally moderate A1B climate scenario and the model combination ECHAM5/RegCM3 (Table 4.1). Our simulations reveal that tree/ shrub cutting strongly stimulates annual production of palatable green biomass in the more humid regions (MAP>500mm), with a medium frequency being most effective (Figure 4.10). In the course of the next 50 years, this effect is further enhanced, even under climate change. However, grazing nearly abolishes the cutting effect (Figure 4.11). Under grazing the biggest stimulating impact, if at all, occurred at the highest cutting frequency. The risk of a great fire is effectively reduced by cutting of shrubs and trees only if vegetation is heavily grazed at the same time (Figure 4.12). Dwarf shrub encroachment is however promoted by cutting (Figure 4.13). The erosion risk increases, although the amount of moved soil is more sensitive to grazing and less sensitive to cutting management (Figure 4.14).

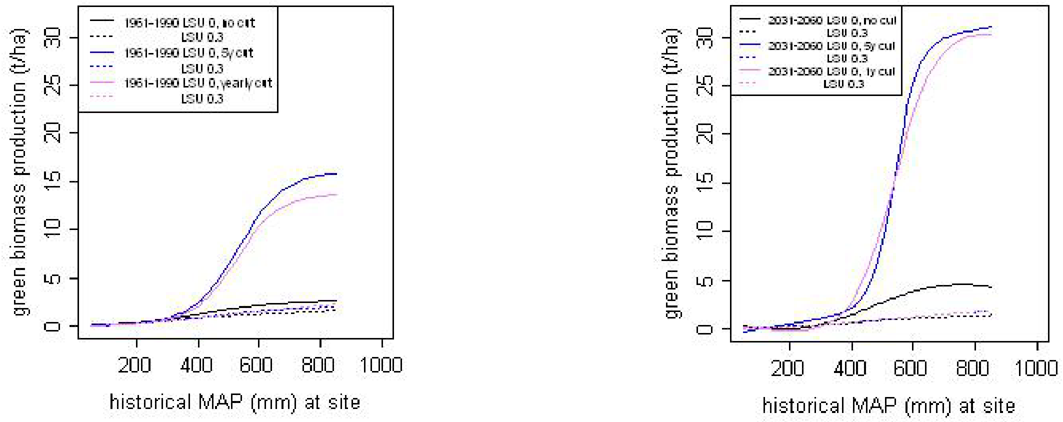


Figure 4.10: Cutting and grazing effect (0.3 LSU) on simulated palatable green biomass production along the gradient of historic mean annual precipitation and under climate change (A1B scenario, ECHAM5/ RegCM3). Averaged across North and South slopes and six wadiscapes (15° slopes). Left: historical period 1961-1990 right: future period 2031-2060. Black: no cutting, Blue: cutting every 5 years, Violett: yearly cutting. Continuous lines: ungrazed dashed lines: grazed.

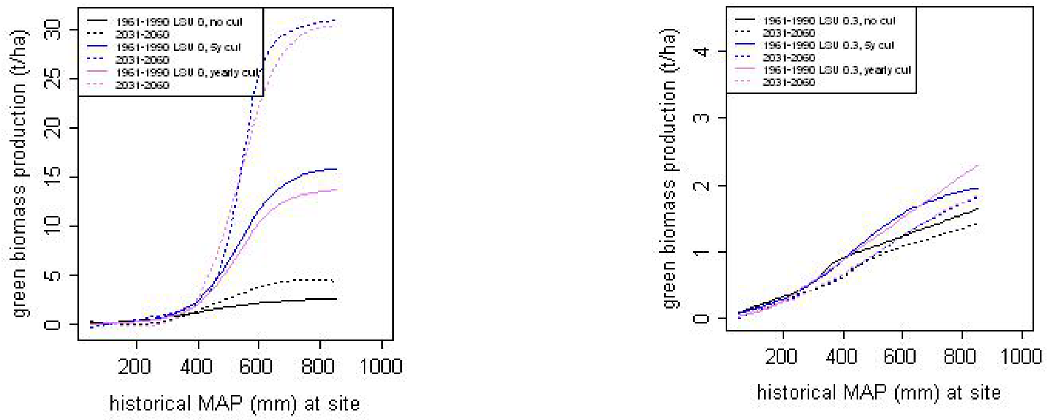


Figure 4.11: Cutting and climate change effect on simulated green biomass production along the gradient of historic mean annual precipitation (A1B scenario, ECHAM5/ RegCM3). Averaged across North and South slopes and six wadiscapes (15° slope). Left: ungrazed, right: grazed (0.3 LSU)
continuous lines: historical period dashed lines: future period 2031-2060 (Colors as in Figure 4.10).

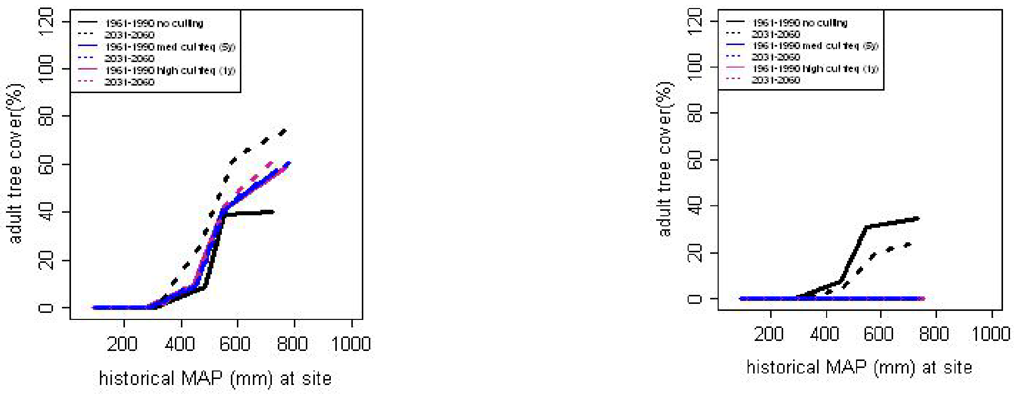


Figure 4.12: Cutting and climate change effect on simulated adult tree cover along the gradient of historic mean annual precipitation and under climate change (A1B scenario, ECHAM5/ RegCM3). Averaged across North and South slopes and six wadiscapes (15° slopes). Left: ungrazed; right: grazed (0.3 LSU).
Continuous lines: historical time, dashed lines: future time period 2031-2060 (Colors as in Figure 4.10).

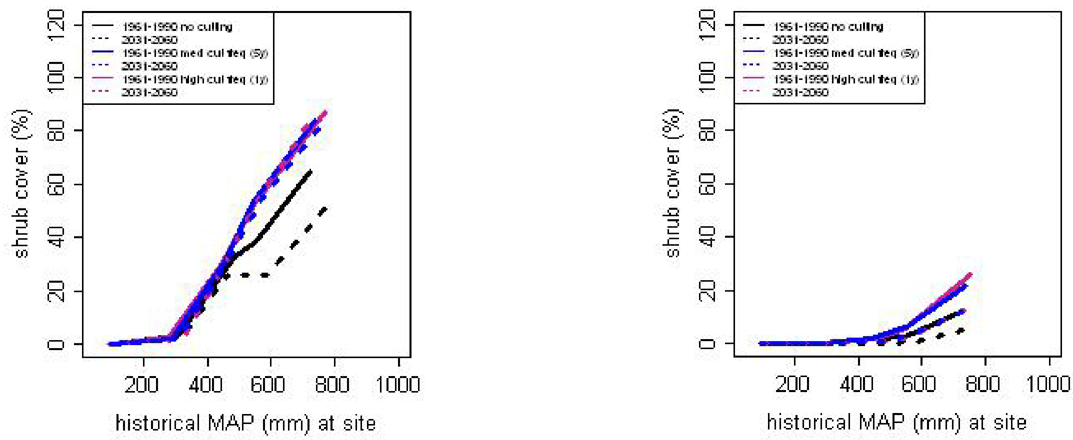


Figure 4.13: Cutting and climate change effect on simulated dwarf shrub cover along the gradient of historic mean annual precipitation (A1B scenario, ECHAM5/ RegCM3). Averaged across North and South slopes and six wadiscapes (15° slope). Left: ungrazed; right: grazed (0.3 LSU)
Continuous lines: historical period dashed lines: future period 2031-2060 (Colors as in Figure 4.10)

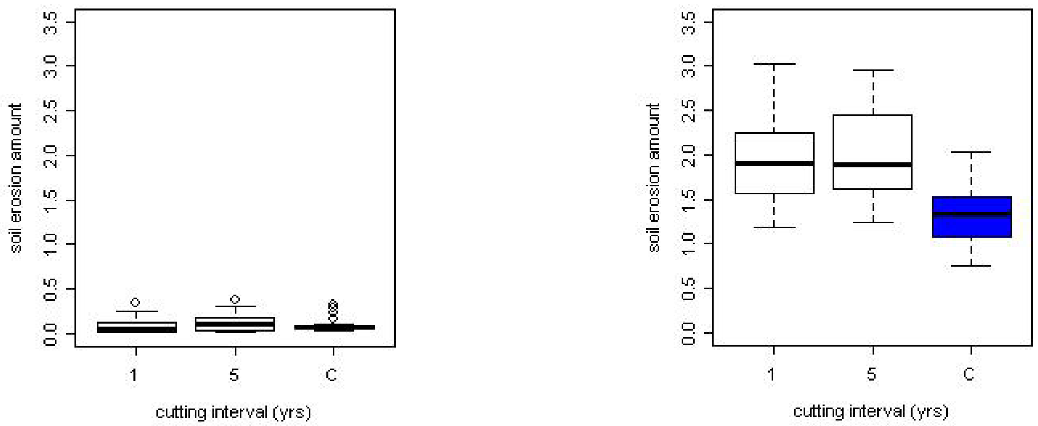


Figure 4.14: Distribution of simulated annual soil erosion amount at North and South slopes in the mesic Mediterranean regions at different cutting intervals across six wadiscapes (15° slopes) and 30 years.
Left: ungrazed; right: grazed (0.3 LSU). C=Control.

4.2.2.6 Biodiversity of grazed landscapes under climatic changes of annual precipitation amount

In contrast to species richness of annuals in Israel per 100 km^2 based on data from the BioGIS data-base (Hebrew University of Jerusalem, 1998-2003, Figure 4.15), the richness per 0.01 km^2 based on GLOWA data tended to increase from the arid/semiarid to mesic Mediterranean climatic regions (Figure 4.16). But even at the 100 km^2 scale of the BioGIS data base individual cells of the arid regions never reach the high species richness of the more moister regions (see maxima in Figure 4.15). At both scales biodiversity is expected to become relatively little affected by climate change.

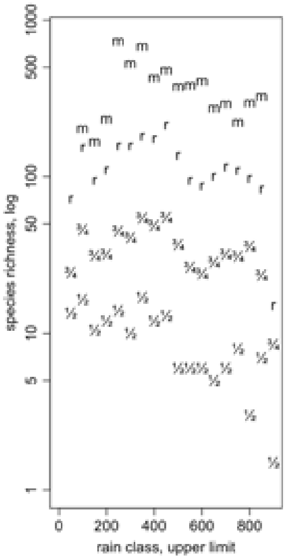


Figure 4.15: Distribution of species richness of annuals per 100km^2 in rain classes in Israel. m: maximum, r: 3×interquartile range, ¾: 75percentile, ½: median.

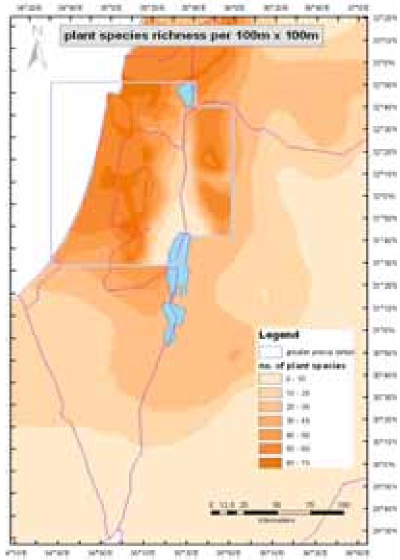


Figure 4.16: Distribution map of projected biodiversity 2031-2060 per 0.01 km^2 without grazing based on GLOWA field data and GLOWA climate projections.

4.2.2.7 Wild fires

In Israel during the years 1991-2007, an annual average of 589 fires occurred; out of which 7.2 fires were big fires which burnt areas larger than 1000 dunams each. In 2006 only, 23 fires out of 699 were big, covering total burnt area of 73,928 dunams. Fires occurred throughout the year, but during May to July they are much more frequent and much larger. Figure 4.17 illustrates the spatial distribution and the hot spots of wildfires in Israel. The blue symbols represent regions in which a high proportion of the landscape was consumed by wild fires. Accordingly, the Golan Heights, the Carmel, the Gilboa and the foothills of Sameria seem to be particularly prone to wildfires.

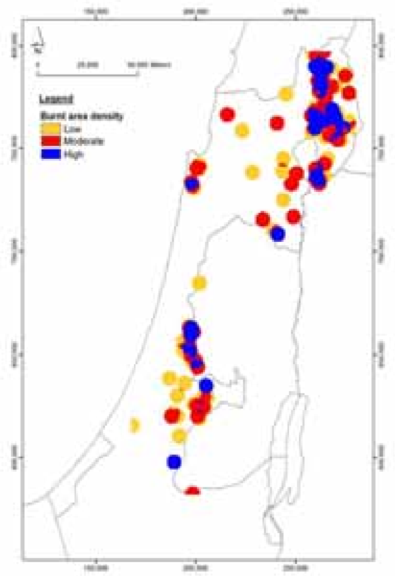


Figure 4.17: Density and proportion of region burned.

The linear regression approach indicated that only relative humidity during the fire event was a signify-ant predictor of wildfire properties. This approach however, assumes a linear response. Finding the best regression model for nonlinear relationships, the Maximum likelihood approach was applied. We partitioned the database into two sub-sets: fires in rangeland and fires in maquis and forests. Several models for multiple explanatory variables were evaluated using the AIC criterion (Tabel 4.2).

It is apparent that maximum daily temperature and maximum windspeed during the fire are the best predictors of wildfire extent in maquis/forested areas, whereas in open rangelands the number of wilting days is important as well. This difference is probably due to the fast response of herbaceous vegetation to lack of water in the soil, and its consequent wilting. Comparing the current climatic conditions with the ones proposed by the climate-simulations does not suggest any significant change it future wildfire distribution.

Table 4.2: AIC values and estimated regression parameters of models with different multiple explanatory variables which are based on climate variables for their effect on wildfire extent. AIC of selected model is shown in bold.

Model	Maquis/forest		Rangeland/Open Areas	
	AIC	params	AIC	params
$\beta(temp_{max} * wind_{max})$	609.8	â=8.55	1092.7	â=11.2
$\beta\frac{temp_{max}}{RH}$	629.6	â=4657	1118.3	â=821.4
$\beta\frac{wind_{max}}{RH}$	616.1	â=1372	1132.1	â=2197.3
$temp_{max}^{\beta1} * exp^{\beta2*wind_{max}}$	608.4	â1=2.04 â2=0.06	1087.9	â1=2.07 â2=0.08
$\frac{temp_{max}^{\beta1} * exp^{\beta2*wind_{max}}}{RH^{\beta3}}$	610.8	â1=2.15 â2=0.05 â3=0.07	1091.4	â1=2.02 â2=0.08 â3=0.0
$\frac{WiltDays^{\beta0} temp_{max}^{\beta1} * exp^{\beta2*wind_{max}}}{RH^{\beta3}}$	611.9	â0=0.06 â1=1.92 â2=0.07 â3=0	1086.6	â0=0.23 â1=1.93 â2=0.065 â3=0

4.2.2.8 Soil erosion risk

The analysis revealed that as a result of the combinations between land cover, soil erodibility topography and rainfall properties, only small regions of Israel are prone to intensive soil erosion (Figure 4.17). A spatial intersection of the results obtained from wildfires distribution and soil erosion potential identifies the upper parts of the Ayalon basin to be particularly sensitive (Figure 4.18).

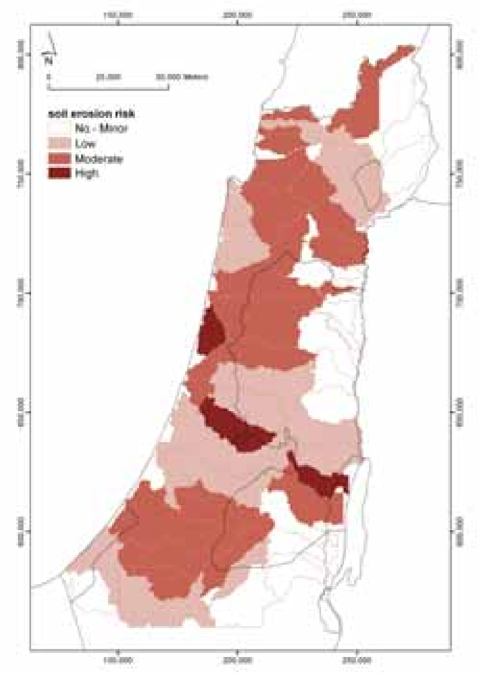


Figure 4.17: Basin classification to soil erosion potential.

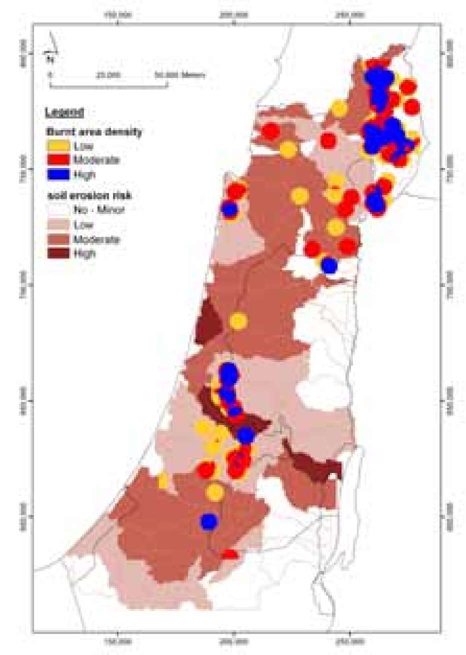


Figure 4.18: Locations of wildfire prone areas and high soil erosion potential.

4.2.3 Discussion and conclusion of scientific highlights and outlook

Simulations of different climate change effects on vegetation at the landscape scale indicated that the vegetation is well adapted to climatic variability and quite resilient to climate change in terms of precipitation. Short term (10y) observations at experimental field sites of GLOWA support these results (METZ 2010). This means that from this perspective more land in the Middle East should be allocated to natural ecosystems, since water productivity under climatic extremes is higher for natural systems than for agriculture. What is not known, however, is what changes can really be expected in the future in terms of critical extreme events. Global and regional climate models are not designed to fully reveal extremes (KRICHAK et al. 2011, MASLIN & AUSTIN 2012). In our simulations average annual biomass production is, however, largely affected by intensive grazing. A drier future climate will reinforce this effect, mainly in the arid and Mediterranean regions. Thus, varying the grazing intensity in these regions of the Middle East may help to buffer against climate change effects. In addition, grazing plays a key role in structuring the tree-shrub-herbaceous vegetation relationship and soil-vegetation feedbacks. But in order to control for example soil erosion effectively, overgrazing has to be avoided. Although the empirical results of our soil erosion vulnerability analysis which was mainly based on topography showed that the majority of the Israeli landscape is classified to a very low degree of soil erosion risk, overgrazing would be a major risk, especially in the northern, Mediterranean regions. Here, resilience of vegetation breaks down before the stocking capacity is reached. The proportion of bare ground increases, which in turn could make the soil much more vulnerable to losses by water erosion. However, it seems that small scale processes are not linear and highly dependent on both spatial vegetation structure and temporal aspects. For example, although our simulations for wetter regions showed a stimulating effect of prescribed fire on herbaceous vegetation and also on overall palatable green biomass production and thus vegetation cover which in turn may increase stocking capacity, annual soil erosion amount increased as well. This occurred even without implementation of post-fire impacts on soil structure in the model (D'ODORICO & PORPORATO 2010). In drylands, there is a rising awareness of the role of feedbacks between soil and vegetation with regard to spatial aspects and different plant functional types (XUE 2006, D'ODORICO et al. 2010, ARCHER et al. 2012, JENERETTE et al. 2012). Regarding shrub encroachment, prescribed fire is no effective management strategy either, neither is the current method of tree/shrub cutting. Grazing by sheep and goats turns out to be the most effective in this respect and thus could be recommended for controlling shrub encroach-ment. Regular small prescribed fires are instead a possible way in reducing the risk of a great catastrophic fire. This is important since climatic factors will not always dictate wildfire properties and mostly humans are nowadays the source of fire ignition in the region (KLIOT& KEIDAR 1992).

4.3 Applied value of results

Our research contributes to the understanding of climate change impacts on natural and semi-natural vegetation in grazed and ungrazed landscapes from rangelands to maquis and forests. Our simulations provided the basis for the estimation of green water fluxes by other subprojects in GLOWA Jordan River to be eventually integrated in the regional WEAP databases. It has further been used to estimate the household income of herders and the potential requirement of grazing area in future socioeconomic scenarios within the modelling framework LandSHIFT (e.g. KOCH et al. 2008). Regional land use managers and nature conservation agencies may use our results to assess the necessity for regulating grazing intensities and other disturbances like prescribed fire and tree/shrub cutting of the vegetation, as well as their combination (http://tobias-lib.uni-tuebingen.de/portal/glowa). Our findings provide further evidence for the effects of grazing, which is a predominant process in the region, on the structure and function of the ecosystems. Additional information on regions with higher potential for soil erosion is supplied.

4.4 References

Archer NAL, Quinton JN & Hess TM 2012. Patch vegetation and water redistribution above and below ground in south-east Spain. Ecohydrology 5, 108-120.

D'Odorico P & Porporato A 2006. Soil moisture dynamics in water-limited ecosystems. In: D'Odorico P, Porporato A Dryland Ecohydrology. Springer, pp. 31–46.

D'Odorico P, Laio F, Porporato A, Ridolfi L, Rinaldo A & Iturbe IR 2010. Ecohydrology of Terrestrial Ecosystems . Bioscience, 60, 898-907.

Gutman M, Henkin Z, Holzer Z, Noy-Meir I & Seligman NG 2000. A case study of beef-cattle grazing in a Mediterranean-type woodland. Agroforestry Systems, 48, 119-140.

Hickey R 2000. Slope angle and slope length solutions for GIS. Cartography, vol. 29, no. 1, pp. 1-8.

Holzapfel C, Tielbörger K, Parag HA, Kigel J & Sternberg M 2006. Annual plant-shrub interactions along an aridity gradient. Basic Appl Ecol 7:268–279. doi: 10.1016/j.baae.2005.08.003

Jenerette GD, Barron-Gafford GA, Guswa AJ, McDonnell JJ & Villegas JC 2011. Organization of complexity in water limited ecohydrology. Ecohydrology

Kliot N & Keidar G 1992. Forest fire in Israel and their causes. Horizons in Geography, 35-36, 23-34.

Koch J, Schaldach R & Kochy M 2008. Modeling the impacts of grazing land management on land-use change for the Jordan River region. Global and Planetary Change, 64, 177-187

Köchy M 2006a. Stochastic time series of daily precipitation for the interior of Israel. Israel Journal of Earth Sciences 55:103–109. doi: 10.1560/IJES_55_2_103

Köchy M 2006b Opposite trends in life stages of annual plants caused by daily rainfall variability — interaction with climate change. In: Ünal Y, Kahya C, Demirhan Barı D Turkish State Meteorological Service (DMI), Ankara, Turkey, pp. 347–357.

Köchy M 2008. Effects of simulated daily precipitation patterns on annual plant populations depend on life stage and climatic region. BMC Ecology 8:4.

Krichak SO, Breitgand JS, Samuels R & Alpert P 2011. A double-resolution transient RCM climate change simulation experiment for near-coastal eastern zone of the Eastern Mediterranean region. Theoretical and Applied Climatology, 103, 167-195.

Levin N & Saaroni H 1999. Fire weather in Israel- synoptic climatological analysis. GeoJournal, 47: 4, 523-538.

Maslin M & Austin P 2012. Uncertainty: Climate models at their limit? Nature, 486, 183-184

Mathaj M 2007. Modellierung von Vegetation und Erosion entlang eines Klimagradienten von mediterran bis semiarid, Diplomarbeit (Msc thesis), Universität Potsdam, Potsdam (Germany).

Metz J 2010. The sensitivity of Eastern Mediterranean plant communities to variations in rainfall and their vulnerability to global climate change. PhD Thesis

Osman AE, Cocks PS, Russi L & Pagnotta MA 1991. Response of Mediterranean grassland to phosphate and stocking rates – biomass production and botanical composition. J Agr Sci 116:37–46.

Pariente S 2002. Spatial patterns of soil moisture as affected by shrubs, in different climatic conditions. Environmental Monitoring and Assessment 73:237-251

Perevolotsky A & Haimov Y 1992. The Effect of Thinning and Goat Browsing on the Structure and Development of Mediterranean Woodland in Israel. Forest Ecology and Management, 49, 61-74.

Perevolotsky A, Landau S, Kababia D & Ungar ED 1998. Diet selection in dairy goats grazing woody Mediterranean rangeland. Appl Anim Behav Sci 57:117–131. doi: 10.1016/S0168-1591(97)00120-2

Tietjen B, Zehe E & Jeltsch F 2009. Simulating plant water availability in drylands under climate change – a generic model of two soil layers. Water Resources Research 45: W01418, doi:10.1029/2007WR006589

Törnros T 2010. Precipitation trends and suitable drought index in the arid/semiarid southeastern Mediterranean region. In: Global Change Facing Risks and Threats to Water Resources (Proc. Of the Sixth World FRIEND Conference, Fez. Morocco, October 2010). IAHS Publ., 340, 6pp

Van Remortel R, Hamilton M & Hickey R 2001. Estimating the LS Factor for RUSLE through Iterative Slope Length Processing of Digital Elevation Data. Cartography. 30(1): 27-35.

Wang G, Gertner GZ, Liu X & Anderson A. 2001. Uncertainty assessment of soil erodibility factor for revised universal soil loss equation. Catena 46: 1–14.

Xue Y 2006. Interactions and Feedbacks between Climate and Dryland vegetations. In: D'Odorico P, Porporato A Dryland Ecohydrology. Springer, pp. 85–105.

5 Medium term effects of climate change and land use change on structure and function of natural ecosystems

Contributing authors:
Katja Tielbörger, University of Tübingen
Mark Bilton, University of Tübingen
Johannes Metz, University of Tübingen
Wolfgang Siewert, University of Tübingen
Sabine Hänel, University of Tübingen
Pierre Liancourt, University of Tübingen
Rüdiger Prasse, University of Hannover
Ayman Salah, University of Hannover
Sarah Bangerter, University of Hannover

In collaboration with:
Marcelo Sternberg, Tel Aviv University

Note that findings on strategies to reduce land degradation in semi-arid regions (intercropping annual fields with perennial plants) are not included in the main text below as they were not part of GLOWA JR phase 3. Yet they represent a key result of the overall GLOWA Jordan River project as they are important for appreciating the use of rainfed land use practices for saving water and protecting natural biodiversity. A summary is presented in Annex 5. The full findings can be found in the Ph.D. Thesis of A. Saleh (see Annex List of Theses, Saleh 2008)

5.1 Aim

Our overall aim was to study the response of arid to Mediterranean ecosystems to climate and land use change and to generate recommendations for sustainable management under global change. This aim was addressed with a set of different analyses, all of which are based on findings from two long-term experimental gradients in Israel and Jordan. These are as follows:

We assessed the sensitivity of semi-arid and Mediterranean plant communities to variation in rainfall for estimating their vulnerability to changing precipitation with future climate change.

Grouping plant species into categories of rainfall preference (species more commonly found in dry regions, compared to species more commonly found in wet regions) we aimed to determine which plant species within communities are likely to become more (resp. less) abundant under future climate change scenarios.

We assessed the sensitivity of arid to Mediterranean plant communities to grazing and climate, to evaluate whether grazing management may help in managing natural ecosystems under climate change. The same rainfall preference groups of ii) were also used to assess how grazing management may impact upon plant communities under the projected drier conditions of future climates.

We used a demographic approach to explore the effects of projected shifts in precipitation on annual plant population dynamics and extinction risk.

Using plants of several species collected from the rainfall treatments, we tested whether nine years of rainfall manipulations has led to selection for adaptive traits, indicating that plants may rapidly adapt to climate change.

5.2 Description of research

5.2.1 Material and methods

5.2.1.1 General setup

All our work of the past ten years has relied on the same larger experimental setups that were established in phase 1 (Israel) and 2 (Jordan) of the GLOWA Jordan River project. In both regions, we have established research sites along the steep climatic gradient which is characteristic for the region. As the setup has been described repeatedly in previous reports and in all our publications, we only briefly outline the general principle of the setup.

In Israel, four sites have been fenced off for protection from grazing and vandalism. They are located along a North-South gradient running from arid (90mm average rainfall) and semi-arid (280mm) to Mediterranean (550mm) and mesic Mediterranean (780mm) conditions. In two of the sites, the SA and M site, we manipulated rainfall in plots of 15m x 25m size according to the initial climate scenarios provided to us at the beginning of the project. In particular, annual rainfall was decreased by 30% with rainout shelters covering 30% of the area, and irrigation increased rainfall by 30% in 'wet' plots (for details of setup and manipulation design see Sternberg et al. 2011). Basic ecosystem properties (soils and plants) were monitored and detailed studies on the plant communities were performed during the entire study period. All response variables were studied with respect to site (4 sites along the climate gradient) and rainfall manipulation (dry, control, wet). The former yielded the predictions for the latter, i.e. response of plants to experimentally manipulated rainfall conditions. Namely, we predicted that community properties in experimentally droughted plots would gradually approach conditions found in adjacent drier sites, and *vice-versa*. (Fig. 5.1). This experiment has been monitored for 10 years, 8 of which have been analyzed in detail.

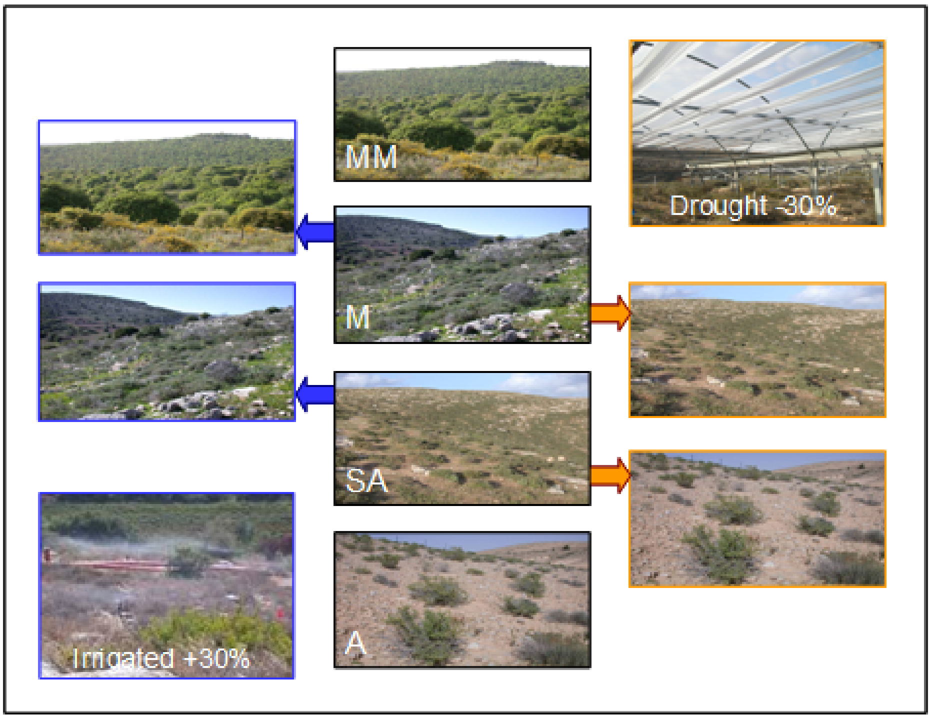


Figure 5.1: Photographic illustration of climate manipulation study and rationale. Under manipulated rainfall conditions (irrigation, drought) community parameters such as species composition, density, diversity and biomass should become similar to those in corresponding adjacent climates. Droughted treatment: SA towards A; M towards SA. Irrigated treatment: M towards MM; SA towards M.

In Jordan, a rainfall gradient running from East to West (near Dead Sea) was selected in Wadi Shueib near Salt (Fig. 5.2) in the year 2005. Along that gradient, again four sites were selected with 190mm, 280mm, 400mm and 550mm mean annual rainfall, respectively (for detailed site description see publications by Liancourt et al.). At each site, we imposed two treatments: a naturally grazed treatment and erected fencing to create ungrazed exclosures. All treatments and data collection were done at two aspects at each site: one Northern aspect(slope) and one Southern aspect, to test for the effect of local differences in water availability on grazing effects. This study was done for four years only, as we established the plots only in phase 2 and our Jordanian counterparts did not want to proceed their investment in phase 3. This experiment was conducted at 8 sites (2 aspects x 4 valleys with climates approximating 420mm/year in the Northeast to 190 mm/year in the Southwest) over the course of 4 years.

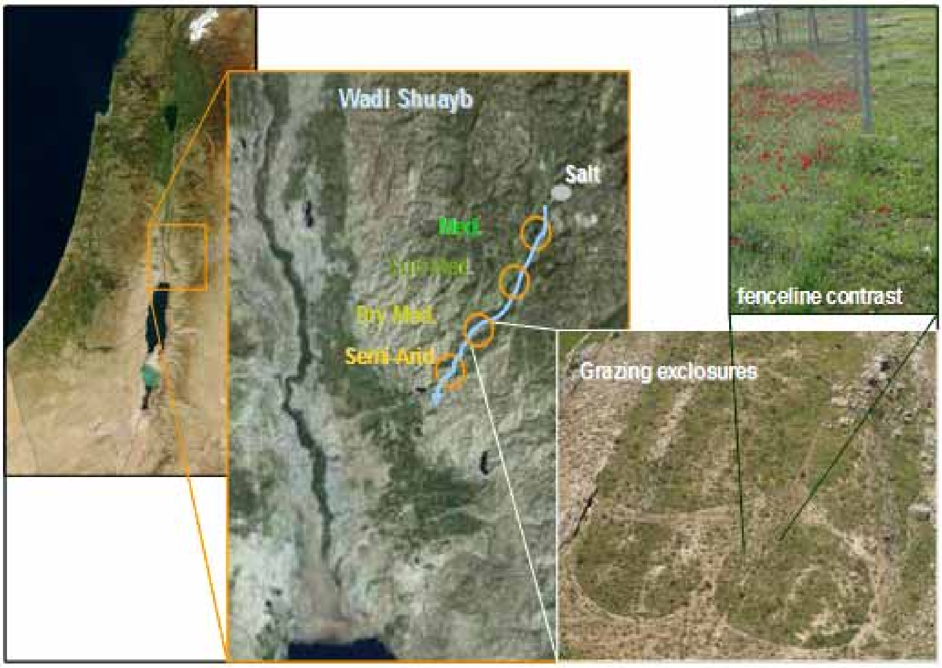


Figure 5.2: Location (left and middle) and close-up (right) of grazing exclosure experiment in Jordan. Four sites represent Semi-Arid, Dry Mediterranean, Sub-Mediterranean, and Mediterranean climatic conditions. In each site, four plots of approx. 1200m2 in size (exclosures) were set up on a Northern and a Southern slope, and plant community parameters measures within and outside exclosures. The fenceline contrast (upper right) shows differences in plant growth within (left, red) and outside (right) a fence in the first season (photos: S. Bangerter, P. Linacourt

Both gradients shared the climatic differences among sites, i.e. the gradients provided us with a proxy for changes in plant community structure with natural climate. However, the gradients differed in that the Israeli gradient (Fig. 5.1) served for in-depth mechanistic studies on climate change, and the Jordanian gradient (Fig. 5.2) provided mechanistic insights into grazing effects and their interaction with climate.

5.2.1.2 Specific activities in phase 3

i) We evaluated plant community parameters (biomass production, diversity, plant density, species composition) by surveying permanent quadrats in three separate dimensions of varying rainfall: The spatial dimension comprised of the four research sites along the steep natural rainfall gradient in Israel; the temporal dimension spanned eight consecutive years within the same sites; the experimental dimension applied manipulations of ambient rainfall (+30%, control, -30%) within the two central sites of the rainfall gradient. Plant community parameters were analysed by univariate and multivariate statistical methods. Namely, we tested whether rainfall manipulations induced community changes in a way that drought manipulated communities would gradually resemble plant communities in adjacent drier sites (and *vice-versa* for wet-manipulations).

ii) 117 annual plant species observed at two study sites in Israel (Semi-Arid; Mediterranean) were categorized into 4 groups of rainfall preference (Observed Rainfall Niche (ORN) 1-4: ORN1 = species more commonly found in the driest regions of Israel; ORN4 = species more commonly found in wettest regions of Israel). Using data collected from the permanent quadrats (see (i)) located at each site under rainfall manipulations, we calculated if densities of each separate ORN group, relatively increased or decreased over 9 years of the study under each different rainfall environment.

iii) During four years, standing biomass, plant densities and species numbers of the realised vegetation and plant densities and species number of the seed bank were monitored in all plots using six randomly placed permanent quadrats of 20 cm x 20 cm (5 cm x 5 cm with a depth of 5 cm for the seed bank samples) per plot. We then used the same ORN rainfall preference groups as in (ii) to categorise plant species within the grazing exclusion experiment in Jordan (Fig. 5.2). This experiment was conducted at 8 sites (2 aspects x 4 valleys with Semi-Arid, Dry-Mediterranean, Sub-Mediterranean, and Mediterranean climate) over the course of 4 years. At each site, annual plant densities, seed densities and biomass were monitored to test if climate and/or grazing management impacted upon some rainfall preference groups greater than others, and to test for local-scale differences in grazing impact (i.e. differences among slopes).

iv) Demographic data of 19 abundant annual plant species collected over 7 years was used to construct periodic matrix models (Fig. 5.7B). These allowed us to investigate the effects of precipitation on population dynamics. Retrospectively we analysed if rainfall could explain population dynamics over the study period (Fig. 5.7A). Prospectively we combined our models with regional climate models obtained from Chapter 11 to conduct stochastic simulations of population dynamics under climate change (transient scenarios until 2065; Fig. 5.7).

v) Using plants of 14 abundant annual plant species collected from the rainfall treatments, we tested for potential microevolutionary response to the treatments, measured as a change in the frequency of climate-relevant traits. From previous studies (e.g. Petrů et al. 2006, Liancourt & Tielbörger 2011), we have generated a list of traits that are relevant for adaptation to a certain climate. We first recorded differences in plant performance traits within the treatments in the field. As these differences can be due to plastic response, too, we raised the offspring of the plants under standard conditions for two more years and then compared the very same traits again. In addition, we grew plants in an artificial rainfall gradient in a greenhouse at Tübingen to test whether plants from dry treatments perform better than plants from wet treatments when exposed to drought. The data were analyzed with various GLMs, and some data is still being analyzed. Therefore, we only show few representative findings from the second greenhouse generation.

5.2.2 Results

i) We found clear trends from dry to wet sites along the rainfall gradient in all community parameters, as well as significant year-to-year variation within all sites. However, the rainfall manipulations (+30%, control, -30%) within sites caused surprisingly little change in plant community structural variables. Except for marginally increased biomass triggered by additional irrigation in one site (Fig. 5.3), all other community parameters (e.g. density, diversity, species richness) did not respond to either irrigation or drought (Tielbörger et al., in revision).

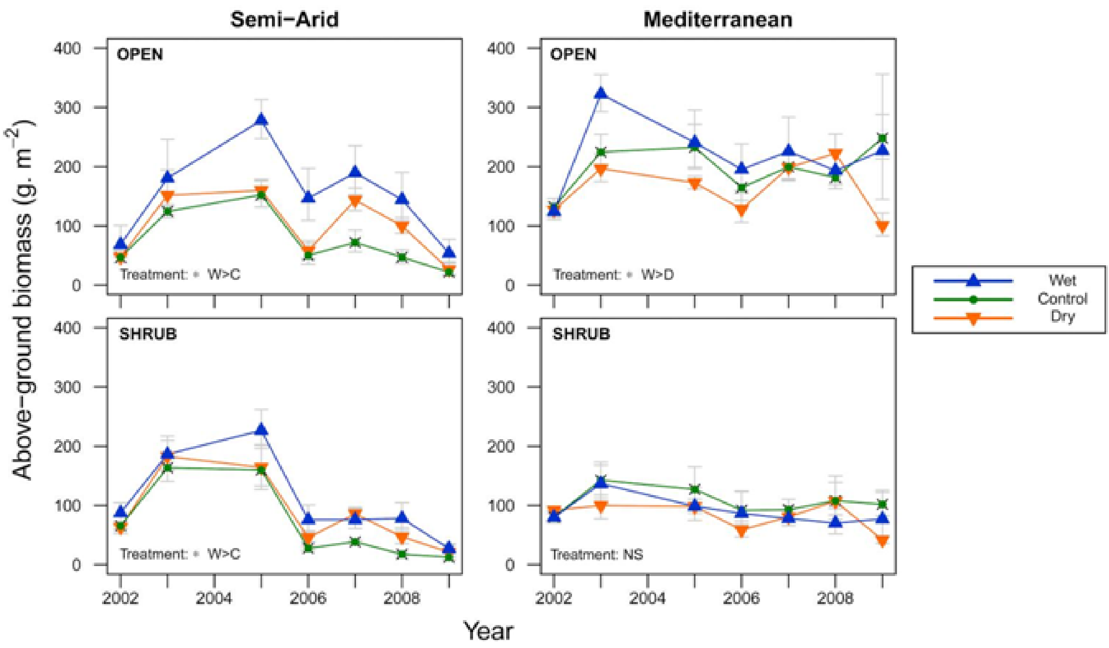


Figure 5.3: Mean above-ground biomass (+/- SE) responses to rainfall manipulation treatments. Linear Mixed Models were used to compare treatments, with overall Treatment effect (DF=2,12; N=150) indicated by asterisks (*p<0.05; ** p<0.01), and significant contrasts showing paired comparisons (w = wet; d = dry; c = control treatment). At the Semi-Arid site, communities in both microhabitats showed a significant response to the wet treatment, with weaker responses in Mediterranean open quadrats (biomass in wet > dry treatment).

The lack of response in overall community structure to the treatments imposed can be best illustrated here by multivariate analyses of species composition (Fig. 5.4, Tielbörger et al. in revision). Here, the annual variations in plant community structure stayed within the 'cloud' characteristic for each site, and no directional trend of change, e.g. towards the climatically 'similar' site, is visible in any of the sites or treatments.

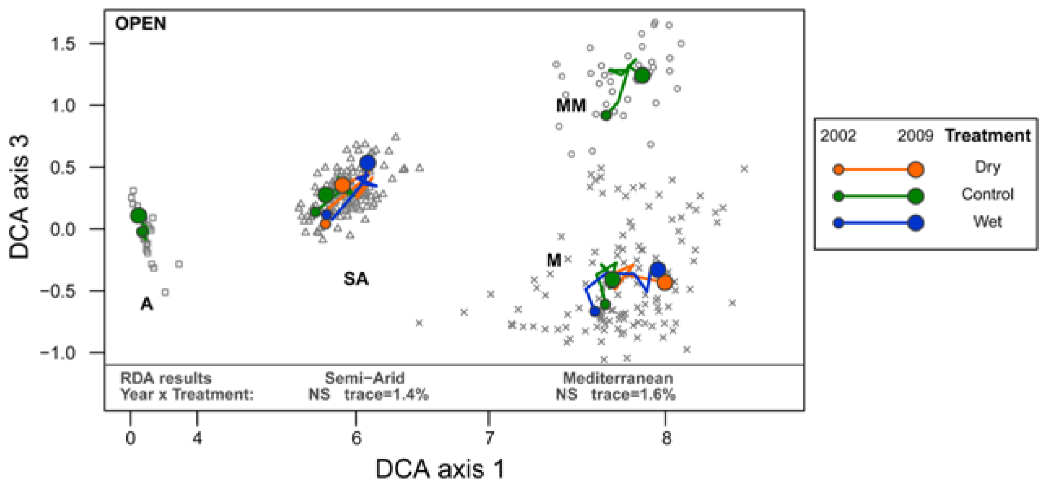


Figure 5.4: Responses of community structure to rainfall manipulation. Multivariate ordination (DCA) illustrating the effect of climatic conditions (arid to mesic Mediterranean), year and rainfall manipulation (drought vs. irrigation) on annual plant community structure. Despite large differences in community structure among sites and years, community structure was largely unaffected by the treatments and thus did not gradually converge with species composition of adjacent control sites with similar climatic conditions.

ii) More detailed analyses were done for identifying whether certain groups of species do show consistent responses to either drought or irrigation. In a first attempt, we grouped species into categories according to traits that are relevant for response of plants to climatic variation (e.g. flowering time, drought resistance), but eventually, a composite grouping strategy was identified that captured most of the variation in the species response data. By dividing the plant density data into rainfall preference groups (ORN), clear patterns emerged from the dataset, which showed that the species from drier regions (ORN1 and ORN2) performed relatively better in the droughted treatment (-30% rainfall) than the irrigated treatment (+30% rainfall), and the species from the wettest regions (ORN3 and ORN4) had relatively higher densities over time in the irrigated treatment compared to the droughted (Fig. 5.5). The shift in species densities, in relation to their rainfall preference, was stronger at the Mediterranean site than the Semi-Arid (Bilton, Metz & Tielbörger, in prep.).

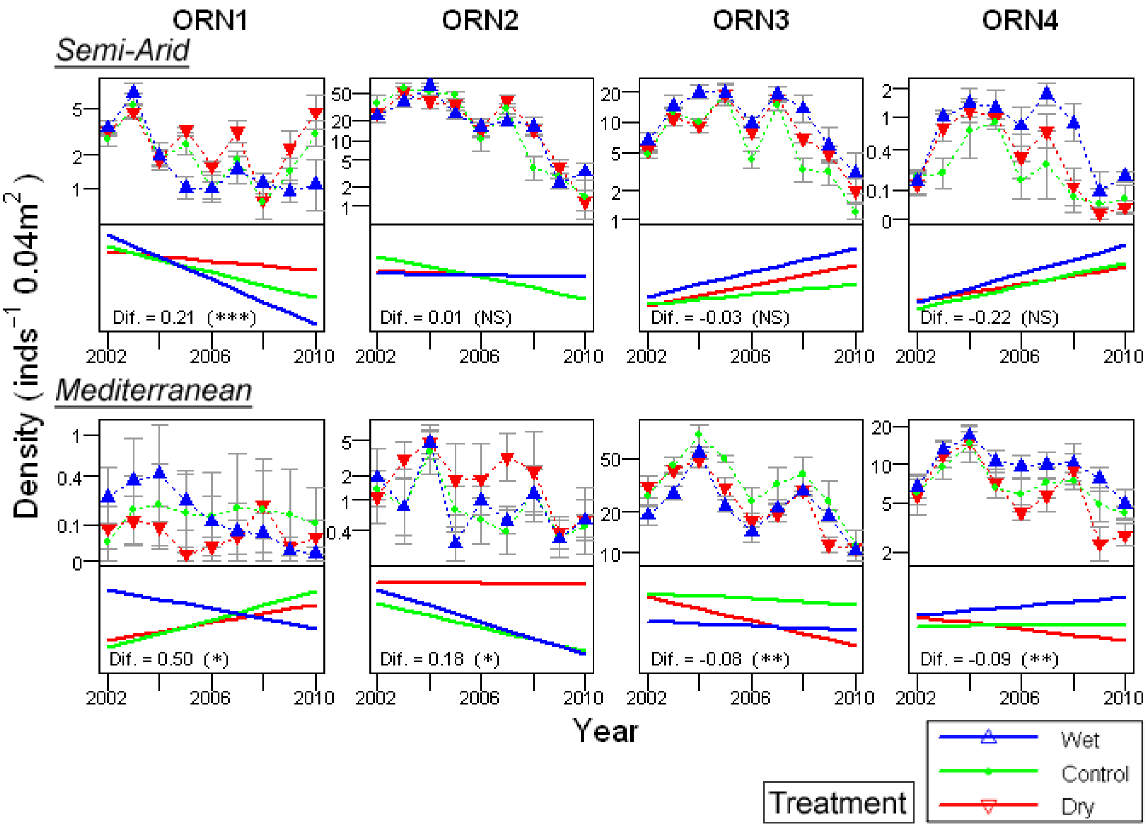


Figure 5.5: The density response of four "Observed Rainfall Niche" (ORN) plant groups to rainfall manipulations ("Wet" +25% water; "Control" natural rainfall conditions; "Dry" -25% water) at two sites in Israel. Points indicate mean number of individuals per quadrat, with associated SE. Lines show the estimated GLMM models. "Dif" indicates the difference between the estimated slope in the dry and wet treatment, with statistical significance.

iii) As expected, plant densities and species numbers varied strongly in accordance with the inter-annual variation in precipitation, showing higher densities and species numbers in wet years. However, inter-annual variation was smallest in un-grazed plots. During four years of investigation, the cessation leads to a rapid increase in plant densities in the realised vegetation as well as in the seed bank, while species numbers showed only a small and not significant increase. However, the exclosures showed significantly higher species numbers than grazed plots in dry years (both in the realised vegetation and in the seed bank, Bangerter et al., in prep.) indicating that the combination of grazing and drought had a negative effect on biodiversity.

The positive effects of grazing cessation on plant densities and in dry years species numbers were most pronounced towards the dry end of the rainfall gradient and on the drier Southern aspect (Fig. 5.6). Namely, in terms of the relative impact of grazing (log response ratio LnRR) on the entire vegetative community ('all' species), results showed that on the drier south aspect slopes, the impact of grazing was nearly twice as large (LnRR = -0.94) than that on the wetter north aspect slopes (LnRR = -0.53) (Figure 5.1). When the community was broken down into the ORN group components (see (ii)), on the north aspect slopes we showed that there was no consistent relationship in the patterns of grazing impact between the different groups, although the driest species group (ORN1) showed the greatest negative mean value which was more significantly different to zero ('no impact') than the other groups (Fig. 5.6). However, on the south aspect slopes there were significant differences between groups, with the species from the driest regions of the Jordan River Valley (ORN1) consistently impacted upon most by grazing, and conversely the species from the wetter regions (ORN4) were impacted upon least by grazing (Fig.5.6)

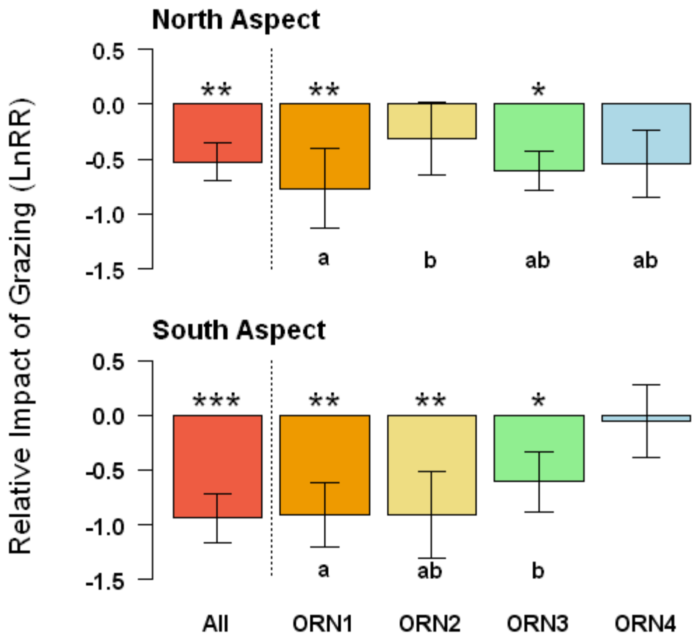


Figure 5.6: The impact of grazing on "Observed Rainfall Niche" plant groups on two slope aspects in Jordan (across 4 sites). "All" species show greater impact in South than North aspect. Stars indicate significant differences from zero (no impact of grazing). Same letters show ORN groups which are not significantly different.

iv) Our tests for relationships between precipitation and population growth (Salguero-Gomez et al. 2012) indicated that rainfall drives population dynamics in arid and semi arid regions, but not (or less so) in Mediterranean climates, where other factors (e.g. competition) might be more important (Fig 5.7A). Therefore, we tested for the effect of climate change on stochastic population growth rate (e.g. Fig. 5.7C) only for the species from the Semi Arid and Arid site. With few exceptions population growth rate of plant species decreased under predicted climate change (Fig 5.7D). While at the Semi Arid site, only 2 out of 10 plant species were able to maintain growing populations, at the Arid site 3 out of 4 plant species achieved this. This indicates that true desert populations may be able to cope with conditions drier than the current ones and thus may be relatively resistant to climate change, while populations from semi arid regions are highly vulnerable to increased frequencies of dry years (Siewert & Tielbörger, in prep.).

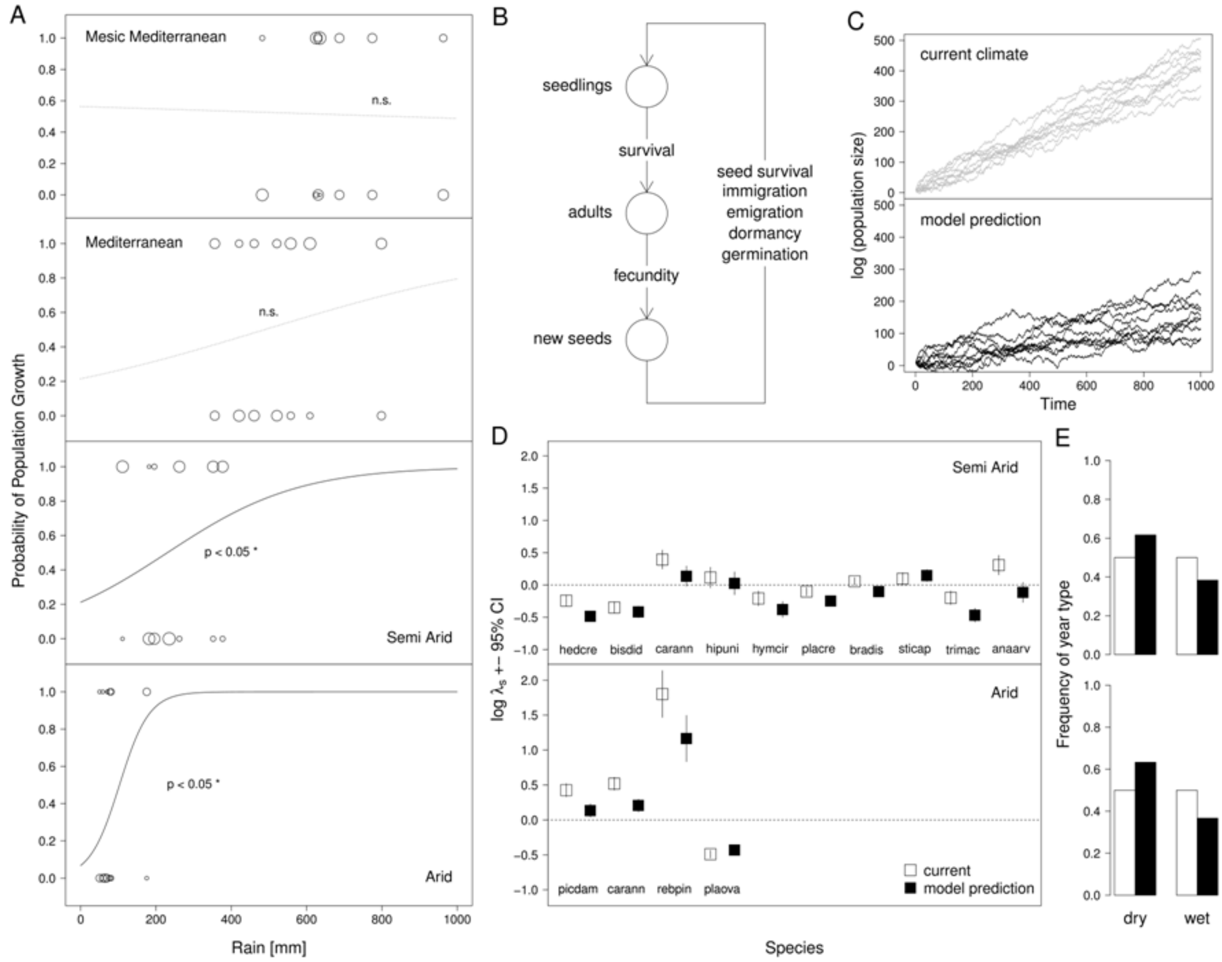


Figure 5.7:

A: The effect of precipitation on deterministic population growth rates of abundant annual plant species at four field sites. A value of 1 represents positive and a value of 0 negative population growth. The size of the data points represents the number of species shown. Significant relationships between precipitation and population growth are shown with solid lines, non-significant relationships with dashed lines.

B: The life cycle of an annual plant. Seedlings survive to become adult plants which produce seeds. Seed processes are manyfold and include seed survival, immigration, emigration, dormancy and germination, which all influence the number of seedlings in the following season. This life cycle was used to construct a periodic matrix model and explore the effect of current and future rainfall conditions on annual plant species.

C: An example for stochastic simulations of population dynamics under 2 scenarios: current climatic conditions (1980 – 2009) and climatic conditions as predicted by the GLOWA JR high resolution regional climate models (2036 – 2065).

D: The effect of climate change on stochastic population growth rate for abundant annual plant species (abbrevions: first three letters of genus plus first three letters of species name) at the semi arid and arid field site. Positive values indicate growing populations, negative values indicate shrinking populations.

E: Current vs. predicted climatic conditions for the semi arid and arid field site. Years with rainfall above the 1980-2009-median are termed wet, years with rainfall below the 1980-2009 median are termed dry. Therefore wet and dry years occur with equal frequencies under current climatic conditions. At both sites climate change is predicted to lead to increased occurrence of dry years.

v) Our tests for the effect of eight years of rainfall manipulation on the expression of climate-relevant species traits were equivocal. As an example for a relatively consistent trait, we show here two species with findings for flowering time (Fig. 5.8), which we would expect to be earlier when the climate is more arid. Flowering time of most species showed either no response or an accelerated flowering after experiencing eight years of consecutive drought, i.e. flowering time increased from the dry, to control and wet treatments. However, many other traits did not show a consistent response (S. Hänel, unpubl. data).

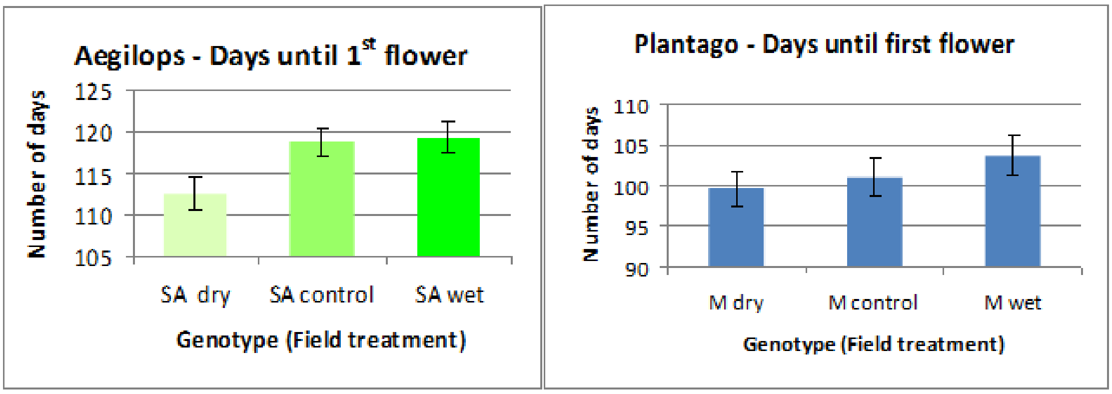


Figure 5.8: Effect of eight years of rainfall manipulation on trait expression (time to flowering) in two representative annual plant species and two sites (SA and M). The plants were collected in the field and raised in a greenhouse under standard conditions for two consecutive years.

5.2.3 Discussion and conclusion of scientific highlights and outlook

Our previous studies have shown that plants will not be able to migrate alongside the 'preferred' climate, as dispersal distances are close to zero (Siewert & Tielbörger 2010). Therefore, in-situ responses to climate change manipulations will likely reflect realistic patterns of future response to ain increasingly arid climate. We found overall little effect of rainfall manipulations on semi-arid and Mediterranean plant communities. This was intriguing as the range of manipulations closely mimicked the recent climate change scenarios for the study region that were developed within the GLOWA Jordan River project (see Chapter 11). Our results therefore suggest considerable resistance of these ecosystems to future climate change. This finding was even more surprising as theoretical studies had ranked these ecosystems among the most vulnerable to global change (Sala et al. 2000; Schröter et al. 2005).

We suggest this resistance to result from adaptation to the tremendous natural temporal variation in rainfall, that is characteristic for all arid to Mediterranean ecosystems. Past selection for particular traits enabled these species to cope with a wide range of rainfall conditions. Such traits include for instance drought resistance, large phenotypic plasticity, bet-hedging mechanisms like seed dormancy (Cohen 1966), and persistent seed banks (Metz et al. 2010).

Despite relatively little response on a plant community level and on a single species level (data not shown), a simple yet novel climatic niche categorization (ORN groups) has highlighted distinct sensitivities of different components of plant communities in response to climate change manipulations. For the projected scenarios of future climate change (drier, more variable conditions Smiatek et al. 2011), these results suggest that gradually over time plants that are currently more commonly found in drier regions of Israel will come to dominate the habitats. This shifting effect is likely to happen in different regions, but is likely to be slower in the more resistant communities inhabiting the variable climates in the southern drier regions. This highlights that these species need to be protected. Interestingly, grazing appeared to have a much stronger impact on the drier areas of the river Jordan region (indicated by the aspect differences). In addition, it is the species more commonly found in drier regions that are most impacted upon by grazing.

Conversely, a release from grazing pressure is likely to benefit most both the dry species in a community, and the plant communities inhabiting the driest regions (Bilton et al. in prep.). This has crucial implications for adaptive management of these regions in an era of climate change. Namely, grazing exclusion or at least a strong reduction of stocking rates in currently overgrazed areas in Jordan and the West Bank will be a prerequisite for maintaining the services of these systems for the future. In combination, grazing and climate change will most likely lead to fast loss of species, decrease in productivity and increase in erosion. Interestingly, these findings, which stem for the extensive field experiments alone, corroborate the result of the modeling group (Geissler et al.).

Our results from the single species modelling show that increased aridity as predicted by climate change may have relatively small effects on Mediterranean ecosystems, since population dynamics there are mainly governed by factors other than rainfall. Based on our previous work (Holzapfel et al. 2006, Schiffers & Tielbörger 2006, Ariza & Tielbörger 2012), we suggest that competition among plants is probably a major force driving plant population dynamics and is likely to be more important than precipitation. However, climate change, expressed in increased frequency of dry years, strongly and negatively affects plant populations in semi arid and arid areas, though species-specific responses were detected (Salguero-Gomez et al. 2012), and the effect was smaller for arid plant species. In semi arid areas, plant populations appear particularly vulnerable to changes in rainfall already within the next decades, pointing to a priority area for conservation. This is underlined by that fact that grazing pressure in the region is largest in semi-arid areas, adding to the pressure on the functioning of these ecosystems.

Previously, we have found that there is strong ecotypic differentiation among populations of the same plant species along the climatic gradient, indicating that the potential for trait variation is inherent in many plant species (Petrů et al. 2006, Petrů & Tielbörger 2008, Ariza & Tielbörger 2011, Liancourt & Tielbörger 2009, 2011, Tielbörger et al. 2012). This was also supported by large genetic variability for important climate-related traits for some plant species (Lampei & Tielbörger 2010). We therefore hypothesized that eight years of rainfall manipulation, e.g. drought, may have selected for plants whose traits indicate a better adaptation to lack of rain (Metz et al. 2010). Our findings from the evolutionary studies are equivocal, as some of the species showed a shift in traits in the predicted direction (e.g. flowering time was shorter for plants of some species in the dry treatment), some species showed no response, and others exhibited even an opposite pattern than predicted, e.g. with larger plant height in dry than wet treatments. Rapid evolution can therefore not fully explain the lack of response of most species to the rainfall manipulations. Yet, we must conclude that for selection to occur and be detectable, we most likely need even longer study periods, even if our experiment extended over a uniquely long period compared to other climate change experiments (Tielbörger & Salguero-Gomez, subm.). Thus a main lesson from our subproject is that as the systems were relatively slow to respond to climate change, it is necessary to continue with the field experiments for identifying potential turning points. The unique setting enabled by the GLOWA Jordan River project provides an ideal precondition for continuing a climate change experiment with world-wide unique duration and extent.

5.3 Applied value of results

Our rather optimistic finding of considerable resistance of Eastern Mediterranean plant communities to climate change has several major implications.

1) The ecosystems of the Eastern Mediterranean, which are classified as global biodiversity hotspots, may maintain their diversity and thus socio-economic and conservational value also for the coming decades, i.e. they are less vulnerable to climate change than previously thought. As this is not the case with land-use practices that need a lot of water (e.g. irrigated agriculture), an effective and economically viable strategy for managing water under future drier conditions would be a shift from water-intensive to rainfed land-use,

especially rangelands (Tielbörger et al. 2010), but also special practices of rainfed agriculture (see summary of results for intercropping from phases 1-2, Salah & Prasse, Annex 3).

2) Secondly, the greatest threat to these ecosystems results from man-made habitat destruction and overgrazing. More important, taking the results of both the climate and grazing manipulations into consideration, the indications are that if the climate gets drier in the Jordan River Valley as predicted, species from dry regions will come to dominate the plant communities. It also seems apparent that heavy grazing severely limits the growth of dry species, and particularly plants in drier regions. Therefore, continued heavy grazing in combination with a drying climate could reduce the vegetative community dramatically.

3) However, our results also suggest that short-term grazing cessation (e.g. 2 to 3 years), or an extended period of partially reduced grazing, could be sufficient to increase plant densities, and allow recovery of plants in the seed bank. This could be an effective and sustainable management strategy to protect the productivity of the rangelands for future generations, consequently reducing water and nutrient run-off and providing sustainable fodder for livestock. Interestingly, such extended periods of 'recreation' were common place in the past nomadic culture, but with increased population growth, such practice was not maintained. Our findings suggest that short-term grazing cessation is an important tool for land-use management especially in semi-arid to arid regions, and particularly in dry years.

4) Yet, a clear recommendation must be drawn from our findings: A sustainable future where grazing is still possible and biodiversity is protected requires a general reduction of stocking rates in many parts of the region. *Vice-versa*, maintaining current stocking rates will lead to the irreversible loss of these ecosystems both for nature conservation and for the farmers and nomads using the land. It must be noted, however, that many previous studies have shown that some grazing is needed for keeping the landscape open, i.e. abandonment of land that has been grazed for millennia will also lead to loss of species.

Our findings also highlighted areas where conservation priorities should be set. First, dry-adapted species may be those surviving under climate change. At the same time, it is semi-arid regions where extinction risks seem to be highest. This is also supported by the studies of the animal ecologist (Chapter 6) who have highlighted the detrimental effects of afforestation, which is particularly intensive in the semi-arid region. As these are also those regions where grazing pressure is highest, semi-arid regions (i.e. between 200mm and 400mm annual rainfall), should be in the focus of conservation efforts in the region.

5.4 References

Cohen D (1966) Optimizing reproduction in a randomly varying environment. Journal of Theoretical Biology 12: 119-129.

Sala OE et al. (2000) Global biodiversity scenarios for the year 2100. Science 287: 1770-1774.

Schröter D et al. (2005) Ecosystem service supply and vulnerability to global change in Europe. Science 310: 1333-1337.

Smiatek G, Kunstmann H, Heckl A (2011) High resolution climate change simulations for the Jordan River area. J. Geophys. Res. 116, D16111.

6 Animal biodiversity

Dr. Azzam Saleh, Al-Quds University, Palestine
Dr. Mohammed Saleem Ali-Shtayeh, BERC, Palestine
Prof. Tamar Dayan, Department of Zoology, Tel Aviv University

6.1 Aim

To study how projected changes in climate (climate change scenarios), development (planning scenarios), modelled changes in land use (socio-economic models, LandShift model), and modelled changes in water availability (hence land use practices), are anticipated to affect patterns of biodiversity in the Jordan River Basin in Palestine and Israel.

6.2 Description of research

This study involved three major parts: theoretical, empirical, and policy analysis. The theoretical part of the work focused on modelling projected changes in mammal distributions in response to climate change scenarios. We used species distributions of extant mammals at the local (Israeli) and regional scale and modelled anticipated shifts using MaxEnt model. These results are important for planning open landscapes to preserve species under climate change. The empirical part of the research involved studies of the olive fruit fly drawing conclusions regarding its projected distribution changes in response to climate change. Moreover, we studied how different land use and land management practices, common in our region, affected patterns of biodiversity, with an emphasis on agro-biodiversity. These results are significant for the conservation of agro-biodiversity and for the development and maintenance of ecological corridors on agricultural landscapes. Finally, we studied Palestinian policies and their relevance to the conservation of agro-biodiversity.

6.2.1 Material and methods

The present and future distribution of each terrestrial mammal species west to the Jordan River was calculated using the MaxEnt model (a relatively new model which works well for small sample sizes) and the maps of present and two future scenarios were then compared in order to study changes in distribution. Moreover, this analysis was upscaled to the assemblage level: the species maps were mounted to create a total species map which contains both species number and probability of occurrence for each 1*1 km grid cell. Similarity indices were computed and drawn on a map to show the degree of change between present and two different future scenarios. The direction of change (increase or decrease in species number) was also calculated. We then tested the sensitivity of our results to size of geographic region tested and to resolution of climatic data.

The field work was carried out using different trapping methods in the Palestinian Authority and in central and northern Israel in different agricultural landscapes. The policy work was carried out by analyzing policy papers.

6.2.2 Results

6.2.2.1 Olive fruit fly experiment, analyse and disseminate the findings to stakeholders

The experiment has been continued over the first 2 months of 2012. All data which has been collected through 2010 and 2011 has been analyzed and integrated in a report that was directed to 0the relevant stakeholders (ministry of agriculture, Environmental quality authority, NGOs and farmers associations).

The report has included a clear analysis for the interactions between the olive fruit fly (*Bactrocera oleae)* as a pest, and olives *(Olea europaea)* as a host crop under the climate influences and the consequent predicted changes in land use and productivity.

The experiment has showed that olive fruit fly distribution is tended to shift to the West and North West along the rain-fall gradients under the influence of the dryness and extreme temperatures which is expected to be more severe in the eastern part of the WB.

However, the damage capability of the fly is more severe in the Al Faraa ecosystem (South East) and this is because the fly activity peaks coincided with the critical fruit ripening stages on September and October, whereas the fly activity peaks in Merkeh (North West) have been recorded in July and November where the fruits still unripe in July and harvested on November (as shown in Figures 6.1 and 6.2), despite of the lower no of flights collected on the sticky traps in Al Faraa experiment site.

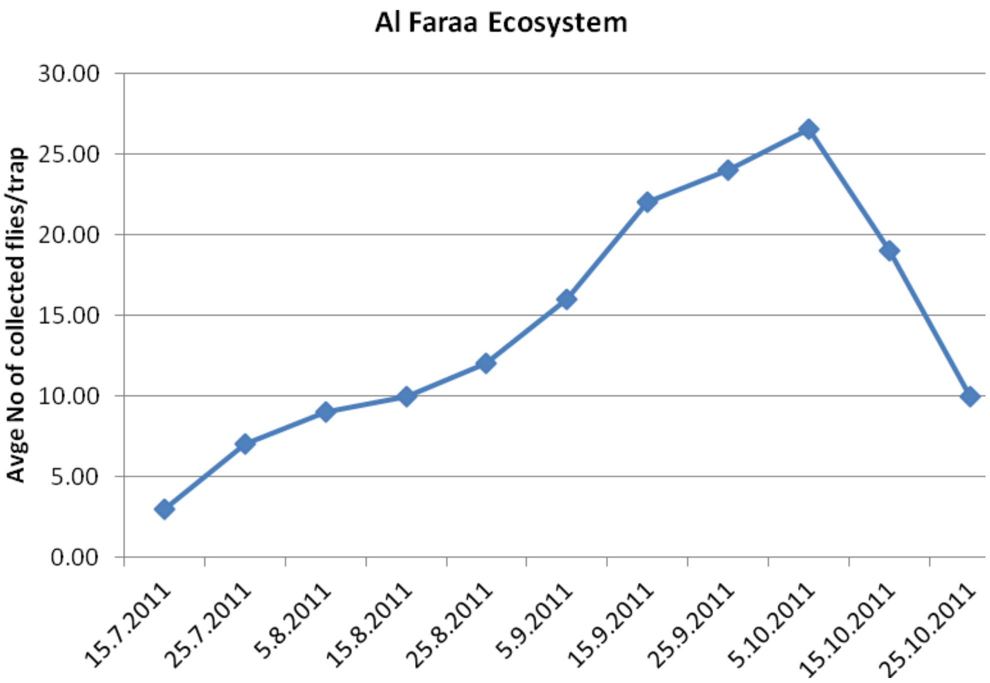


Figure 6.1: Olive fruit fly population dynamics in Al-Faraa (Season 2012/2012).

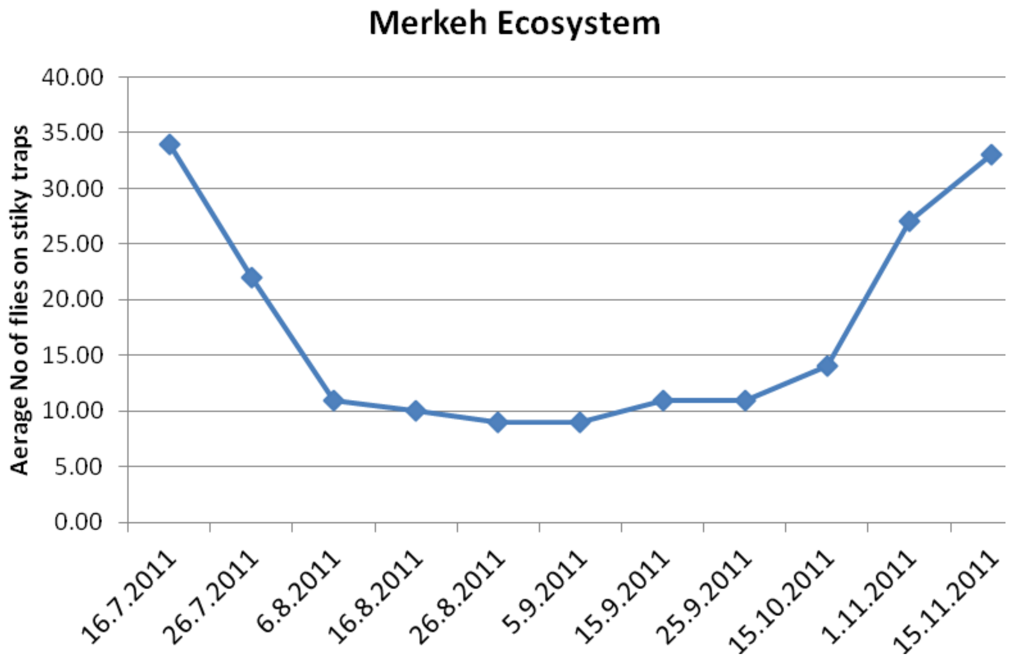


Figure 6.2: Olive fruit fly population dynsmics in Merkeh (season 2011/2012).

6.2.2.2 Analysing the Palestinian policies that are relevant to the conservation of agro-biodiversity

This activity has started in 2011 and accomplished by April 2012. The Palestinian polices and regulations' which are relevant to the protection of biodiversity and ecosystem services were identified and deeply reviewed. We analyzed 5 local strategies and enacted laws within the Palestinian regulatory framework which have addressed by one way or another the protection of agro-biodiversity and ecosystem services.

The main formal relevant p=formal polices that analyzed are:

- Climate change adaptation strategy and programme of action
- Palestinian environmental law 1999
- The Palestinian strategy to combat desertification
- environmental strategy and national plan 2011-2013
- Palestinian national agricultural strategy 2011-2013

The conclusion summarizes the main findings of the Palestinian policies and strategies relevant to the conservation of agro-biodiversity and ecosystem services. There are important technical and financial challenges to the development of effective environmental and climate change adaptation planning in the opt, but the most significant constraints are external political barriers, as represented by the continuing Israeli occupation of the west bank and the Gaza strip. The political feasibility of addressing these barriers depends of the uncertain prospect of final status negotiations between the Palestinians and Israelis. It is conceivable, nevertheless, that the shared challenge of climate change could at least lead to the Palestinian - Israeli technical cooperation.

6.2.2.3 Spatial modelling

Hadass Steinitz's modelling included mammal data from Israel and Israel level environmental layers. Our analyses show that many Mediterranean species will shift their distribution westward especially in the central parts of the country. Some species that require cooler climates will move northward and higher in elevation. Most desert species will increase their distribution northward. Psammophylic species will not change their distribution. In all comparisons at the community level analysis and of the two future scenarios the green scenario was more similar to the present in species composition and in species number, thus, rendering the green scenario as preferable for conservational purposes. The coastal region is predicted to be enriched with more species than currently inhabit it. The Rift Valley on the other hand is predicted to lose some of its species. This conclusion is a result of the limited range for this work. Only observations within Israel were taken so the model was prone o mistakes derived from extrapolation. Future research should enlarge the geographical focus of the model so no border effect of extrapolation will hinder the results. However, since the rift valley is very different in its environmental parameters from its surrounding (especially in Jordan) it is very hard to predict what will happen if some of the species will relocate (as predicted) to western parts of the country. Either some species from the mountains in Jordan will climb down to the valley to fill the vacant niche or the species will only enlarge their distribution to the west rather than relocate since there aren't many species which can be located at the eastern part of the valley but not on the western side of it.

At the community level, the similarity maps computed for each future scenario show that the "green" scenario which assumes a full adherence of the Kyoto protocol results in greater similarity to species composition of the present. The business as usual scenario resulted in a much greater change in species composition. In both scenarios two main 'hot' areas were found, with a greater degree of change in species composition. In the Dead Sea basin and the Arava valley number of species is expected to decline and in the western Negev there is an increase in species number. Different groups of species reacted differently (predators differed from herbivores etc.).

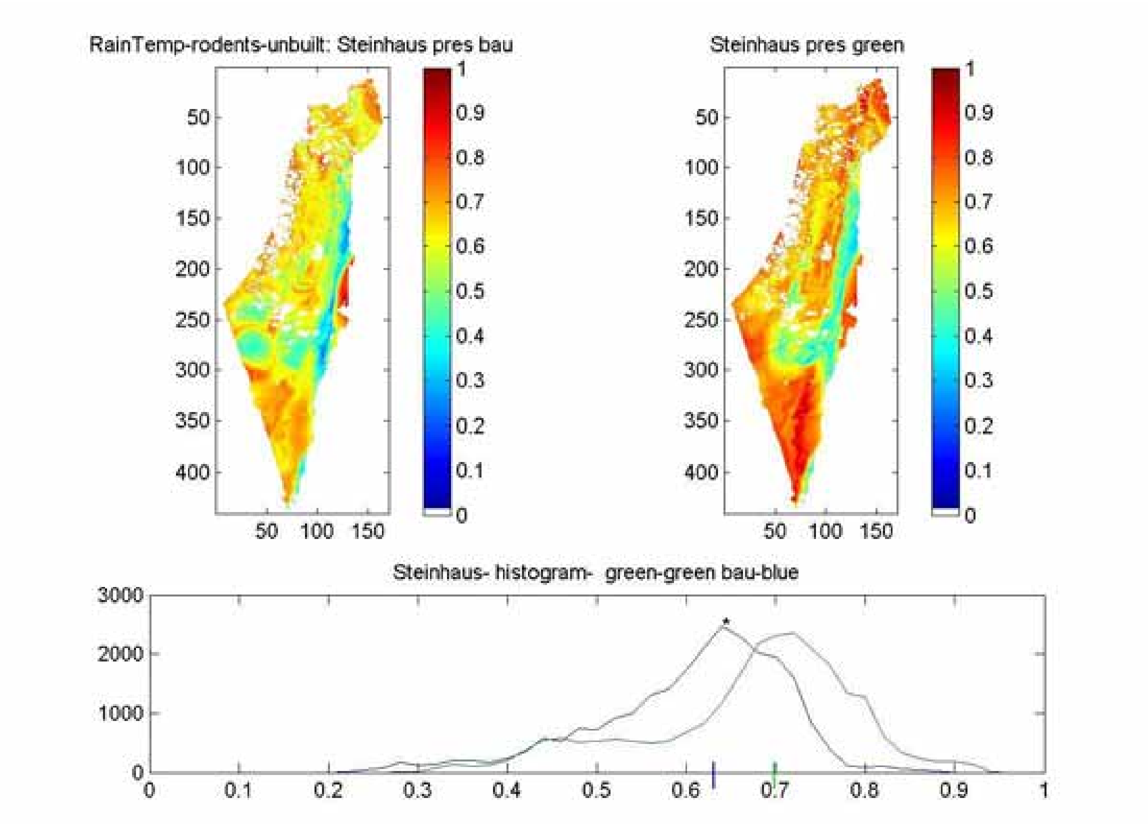


Fig. 6.3: For illustration - maps of the Steinhaus similarity index calculated for rodents left – "business as usual" scenario right- "green" scenario.

In 2011 Tamar Marcus, an MSc student, concluded her study on mammal distributions, that aimed to test Hadass's results by using regional rather than local mammal data and regional environmental maps. With the proliferation of available sources of both environmental data and presence data for a wide range of species across the globe, new opportunities for research were opened, and Tamar used MaxEnt, the same species distribution model previously used, but with different data sets.

As high quality local data sets are hard to obtain, among the most commonly used sources of climate data is the Worldclim database, which provides high resolution, global climate data for past, present, and future climates. Models of 53 species of Israeli mammals were created using Worldclim data together with a global soils layer. The resulting models were compared to models created with high quality, localized data in order to investigate the validity of using global databases in lieu of local data.

In cases where a given area is of interest and not the general distribution of a species, models are sometimes built using a part of the given species' estimated distribution. Models built using data for Israel only were compared to the area covering Israel in models built using Israel together with Syria, Lebanon, Jordan, and the Sinai Peninsula. This was done in order to test the effect of enlarging the study area on the model output.

All of the models comparisons were carried out using four methods. Both threshold dependent and threshold independent methods were used. Model quality as represented by AUC values, correlation of probability values, size of area predicted as present and thresholded similarity using kappa values were compared. Future models were based on the IPCC A2a and B2a emission scenarios.

Environmental data source did not affect model quality, but significant differences were found in thresholded predictions. This highlights possible problems with use of global data sources often used in species distribution today. Expanding the area of study improved model quality, emphasizing the need to select study areas based on ecological and biological considerations regardless of study aim.

For illustration see figures from Tamar Marcus's thesis showing different model outputs using different sources (with different resulutions) of climate data.

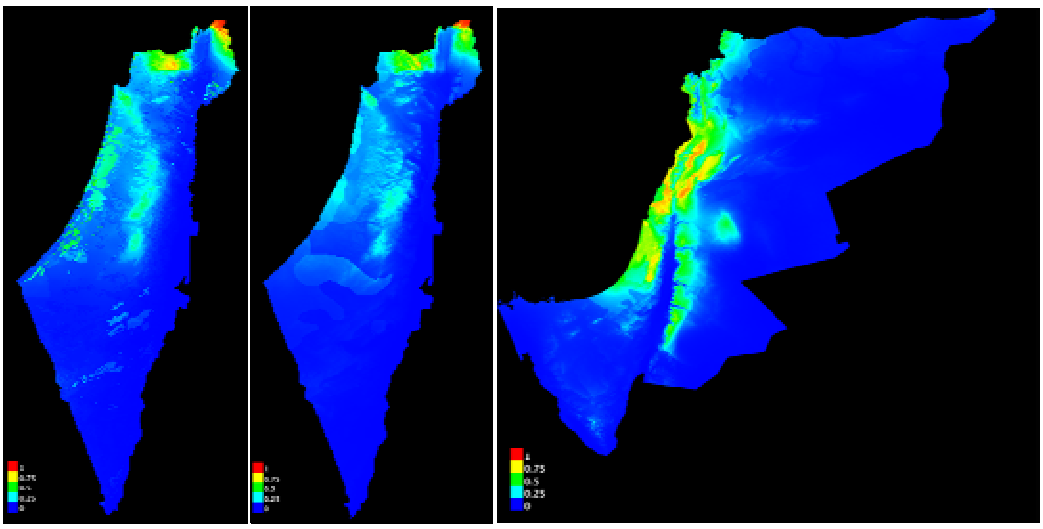


Figure 6.4: Example of output maps created by MaxEnt for Cricetulus migratorius present scenario. A – Israel Specific, B – Israel Worldclim, C – Middle East.

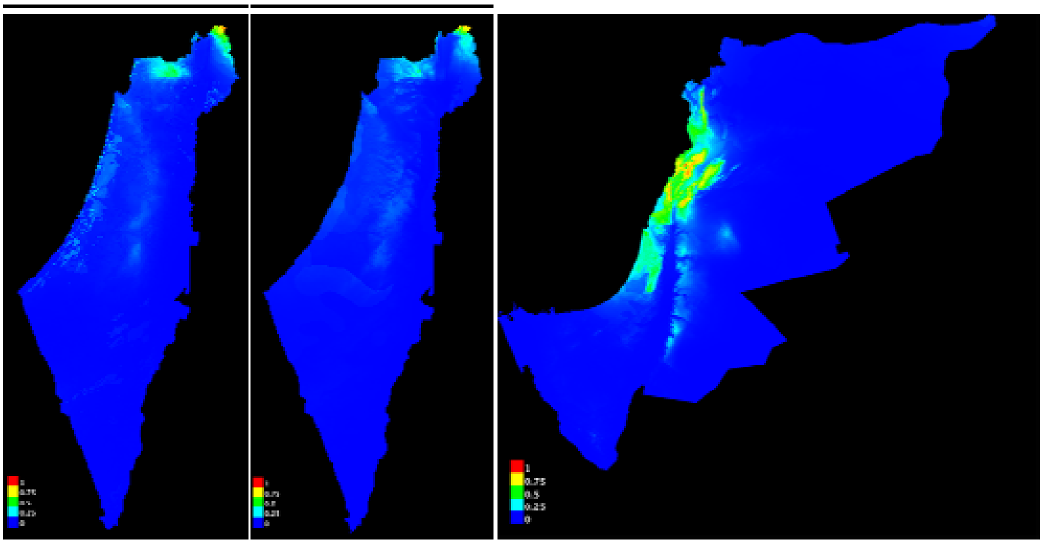


Figure 6.5: Example of output maps created by MaxEnt for *Cricetulus migratorius* A2a scenario. A – Israel Specific, B – Israel Worldclim, C – Middle East.

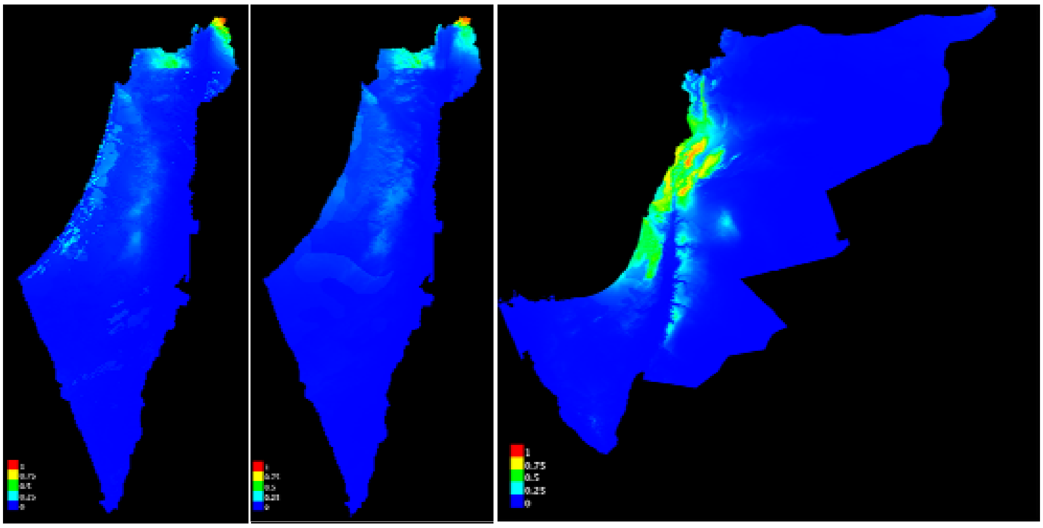


Figure 6.6: Example of output maps created by MaxEnt for *Cricetulus migratorius* B2a scenario. A – Israel Specific, B – Israel Worldclim, C – Middle East.

6.2.2.4 Land-use and patterns of biodiversity

Two studies took place: Orit Skultelsky's dissertation on agricultural land-use and biodiversity focusing on arthropods in the Judean foothills (a), and Yahel Porat's MSc thesis forcusing on the herpetofauna of the Yissachar Heights (b).

(a) One of the main questions, regarding the future of biodiversity conservation, is how to balance between growing demands for agricultural products on the one side, and the need to conserve the vitality of ecosystems on the other side. Biodiversity is vital for the sustainability of agricultural systems, because it provides agricultural systems with diverse ecosystem services such as regulation of runoff and soil erosion, recycling of organic matter and nutrients, pollination and biological control of pests. Although there is no doubt about the importance of biodiversity for the sustainability of agro-ecosystems, agricultural landscapes in the world and in Israel are undergoing processes of industrialization and intensification, or abandonment. These processes intensify fragmentation of natural ecosystems, and enhance biodiversity loss and degradation of ecosystem functions.

In many countries all over the world, acknowledgement of the importance of conservation of biodiversity in agricultural areas is translated to changes in agricultural policy. In Europe, for example, economic incentives are used in order to enhance biodiversity conservation and provision of ecosystem services in agricultural landscapes. In addition, High Nature Value Farmlands (HNVs) are included in protected areas, in order to protect types of traditional agricultural management that supports the conservation of farmland biodiversity. In Israel however, planning policy does not discriminate between various types of agricultural landscapes according to ecological criteria. Moreover, the agricultural policy is not aimed to conserve natural assets or to enhance provision of ecosystem services in agricultural landscapes.

Orit's part of the research aimed to investigate the influence of various types of agricultural management, and of agricultural intensification on biodiversity in High Nature Value farmland in Mediterranean areas. The research characterizes the tension that exists between the demands of local farmers, and the needs of biodiversity conservation in these landscapes, and evaluates whether different types of economic incentives, such as payments for ecosystem services (PESs, agri-environemntal programs ect.), might be suitable to encourage agricultural practices that support biodiversity conservation in ecologically sensitive areas (HNVs) in Israel. The research took place in the region of Adullam, in Judean Foothills area (Shfelat Yehuda). Adullam region is characterized by extremely high biodiversity, because it is located in a meeting zone of flora and fauna that originate from different phytogeographic zones. Adullam region represents a complex Mediterranean HNV landscape, that is characterized by a mosaic of natural and agricultural patches and high biodiversity - typical to agricultural landscapes in the Mediterranean basin.

We examined the influence of agricultural management on patterns of community composition of beetles and spiders in Adullam. We compared characterizations of patterns of community composition of ground dwelling beetles in vineyards (intensive, irrigated agriculture) and wheat/barley fields (extensive, rainfed agriculture), with beetle community composition in patches of natural Mediterranean shrubland vegetation ("batha"). Investigation of patterns of beetle community composition shows that the type of agricultural management significantly influences the community of beetles that inhabit the fields or cross through them. The research shows that wheat fields and conventional vineyards act as "barriers" in the landscape for species of large ground dwelling beetles that typically inhabit natural Mediterranean shrubland. Thus wheat fields and vineyards reduce the connectivity of the agricultural matrix for these species, and may endanger the existence of populations over time. However, the findings show that relatively minor changes in agricultural management may support conservation of ground dwelling beetles in the landscape. For examples, introducing cover crops into vineyard ground-management practices ("conservation agriculture"), and introducing crop rotation into rainfed wheat fields (yearly rotation between wheat and legumes), are changes in agricultural practices that open the barriers that wheat fields and vineyards create in the landscape, and may increase landscape connectivity for ground dwelling beetles. Unlike the beetles, most species of spiders do not seem to be significantly affected by the different types of agricultural management in Adullam. According to our findings, agricultural management does not seem to influence patterns of community composition of spiders. Most spider species do not seem to avoid agricultural fields, nor do they seem to be drawn to them. These finding suggest that spiders may be less sensitive than beetles to trends of intensification or extensification in the agricultural matrix. In addition, the research shows that some of the families of beetles and spiders (such as many species of *Tenebriondae* beetles) that inhabit Mediterranean shrubland, tend to avoid all types agricultural patches. These species may be suitable indicators for investigations on the effects of changes in land management in agricultural landscapes on conservation of biodiversity.

The research findings suggest that it may be possible to improve connectivity of the agricultural matrix in Adullam by changing the structural complexity in the landscape in two dimensions – the spatial dimension, and the temporal dimension. The research shows that introducing conservation agriculture (cover crops) into vineyards raises the structural complexity of the agricultural landscape in the spatial dimension, and may turn agricultural fields from barriers to corridors and thus increase connectivity in the landscape. In a similar manner, use of traditional crop rotation (rotating between wheat and legumes in different years) for improving ground productivity raises the complexity of the landscape in the temporal dimension and contributes to landscape connectivity by opening temporal corridors through the fields.

Below see illustrative figures from Orit Skutelsky's study depicting cumulative richness in wheat fields in comparison with natural shrubland.

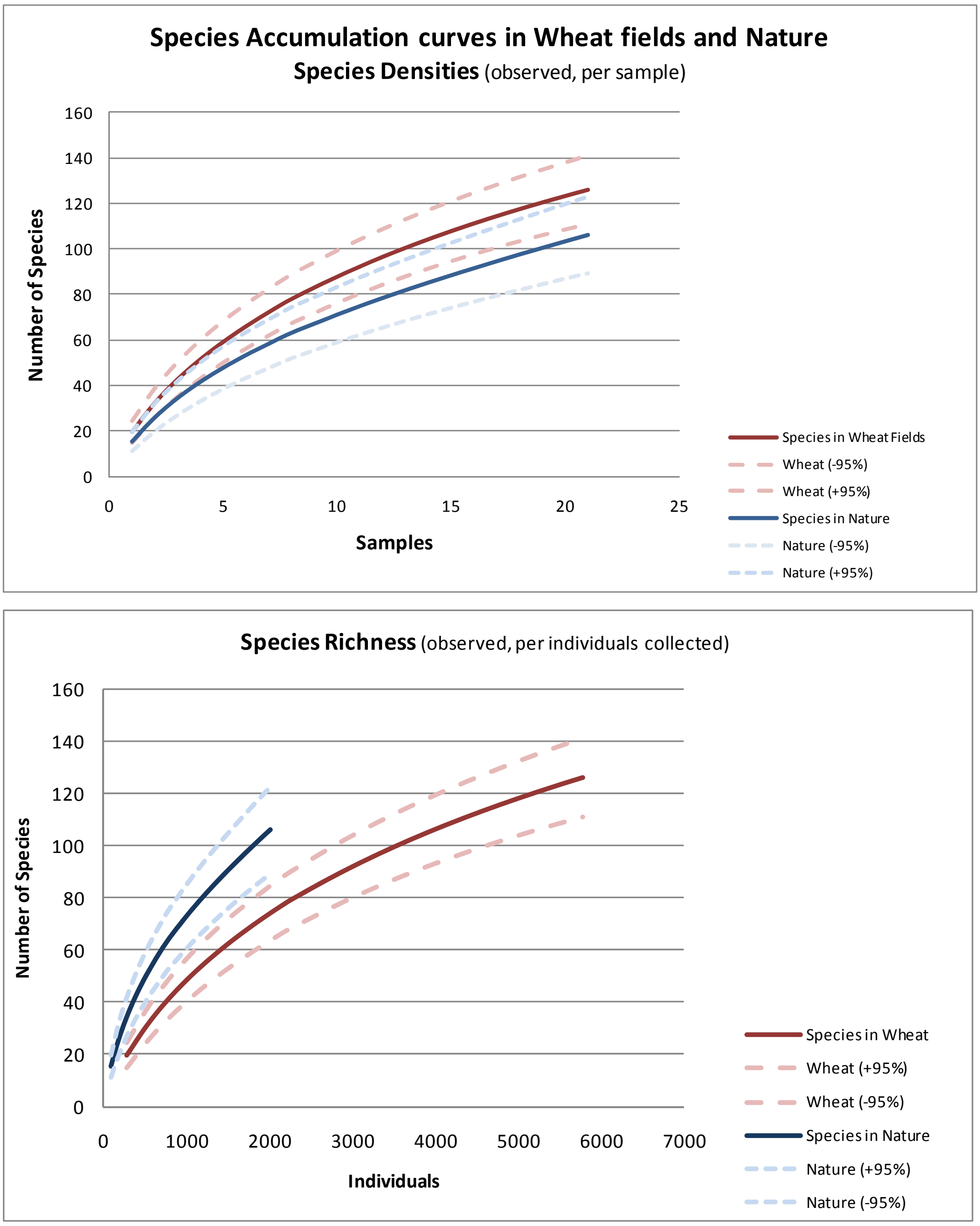
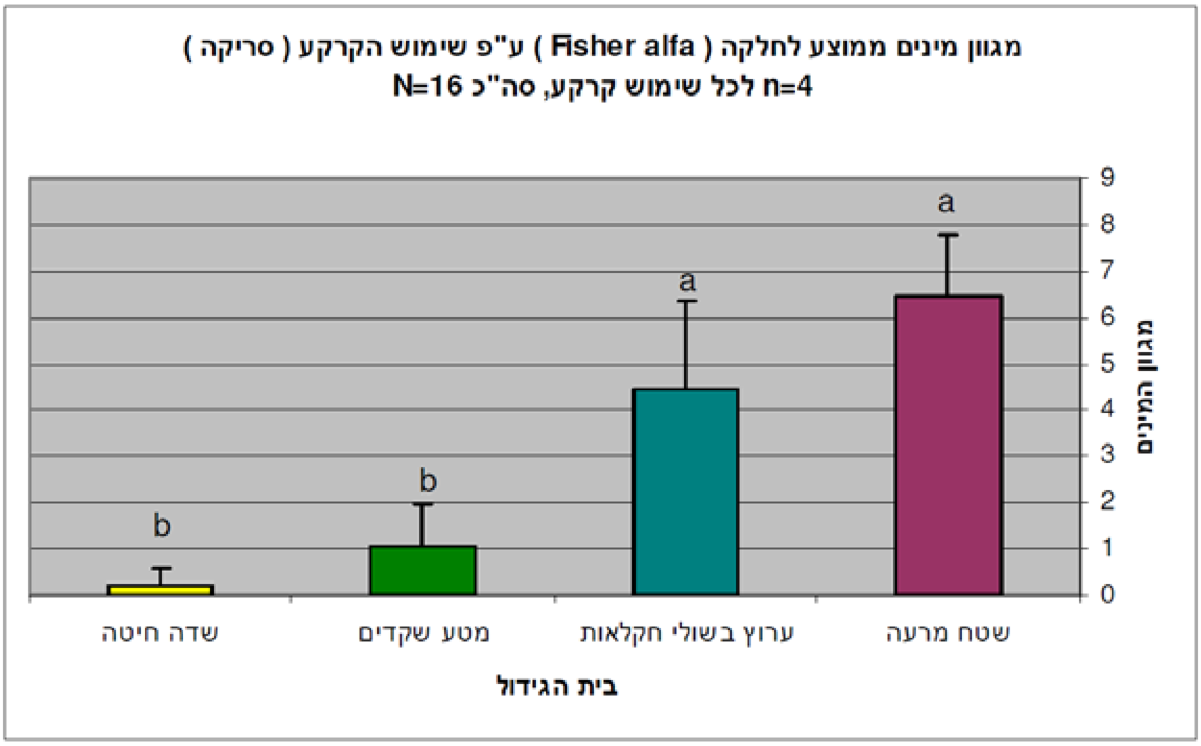


Fig. 6.7 a&b: Cumulative richness in wheat fields in comparison with natural shrubland.

(b) Israel enjoys exceptionally high reptile species richness but one third of these species are already threatened by extensive habitat transformation. We studied reptile communities in major land uses of the Mediterranean agro-ecosystems of Israel using pitfall traps and active time-limited searches over 18 months in two regions with replicated plots of each land use in each. Land uses with high structural complexity (grazed shrubland, narrow natural wadis that drain agricultural plots) harbor significantly higher species richness and diversity than land uses with lower structural complexity (almond groves, wheat fields) do. Almond groves where a vegetation strip between trees is retained (soil erosion control) have higher structural complexity and support higher species richness and diversity than do wheat fields, but the community is dominated by generalists. Species diversity in wheat field is extremely low; it is significantly higher in natural components within the field (trees, bushes, grass strips, rocks patches) than in the wheat rows. Our results highlight the necessity of preserving structural complexity and habitat heterogeneity of agro-ecosystems, at both the landscape level (preservation of continuous and significant natural vegetation patches) and at the level of the agricultural fields as well (preservation of natural components, creation of vegetation strips, etc.).

Below is an illustrative figure from Yahel Porat's study depicting different levels of species richness with wheat fields the poorest, followed by almond groves, narrow gulleys, and pasture lands (the richest).



One way Aanova: $F(3, N=16) = 20.76801$ $p = 0.000048$

Fig. 6.8: Different levels of species richness with wheat fields the poorest, followed by almond groves, narrow gulleys, and pasture lands (the richest).

6.2.3 Discussion and conclusion of scientific highlights and outlook

Our work aimed to provide decision-makers and conservation managers with information regarding the projected changes in biodiversity in response to global change focusing on climate change and land use changes. We modeled the distributions in terrestrial mammals in different climate change scenarios and how these changes should affect current plans for open landscape preservation. Results of this work demonstrate that most species are expected to shift their distributions to the west or north-west, while the ecological corridors of Israel are oriented north to south. This work was already presented both in scientific meetings and to decision makers (Ministry of Environmental Protection task force, the Israel Nature and Parks Authority) and is expected to come up in other climate change scientists and decision maker panels in the near future (Open Landcapes Institute).

Global change including climate change affects land management patterns and consequently patterns of biodiversity and ultimately – ecosystem functions. We asked how different types of agriculture affected biodiversity – in particular beetles and reptiles. This empirical part of the research is key to recommendations regarding biodiversity-friendly agriculture and planning for landscape connectivity for biodiversity conservation. Results of our research shed light upon the effects of different land management practices and biodiversity and are already influencing the discourse in the forest service and Ministry of Agriculture (Israel). Because land use and land management are key to the preservation of ecosystem services and are now increasingly in the focus of conservation discourse globally, our results are expected to contribute to achieving this goal.

6.3 Applied value of results

The relevant Palestinian strategies and policies have been analyzed. Ecosystem services protection has been addressed as a crosscutting issue within the policies of analyzed strategies and environmental regulations. The relevant polices has emphasized on the sustainable management of natural resources and landscape. Reduce the environmental impacts of human activities (agricultural, industry). It clearly recommended measurements for protecting natural heritage, prevents deforestation and maintains the ecosystems biodiversity.

The produced results of our research indicated the potential economical impacts of climate change on agricultural productivity and thereby the agricultural income which could be reasoned by the expected changes in activities and population distribution of insect plant pests.

Palestinian officials particularly from the Ministry of Agriculture and Ministry of Environment (Environment Quality Authority) have been involved from the beginning in the project activities and have been made aware of its concepts and results (through consultative workshops). The concepts and results were utilized at different levels starting from the policy and strategy level to the agricultural extension massaging and approaches. For example the Ministry of Agriculture and the Environment Quality authority utilized our results in their current work of developing the national Climate change adaptation polices with a pronounced participation for our investigators.

On the Israeli side, the stakeholders with an interst in our results are the Ministry of Environmental Protection, the Israel Nature and Parks Authority, the Open Landcapes Institute, and KKL (the Forest Service). We presented results of this research in round-table discussions, seminars, and participated in discussions. The relevant information was both on shifts of distributions in response to climate change – for open landscapes planning, and on management practices compatible with biodiversity conservation. The work on reptile distribution in agricultural landscapes was picked up and continued by the Israel Nature and Parks Authority. The work on agro-biodiversity is relevant also for new projects focusing on the provision of ecosystem services. The Ministry of Agriculture hired, for the first time, an ecologist. The young scientists trained as part of this project are now involved in the relevant organizations: Dr. Orit Skutelsky now works in the Conservation Division of the Society for the Protection of Nature in Israel, Dr. Hadass Steinitz works in the Agricultural Research Institute of the Ministry of Agriculture, and Yahel Porat is the KKL (Forest Service) ecologist. Therefore, their knowledge and expertise are directly at the disposal of the relevant organizations.

7 Socioeconomic benefits of ecological system services and their integration into models of optimal land use under climate change

Hebrew University working group

Aliza Fleischer, Hebrew University of Jerusalem
Iddo Kan, Hebrew University of Jerusalem
Jonathan Kaminski, Hebrew University of Jerusalem

7.1 Aim

This study proposes a proactive approach for analyzing agricultural adaptation to climate change wherein agricultural production technologies are regarded as potential targets of R&D efforts. We develop a structural land-use model wherein farmers maximize profit by allocating their land among crop-technology bundles.

7.2 Description of research

Global climate change is expected to affect agriculture production to varying extents in various world regions. While the livelihood of a large part of the population, especially in the southern hemisphere, might be threatened, other regions might nevertheless benefit (Parry et al., 2004). Farmers are likely to react to climate change by selecting the most profitable production technology under the new climate conditions. Production technologies are made available to farmers via long-run processes of research and development (R&D) conducted by agents in the private and public sectors. Thus, R&D agents determine production technologies' attributes vis-à-vis climate conditions. However, due to the public-good nature of R&D; imperfect information; the presence of externalities and uncertainties; and the long time frame required for R&D programs to produce, R&D efforts do not necessarily provide farmers with the most suitable production technologies to cope with forecasted future climate conditions. Suppose, however, that R&D agents are informed in advance about the potential benefits associated with altering each of the current technological attributes that are sensitive to climate change. This information would help them design their R&D efforts so as to provide, in time, production technologies fitting the anticipated climate conditions.

7.2.1 Material and Methods

We develop a methodology for identifying and evaluating such ex ante potential R&D directions, and term it the proactive approach. The proactive approach differs from what we term the reactive approach, which analyzes farmers' reactions to climate change given the attributes of the existing production technologies. Our methodology is based on a structural economic model that decomposes the profit function into its technological components. By applying the model to Israeli data and a simulated future climate scenario, we show how to derive potential R&D directions for adjusting agricultural production technology so as to mitigate possible adverse effects of climate change on agricultural profits.

To date, the economic literature has focused on the evaluation of climate-driven farm losses and farmers' reactions to climate change. The main debate in most studies surrounds the methodology used to evaluate this loss while accounting for adaptation, given readily available production technologies. Studies conducted in the US illustrate these methodologies' evolution. Adams (1989) developed the agro-economic approach whereby climate change's impact on various crops' yields affects farm profits. Mendelsohn, Nordhaus, and Shaw (1994) proposed the Ricardian (hedonic) approach, suggesting that farmers adapt by switching crops. Allowing adaptation, the damages they predicted were much smaller than Adams' (1989). By applying the hedonic approach, Schlenker, Hanemann, and Fisher (2005) demonstrated the importance of assessing separately climate change's economic effects on agriculture in both dry land and irrigated farmland. Deschênes and Greenstone (2007) used variations of weather conditions over time in order to avoid the possible bias stemming from omitted variables in the hedonic approach. Their findings predicted smaller yet more robust adverse climate change-related impacts than did previous papers. Based on these studies, it is clear that climate change affects farm profits, whereas the magnitude of the forecasted effects depends on methodological choices. Less attention is given to evaluating R&D efforts that could improve agricultural production technologies and thereby help farmers mitigate the projected damage.

Another branch of the literature that aligns with the reactive approach analyzes farmers' adaptation measures to climate change. Studies show that farmers in various parts of the world use irrigation and switch crops or livestock species (Mendelsohn and Dinar, 2003; Kurukulasuriya and Mendelsohn, 2008; Kurukulasuriya et al. 2006, Seo and Mendelsohn, 2008a and 2008b) to adjust to climate change. Fleischer, Mendelsohn, and Dinar (2011) showed that farmers react to climate change by changing their choices of crop-technology bundles.

By referring to adaptation as a reaction to climate change, the aforementioned studies implicitly assume the existence of perfectly functioning markets for the development of new agricultural technologies that farmers pick off the shelf. However, such R&D markets might suffer from market failures, which might in turn be due to the free-riding phenomenon associated with the public-good nature of knowledge; information asymmetries between scientists and public goods' suppliers; and uncertainties associated with long-term climate predictions. Moreover, governments intervene heavily in the agricultural sector through policies that seek to internalize externalities and support farm incomes; as well as by designing and financing utilities such as roads and water networks, as well as long-running R&D programs. Hence, governments actually play a key role in adaptation to climate change, and affect both the provision of production factors and the development of new production technologies. For these reasons, unlike the reactive approach prevailing in the existing literature, this article stresses the need for a proactive approach.

Our methodology rests on land-use decisions. Following McGuirk and Mundlak (1992), we assume a recursive nature of decisions on a farm. In the first phase, as in Fleischer, Mendelsohn, and Dinar (2011), land is simultaneously allocated among crop-technology bundles. The technologies considered in this phase are characterized by limited short-term mobility, such as irrigation systems and greenhouses. The second phase begins once land allocation is accomplished, when profit is determined solely by intra-growing-season applications of mobile inputs (fertilizers, pesticides, etc.) and farm management. We assume optimality in this two-phase decision-making. That is, when contemplating land allocation in the first phase, farmers take into account their ability to optimize profits in the second phase. This ability, in turn, relies on the available farm technologies' attributes, which are exogenous to the farmers, but not to R&D agents. These technological attributes include the performance of crop varieties and the conditional productivity of agronomic machinery and inputs, which in turn depend on climate conditions and other environmental factors. Under climate change, farmers ordinarily react by reallocating their land at the land-allocation phase, while taking into account climate's impact on farm profits through its impact on these technological attributes. Thus, even after adaptation through land reallocation, farmers might still lose, or not earn as much as they might. The blame for this loss should be placed on the existing production technology's characteristics.

The challenge of our proactive approach is to identify the climate variables via which land reallocation does not prevent loss, the attributes of the technologies responsible for this deficiency, and the corresponding agricultural loss. This identification enables us to recommend the specific features of the existing production technology that might merit further R&D efforts in order to improve farmers' adaptation to future climate conditions.

In order to derive such proactive R&D recommendations, the farm profit function can no longer be treated as an unspecified reduced-form function; instead, it needs to be broken down into its structural components. Following Letort and Carpentier (2009), in our land-use structural model we consider three levels of profit decomposition: The upper level incorporates the profitability (defined as profit per land unit) associated with each land-allocation decision variable, i.e., the crop-technology bundles. These profitability functions incorporate technological attributes, which constitute the mid level of profit decomposition. Four technological attributes are considered: yield potential; production-input requirements; yields' tolerance to inaccurate or wrong applications of inputs; and farm-level constraints and managerial costs. At the bottom level of profit decomposition, these four technological attributes are treated as functions of exogenous variables, among which are climate variables. This tri-level structure treats the technological attributes as mediators between the climate variables and each bundle's profitability. R&D efforts can modify climate variables' impact on technological attributes, and thus improve each bundle's profitability under future climate conditions. We evaluate the benefits associated with such R&D avenues; however, the final decision on R&D programs should also consider the cost side of each, which is beyond the scope of this study.

Our structural approach has several advantages over previous studies. Firstly, the estimated land-share regression equations derived by a structural analysis retain the components of the original optimization problem (as in Chambers and Just, 1989; Fezzi and Bateman, 2011[1]); in our model, this property allows inference about climate impacts on production technologies' attributes. For comparison, estimations of non-structural land-use models are based on assumed reduced-form land-share functions, wherein the original parameters are unidentifiable (e.g., Lichtenberg, Zilberman, and Bogen, 1989; Wu and Segerson, 1995; Hardie and Parks, 1997; Miller and Plantinga, 1999). Secondly, its advantage over the hedonic (Ricardian) approach stems from its reliance on land-use data rather than on records of farm profit or farmland value. Unlike land-use data, which are readily available from official acreage reports, reliable profit or farmland value data are not always available. Farmland value may also be problematic because of measurement errors. As noted by Deschênes and Greenstone (2007), the use of land value as a proxy for profit can result in biased estimates due to omitted variables. Moreover, farmland value does not accurately reflect long-term profits when land markets are heavily regulated, as in Israel, our illustrative case study. Thirdly, since the information at planting time does not include conditions along the growing season, land-use data are less sensitive than is profit to the effects of unpredictable intra-growing season events such as pest outbreaks and sudden fluctuations of output and input prices. Lastly, this timing of information available to the farmers makes land use a reliable reflection of long-term changes in farm profitability and accordingly adaptation to climate change. In order to optimize profits by land allocation at the beginning of the growing season, farmers should anticipate the weather conditions along the season. To this end, they can rely only on their long-term experience with weather, i.e., on past climate conditions.

[1] Structural approaches identify the parameters of agricultural technologies needed for some theory or empirical questions. Chambers and Just (1989) estimate multi-output technologies and derive a test for input non-jointness. Fezzi and Bateman (2011) simulate diffuse pollution reduction measures.

Therefore, observed spatial variation of land allocation reliably represents farmers' optimal adaptation to spatially distributed climate conditions. Our empirical strategy thus revolves around the estimation of crop-technology bundles land-share equations.

Israel, chosen as a case study, has several advantages for the purpose of this study. Firstly, although small, its climatic gradient provides spatial diversity varying from Mediterranean climate in the north to arid conditions in the south (Dayan & Koch, 1999). Secondly, with respect to adaptation, Israel is known as a leader in agricultural innovations, and its agricultural sector generally employs state-of-the-art technologies. Thirdly, a panel of detailed bundle-acreage data on both regional and annual bases is accessible from official sources. Finally, daily weather data are available from a high spatial-resolution model (Krichak et al., 2010), which well reproduces past climate conditions and simulates future climates under the IPCC A1B (IPCC, 2001) scenario. This rich weather dataset allows us to account not only for changes in temperature and precipitation levels, but also for their intra- and inter-annual volatility. This is a key feature, since there is a growing consensus that climate change is going to be characterized by extreme events wherein variability is found to be important, as are absolute values (Katz and Brown, 1992). Our weather data also incorporate wind and solar radiation, the latter enabling distinguishing between temperature and radiation effects.

Our findings have two tiers, reflecting the reactive and proactive analytical approaches. In the first tier, we show that, similar to reduced-form studies, our model identifies farmers' expected reactions to changes in climate variables by land reallocation. The application to the case of Israel predicts reductions in total cultivated land and farm profitability in the long run, and points to the group of precipitation variables as the main drivers. Unlike reduced-form models, our structural model can also identify the technological attributes via which the impacts of climate variables on bundles' profitability are channeled, and thereby lead to these land reallocations. In the case of the Israeli agricultural sector, our results indicate that the main driver for the expected decline in long-run profits is the increase in crops' input requirements (and hence input costs). This negative effect is partly offset by the positive impacts of the climate changes channeled through the other technological attributes, so that the overall effect amounts to an 8.8% decline in profit in the long run. This analysis emphasizes the advantages of the structural analysis in identifying proactive R&D directions; in this case, toward reducing input requirements. Reduced-form studies would overlook climate change's strong underlying effects on each technological attribute, and owing to the small estimated impacts on agricultural profits, might errantly conclude that there is merely minor potential for improving adaptation by further development of the existing farming production technologies.

7.2.2 Results

We found that in Israel long-term losses stem from increases in crops' input requirements and changes in the inter- and intra-annual distribution of precipitations. Therefore we identify these vulnerable points as the main potential targets of further R&D efforts.

7.2.3 Discussion and conclusion of scientific highlights and outlook

In this study, we propose a new approach to understanding and taking long-term proactive measures in farmers' adaptation to climate change. Specifically, we introduce a structural model wherein farmers maximize profits by allocating their land among crop-technology bundles in view of climate variables' impact on profitability, as channeled through climate's impact on attributes of production technologies. The model allows us to provide policymakers not only with estimates on expected land-use changes and evaluations of losses in climate change-driven agricultural profits, but also with information on which of and how these technological attributes should be considered for further development in order to minimize losses. We applied the model to the case study of Israel based on the IPCC A1B climate scenario, and forecasted a slight decrease in agriculture profits in the long run. We show that input requirements' sensitivity to precipitation variables is the main cause thereof, and therefore identify this vulnerable point as the main potential target of further R&D efforts. The model also enables refining proactive R&D

measures through the bundle-specific identification of the technological attributes most vulnerable to each climate variable, as we illustrate for citrus and precipitation. This analysis emphasizes the structural econometric approach's advantages in identifying proactive R&D directions. It also stresses the possibility of missing the needed adaptation recommendations in reduced-form equation studies that estimate yields, land uses, or profits.

Our proactive analysis is based on the objective of maximizing agricultural profits. From a societal standpoint, however, proactive measures should be designed based on a more comprehensive, normative approach that accounts for climate impacts on farmland's non-market environmental services such as landscape and biodiversity. For instance, the move toward protected bundles is expected to decrease landscape amenities, whereas switching to orchards is expected to increase landscape value (Fleischer and Tsur, 2009).

7.3 References

Tielbörger, K., Fleischer, A., Menzel, L., Metz, J., Sternberg, M. (2010). The aesthetics of water and land: a promising concept for managing scarce water resources under climate change. Philosophical Transactions of the Royal Society A, 368: 5323-5337.

Fleischer, A. Mendelsohn, R. and Dinar, A. (2011). Bundling Agricultural Technologies to Adapt to Climate Change, Technological Forecasting and Social Change, 78(2011): 982-990.

Fleischer, A. Kurukulasuriya, P. Mendlsohn, R. (forthcoming).The Interaction of Crop and Irrigation Technology Choice as Climate Changes Across Agro-Ecological Zones. Mendelsohn R. and Dinar, A. (eds.) In: Handbook on Climate Change and Agriculture. Edward Elgar.

Kaminski, J., Kan, I. And Fleischer, A. (forthcoming). A Structural Land-Use Analysis of Agricultural Adaptation to Climate Change: A Proactive Approach, American Journal of Agricultural Economics.

University of Haifa working group

Mordechai Shechter, University of Haifa, Israel
Dafna M. DiSegni, University of Haifa, Israel
Shiri Zemah Shamir, University of Haifa, Israel
Mickey Rapaport-Rom, MSc., University of Haifa, Israel
Iddo Kan, The Hebrew University, Israel

7.4 Aim

The main activities within the last year of the project were to empirically evaluate the economic value of climate change impact of the supporting services, estimate the impacts of changes in vegetative agriculture under updated climate scenario and empirically evaluate the economic value of climate change impact and land use of the biodiversity and ecosystem services in the Jordan region.. Our valuation is provided for both Israel and Jordan.

7.5 Description of research

The VALUE model was developed and calibrated for Israel's 21 "ecological" regions (Howitt, 1995; 2005). In each region the model incorporates 45 crops and calculates the allocation of land among those 45 crops, as well as the allocation of freshwater, treated waste-water and brackish water. In the first stage, the model was calibrated in order to represent the land and water allocations observed in 2002 (the base year of the analysis). We assumed that these allocations maximized the farming profit. In a second stage, the VALUE model was updated for assessing climate-change impacts on vegetative agriculture based on farmers' adaptations through water and land-use management strategies.

The value of supporting services is carried using a simple macroeconomic growth model that was extended to include the impact of climate change on the natural stocks within the system. The model we have developed, referred as MEVES model, integrates into a specific growth model the impact of changes in natural stocks that are associated with non-market services. Within this model, the average value of marketed ecosystem services (like grazing, tourism) is fixed, and mainly associated with its market values. The value of non-market goods provided by natural stocks (like green biomass, soil deposition, and plants' seeds) is associated with the impact of the stock on the optimal path of social growth.

The value of the ecosystem services is carried out using two main models: the first model, use the reintroduction costs in order to calculate the value of the damaged caused by climate change and human interference and the other model use characteristics valuation method of the biodiversity that had been extinct since the changes. Based on data of the Water Authority and NPA, we conclude that since there were over extracting of water from different wellsprings, especially Ein Izrael wellspring (part of Harod river), different flora species had been extinct.

7.5.1 Material and methods

We developed a regional scale model named VALUE (Vegetative Agricultural Land Use Economic) model to effectively estimate the impacts of changes in vegetative agriculture. The objective of VALUE is to simulate the behavior of farmers under changes of climate conditions (precipitations), the availability of irrigation water and different prices and limitation of water. Such changes can be attributable to processes of climate changes, global changes (like trade conditions), technological improvements, etc. The seccond model we have developed, referred as MEVES model, integrates into a specific growth model the impact of changes in natural stocks that are associated with non-market services. Within this model, the average value of marketed ecosystem services (like grazing, tourism) is fixed, and mainly associated with its market values. The value of non-market goods provided by natural stocks (like green biomass, soil deposition, and plants and plants' seeds, is associated with the impact of the stock on the optimal path of social growth.

7.5.2 Results

Our simulations indicate a reduction of about 15% in the cultivated land and of 5-7% in the profits of the vegetative agricultural sector. Although the use of freshwater is sensitive to changes in freshwater quotas and prices, land-use and profits are quite robust to these changes.

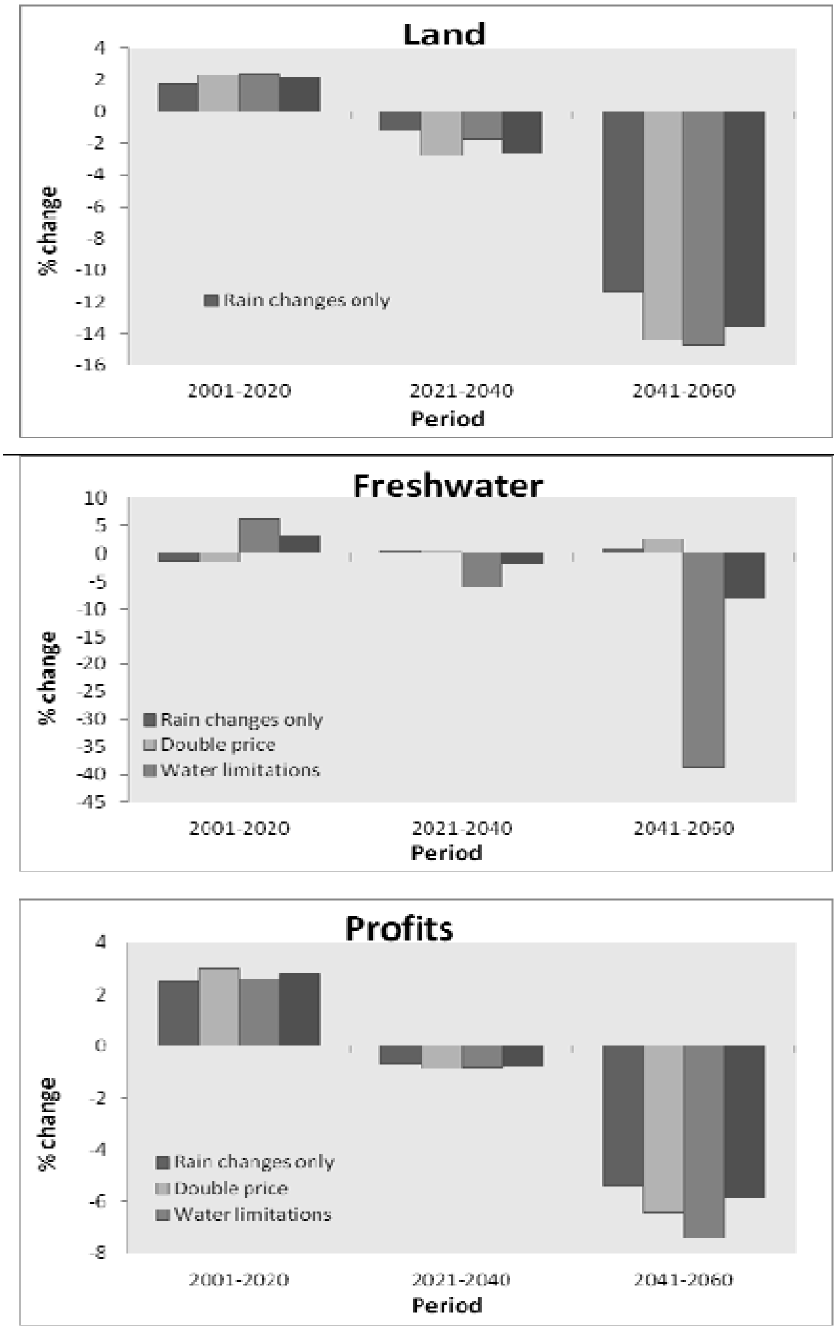


Figure 7.1: The forecasted (relative to the 1981-2000 period) in land and water usage by the agricultural sector and the profits, under various scenarios with respect to freshwater quotas and freshwater prices

We have evaluated the impact of climate change on optimal growth path to be about 0.11% of Israel GNI along the period 2000-2010 and 0.35% of Jordan GNI. This estimation is based on an average impact of climate change effect on natural stocks that are considered to provide a large range of ecosystem services. These include (i) Plant seeds volume and diversity; (ii) Extinction risk of certain species; (iii) Stocking capacity as function of climate change; (iv) Green biomass production; (v) Plant cover; (vi) Soil deposition and runon; (vii) Leaf area index.

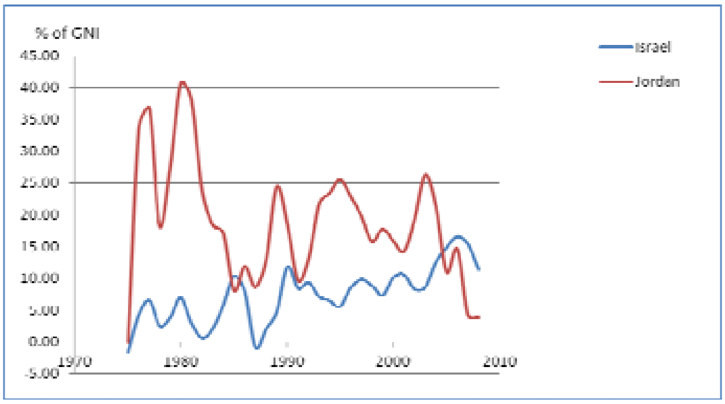


Figure 7.2: Adjusted Net Saving Index of Israel and Jordan for the period 1965-2010 without taking into consideration the impact of climate change on ecosystem services indirectly consumed by society.

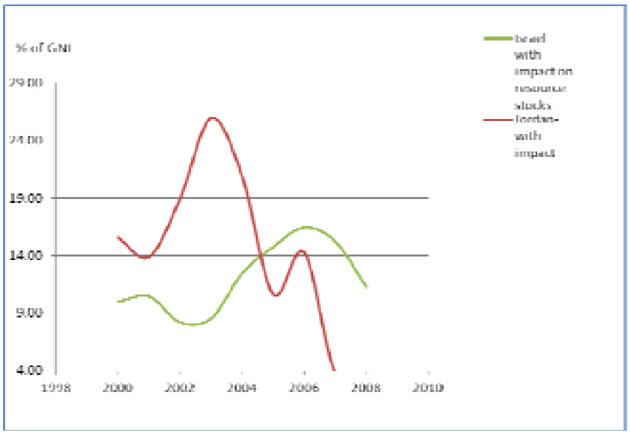


FIgure 7.3: Adjusted Net Saving Index of Israel and Jordan for the period 2000-2010 while taking into consideration the impact of climate change on ecosystem services indirectly consumed by society.

Our main results based on the reintroduction values are:

- Reconstructing of the habitat – 1200 euro/1000m/year
- Irrigation of the replanted fauna – 600 euro/1000m/year
- Shifting trees to the selected habitat – 400 euro per unit

The results based on the characteristics values the losses of the extinct species are:

- Stachys viticina boiss, Persicaria lapathifolia, Blue water speedwell, Convolvulus scammonia, Helminthotheca echioides – 4,491 euro/1000m
- Verbena officinalis – 45,318 euro/1000m
- Piptatherum miliaceum – 28543 euro/1000m
- Dittrichia viscosa – 4596 euro/1000m

7.5.3 Discussion and conclusion of scientific highlights and outlook

The main activities within the last year of the project were to use VALUE in order to estimate the impacts of changes in vegetative agriculture under updated climate scenario.

Changes in precipitations lead to changes in direct rainfall contribution to winter crops, and indirect effect on the water quotas allotted to farmers. Moreover, these changes, in combination with population growth, would lead to increase reliance on desalinated water, and thereby to increase in freshwater prices. These changes are simulated by VALUE, ceteris paribus.

We have evaluated the impact of climate change on optimal growth path to be about 0.11% of Israel GNI along the period 2000-2010 and 0.35% of Jordan GNI. This estimation is based on an average impact of climate change effect on natural stocks that are considered to provide a large range of ecosystem services. These include (i) Plant seeds volume and diversity; (ii) Extinction risk of certain species; (iii) Stocking capacity as function of climate change; (iv) Green biomass production; (v) Plant cover; (vi) Soil deposition and runon; (vii) Leaf area index.

Also, from the biodiversity assessments we see above, these values we conclude that climate change and human interference damage the biodiversity and the ecosystem services flow. There is a need for social planner intervention for sustainable and adapted development.

7.6 Applied value of results

VALUE model simulates the behavior of farmers under changes of climate conditions and the availability of water, and reports changes in cultivated land and water allocation among the different crops, and as a result, changes in profits.

This project also has emphasised and demonstrated the strong links beteen economic indicators (as national net savings, consumption, human capital and technological capital) and environmental indicators, and has offered an approach of valuation that relies on long term benefits from resources.

7.7 References

Krichak, S.O., Alpert, P. and Kunin, P. (2010). Numerical simulation of seasonal distribution of precipitation over the eastern Mediterranean with a RCM, Clim. Dyn. 34:47–59.

Howitt, R.E. 2005. “Agricultural and Environmental Policy Models: Calibration, Estimation and Optimization.” http://www.agecon.ucdavis.edu/aredepart/facultydocs/howitt/master.pdf.

Howitt, R.E. 1995a. “Positive Mathematical Programming. ” American Journal of Agricultural Economic, 77(2):pp. 329-342.

Kan, I., Rapaport-Rom, M. and Shechter, M. (2007). Assessing Climate Change Impacts on Water, Land-Use and Economic Return in Agriculture. Social Science Research Network (SSRN), Agricultural & Natural Resource Economics, Vol 11, No. 67: December 17, 2007

ATEEC workin group

Prof. Amer Salman, ATEEC, Jordan
Dr. Emad Karablieh, ATEEC, Jordan
Dr. Mohammad Majdalawi, ATEEC, Jordan
PhD Students: Mohammad Tabieh

7.8 Aim

The main activities within the last year of the project were to empirically evaluate the economic value of climate change impact of the supporting services, estimate the impacts of changes in vegetative agriculture under updated climate scenario and empirically evaluate the economic value of climate change impact and land use of the biodiversity and ecosystem services in the Jordan region.

7.9 Description of Research

The SAWAS model was developed and calibrated for Jordan (Salman et. all 2000, Salman and Karablieh 2004)). In each region the model incorporates all crops and calculates the allocation of water and land among all crops. Water has been allocated according to different qualities, freshwater, treated waste-water and brackish water. In the first stage, the model was verified and validated in order to represent the land and water allocations observed in 2004 (the base year of the analysis). We assumed that these allocations maximized the farming profit. In a second stage, the SAWAS model was updated for assessing climate-change impacts on vegetative agriculture based on farmers' adaptations through water and land-use management strategies. Two main aspects were investigated, these are:

- Assessing the socioeconomic benefits of ecological system services was done by assessing and substantiate Jordan's environmental losses due to the expectation of the impact of climate change in the future.
- Incremental changes on the various fragile elements of the environment including natural habitat, rangeland, forest wetland, and degradation in species biodiversity are to be linked with the climate changes.

7.9.1 Materials and Methods

Two linear programming models were developed to determine the optimal water resource allocation for the Jordan Valley. They use data on the total land available, the water requirements per unit area of land for different crops, and the water related contributions (WRC) per unit of land area resulting from the growing of those crops. WRC is the gross margin minus water expenses per unit area of specific crop. These WRC's do not include payments for water, which are handled separately. The models take prices and quantity allocations for water and generate a cropping pattern that maximizes net income. The model can also be used to examine the effects of water quantity allocations between crops as a result of changes in the prices of agricultural outputs, or the effect of water restrictions on agricultural outputs and income.

The first model was formulated in such a way that water and land constraints were built-in, as well as constraints to prevent the exaggerated expansion of fruit trees, such as citrus and banana, while at the same time ensuring that the market was provided with sufficient quantities of vegetable crops like potatoes and tomatoes. Moreover, water storage-transfer activities were incorporated in order to obtain the optimal water allocation to maximize net income. Two types of water transfers were allowed - direct and indirect. In direct transfers, water is moved to an assigned activity for immediate use, while indirect transfers involve the simulated storage of excess water and its later transfer to satisfy the needs of activities in subsequent months. In this model, the optimization process is based on a mean level of activities, and no allowance is made for the implicit risks that are inherent in every possible solution.

7.9.2 Results

The main results that have been accomplished according to the overall goal and mile stones were analyzed from the macroeconomic valuation on CC impact on ecosystem services in addition to this, changes were in Welfare in the Jordan with regard to climate change and land use changes were assessed.

7.9.2.1 Macro Economic Valuation of CC Impact on Ecosystem Services

Tab. 7.1: Economic Losses due to Forest and Rangeland Degradation as a results of CC.

Present Value of Economic Loss	Period	Jordan (million US$)	Northern Areas (million US$)
Forest Damages Cost	100	49,494	26,430
Forest Replacement (reforestation) Cost	100	30,620	16,351
Rangeland Damage Cost	100	229	
Forest Damages Cost	50	832	444
Forest Replacement (reforestation) Cost	50	565	302
Rangeland Damage Cost	50	182	302

Tab. 7.2: Measuring Changes in Welfare in Jordan: the Case of Climate Change and Land Use Changes.

code	Land-use/land-cover type	Ecosystem service(s)	Ecosystem Value ($/hectare) in 2000	Ecosystem Value ($/hectare) in 2050	Applied Method to value ESS
0	Water, Shore land, coral beach, marine Park	Recreation, Diving, Snorkeling	10,848.4	14,439	Coral Reef Valuation Tool (v2.0)
1	Evergreen needle leaf forest	Recreation, Soil erosion, Wood	392.8	153.5	Travel Cost, Damage Cost avoided, Market Price of Wood
2	Evergreen broadleaf forest	Recreation, Soil erosion, Wood	387.1	207.7	Travel Cost, Damage Cost avoided, Market Price of Wood
3	Deciduous needle leaf forest	Recreation, Soil erosion, Wood	282.8	98.2	Travel Cost, Damage Cost avoided, Market Price of Wood
4	Deciduous broadleaf forest	Recreation, Soil erosion, Wood	361.1	173.1	Travel Cost, Damage Cost avoided, Market Price of Wood
5	Mixed forests	Primary production, Prevention of soil erosion	291.7	192.6	Productivity Approach
6	Closed scrublands	Recreation, Soil erosion, Wood, Biomass, Grazing	77.8	30.6	Productivity Approach, WTP
7	Open scrublands	Grazing	8.84	2.2	Productivity Approach, Damage Cost Avoided
11	Permanent wetlands	Biodiversity, Recreation	645.0	81	Habitat Equivalency Analysis (HEA)
12-1	Fruits excl melons rainfed	Primary production	860.8	748.7	Market, Behavioral approach
12-2	Fruits excl melons irrigated	Primary production	2,391.9	1,962.0	Market, Behavioral approach
12-3	Vegetables incl melons rainfed	Primary production	1,962.3	1,771.4	Market, Behavioral approach
12-4	Vegetables incl melons irrigated	Primary production	5,991.2	5,233.0	Market, Behavioral approach
12-5	Cereals rainfed	Primary production	170.3	159.4	Market, Behavioral approach
12-6	Cereals irrigated	Primary production	1,129.3	1,067.9	Market, Behavioral approach
12-7	Other crops rainfed	Primary production	175.9	141.5	Market, Behavioral approach
13	Urban and built-up	Amman Residential Areas	304,566.1	1,118,800	Market Based Approach
16	Barren or sparsely vegetated	Grazing	3.54	1.2	Productivity Approach

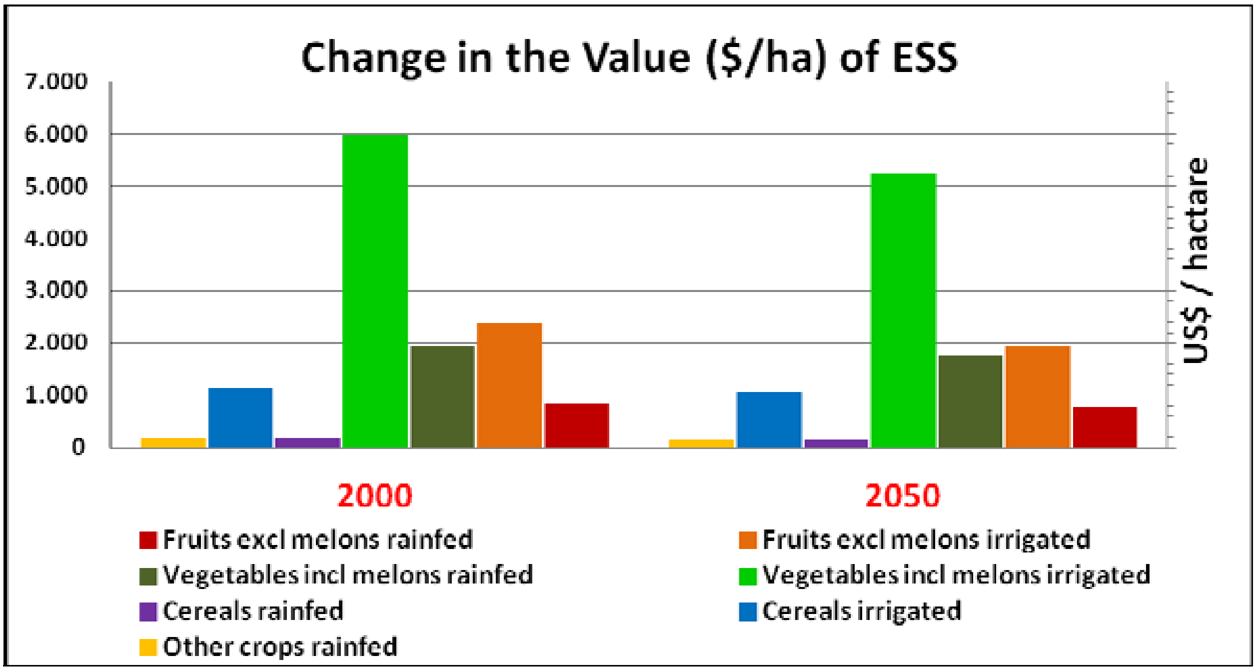


Fig. 7.4: Measuring Changes in Welfare in Jordan: the Case of Climate Change and Land Use Changes.

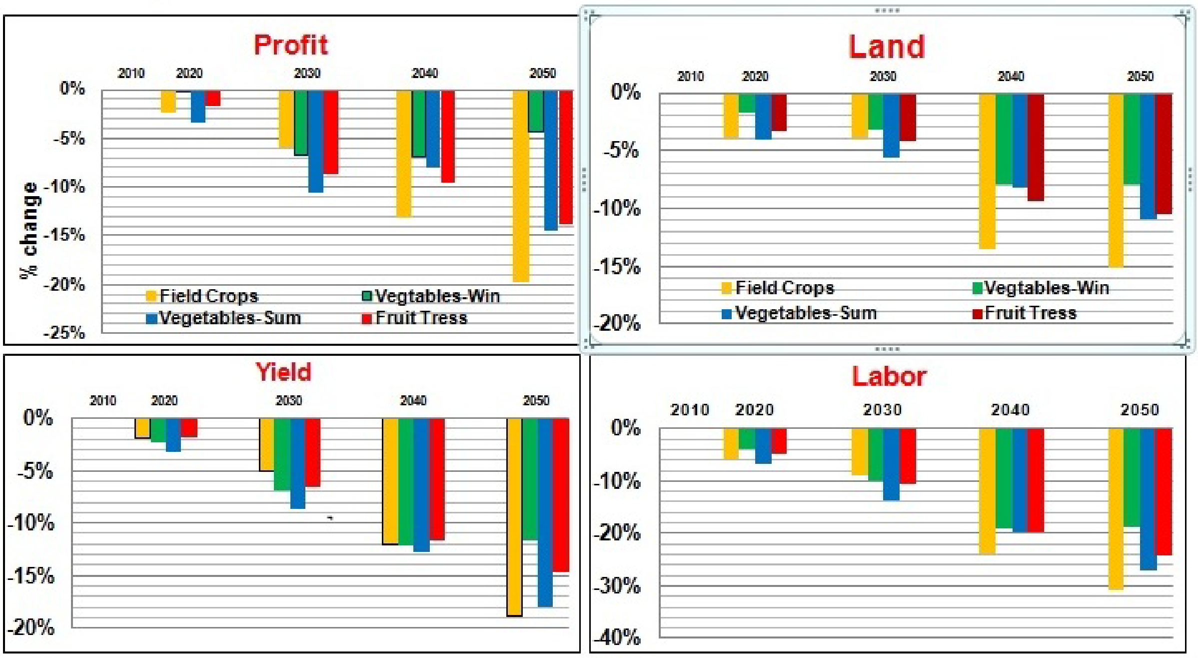


Fig. 7.5: Land Use Change and Environmental Impacts: The Optimization Model – Climate Change Impacts.

7.9.3 Discussion and conclusion of scientific highlights and outlook

The water demand from agriculture reacts to increasing water prices in a quite inelastic manner over a long interval, so long as the planning of cropping patterns is based on the expectation of average results only. If planners consider risk, however, even marginal increases of the water price change the production structure, reduce agricultural production and initiate negative impacts on the supply situation and the living standards of the local rural population. It may be expected that raising water prices under the existing cropping pattern would lead to a mixture of effects from both scenarios. Discussions on the allocation of water between the different sectors of society on the basis of pricing mechanisms have to consider the substantial impacts on market supply in terms of quantity and variety of agricultural products.

The impact of climate change on the optimal growth path has been evaluated to be about 0.35% of GNI along the period 2000-2010. This estimation is based on an average impact of climate change effect on natural stocks that are considered to provide a large range of ecosystem services. These include (i) Plant seeds volume and diversity; (ii) Extinction risk of certain species; (iii) Stocking capacity as function of climate change; (iv) Green biomass production; (v) Plant cover. Also, from the biodiversity assessments, these values we conclude that climate change and human interference damage the biodiversity and the ecosystem services flow. There is a need for social planner intervention for sustainable and adapted development.

7.10 Applied Value of the results

The suggested mathematical models proved to be relatively easy to handle, and have a sufficient level of generality that would allow their use as a decision aid and prognostic tool in other locations of the region too. In addition, the results can serve as a decision support devise suggesting to a planner what crop patterns are likely to prove optimal under different water policies and under the risk of market price variations.

7.11 References

Salman Amer, E. Al-Karablieh, and F. M. Fisher, “An Inter-seasonal agricultural water allocation system (SAWAS)”, Agricultural Systems, Volume 68, 2001, p 233-252.

Salman Amer and Emad Al-Karablieh (2004). “Measuring the Willingness of Farmers to Pay for Groundwater in the Highland Areas of Jordan” Agriculture Water Management, Volume 68/1, 2002, p 61-76.

Al-Omari, A., Amer. Salman , and E. Al-Karablieh (2011) The Red Dead Canal Project: An Adaptation to Climate Change in Jordan. 1st Water and Environment International Conference, WATEIC-2011, October 26 - 29, 2011, Marrakech- Morocco

Emad K. Al-Karablieh, Amer Z. Salman, Abbas Al-Omari, Heniz-Peter Wolff, Tamer Al-Assa’d, Ali Subah (2011). Estimation of the Economic Value of Irrigation Water in Jordan.1st Water and Environment International Conference, 26-29 October, 2011, Marrakech, Morocco.

Tamer A. Al-Assa'd, Emad K. Al-Karablieh, Amer Z. Salman, Heniz-Peter Wolff (2011) Recognizing the Economic Value of Domestic Water in Jordan as a Way for Appropriate Setting of Water Pricing, 1st Water and Environment International Conference, 26-29 October, 2011, Marrakech, Morocco

Mohammad Tabieh, Amer Salman, Emad Al-Karablieh, Hussein Al-Qudah and Hazem Al-khatib (2012). The Residental Water Demand Function in Amman-Zarka Basin in Jordan. Wulfenia Journal Vol 19, No. 11; Part II, pp 324-333.

Taleb M. Abu-Sharar, Emad K. Al-Karablieh and Munther J. (2012). Role of Virtual Water in Optimizing Water Resources Management in Jordan. Water Resources Management: Volume 26, Issue 14 (2012), Page 3977-3993

Wolff H. P., L. Wolf, A. Subah, J. Guttman, A. Tamimi, A. Jarrar, A.Salman and E. K. Karablieh (2012). Methodological challenges in evaluating performance, impact and ranking of IWRM strategies in the Jordan Valley. Water Science and Technology. Volume 66, Number 2, pp. 1406-1415.

Al-Karablieh Emad; Amer Salman, Abbas Al-Omari, Heniz-Peter Wolff, Tamer Al-Assa'd, Doukhi Hunaiti, Ali Subah (2012). Estimation of the Economic Value of Irrigation Water in Jordan. Journal of Agricultural Science and Technology .Volume 5, B2. pp. 487-497

Heinz Peter Wolff, Emad Al-Karablieh, Tamer Al-Assa'd, Ali Subah, Amer Z. Salman (2012). Jordan Water Demand Management Study. Water Science and Technology: Water Supply. Volume 12, No. (1) pp 38-44

Karsten Schacht , Sven Gönster, Elisabeth Jüschke, Yona Chen, Jorge Tarchitzky, Jawad Al-Bakri, Emad Al-Karablieh and Bernd Marschner (2011). Evaluation of Soil Sensitivity towards the Irrigation with Treated Wastewater in the Jordan River Region. Water , Volume 3, No (4), pp, 1092-1111. (www.mdpi.com/journal/water)

E. K. Al-Karablieh, A.S. Jabarin and M. A. Tabieh (2011). Jordanian Horticultural Export Competitiveness from Water Perspective Journal of Agricultural Science and Technology. Volume1, No 7B, pp. 964-974.

Al-Karablieh Emad K. and Amer S. Jabarin (2010). Alternative Rangeland Management Options to Reduce Livestock Feeding Costs in Arid and Semi-Arid Areas in Jordan Quarterly Journal of International Agriculture. Vol. 49 (2), 91-110

Amer Salman, Emad Al-Karablieh , Hans-Jochen Regner, Heinz-Peter Wolff, and Munther Haddadind (2008) Participatory Irrigation Water Management in the Jordan Valley. Water Policy. Vol. 10. No 4, pp 305-322.

Amer Salman , Emad AL-Karablieh and Munther Haddadin (2008) Limits of Pricing Policy in Curtailing Household Water Consumption. Water Policy. Vol. 10. No 3, pp 295–304.

Amani Al-Assaf, Amer Z. Salman , Franklin M. Fisher, Emad Al-Karablieh (2007) A Trade–off Analysis for the Use of Different Water Sources for Irrigation (The Case of Southern Shounah in the Jordan Valley). Water International. Volume 32, Number 2, pages 244-253.

AIRD working group

Dr. Thameen Hijawi, Association for Integrated Rural Development (AIRD), Palestinian Authority

7.12 Aim

- To generate monetary estimates of the benefits of ecosystem services associated with natural and open space land-use in the Jordan River basin and how they will be impacted by climate changes.
- To assess and valuate the unique characteristics of the region in terms of ecosystem services provision, treating them in terms of portfolio of the various ecological characteristics, and incorporate them into an overall economic valuation model of land use changes associated with climate change impacts.

7.13 Description of Research

The economic valuation for land use types and main crop species has been accomplished in the identified ecosystems. The economic valuation has been mainly made according to Fleischer and Sternberg (2006), Fleischer and Tsur (2009), and Costanza et al (1997). The valuation data was expressed by the gross margin/profit of each respective land use/land cover types and presented in the US$/hectare/year.

The economic valuation of land uses and flora in the studied ecosystems, including the economically cultivated species, was done using the agricultural productivity valuation method for the main agricultural land use patterns. Economic values were presented in local market prices. The valuation models determined the specific land use which is consistent with the behavioral patterns observed throughout its large cross-sectional and time series database.

The identified economic values of the cultivated specie are mainly the production of food, raw materials for industry, Genetic resources, medicinal resources and ornamental values.

For other landuse types (recreational, grazing, wildlife habitat, soil preservation, etc.), we applied the contingent valuation method which was based on surveys for local people.

Economic valuation was based on the premise that individuals have preferences for different market and non-market goods. These preferences have a degree of substitutability; if the quantity of one good is reduced, the quantity of a different good can be increased to leave the person no worse off. The trade-offs made during this substitution reveal something about the values held for each good. Measurements of these values are expressed as either willingness to pay, the maximum amount a person would be willing to pay for an increment of a good, or willingness to accept, the minimum amount a person would require as compensation for the loss of an increment of a good (Freeman 2003).

Table 7.3: The identified economical values and valuation method for the main land use types of Arraba and Yabbad ecosystems

Land-use/land-cover type	Ecosystem service(s)	Applied method to value ESS
Mixed forests	Generation and preservation of soils, recreation	Contingent Valuation Method
Open shrub lands	Grazing, Recreation	Contingent Valuation Method
Grasslands	Grazing, Pharmaceutical, recreation	Contingent Valuation Method
Croplands	Food supply	Productivity valuation method
Urban and built-up	habitat, Recreational & Cultural values	Contingent Valuation Method
Cropland/natural vegetation mosaic	Food supply, Biodiversity, recreation	Contingent Valuation Method
Barren or sparsely vegetated	Grazing, Biodiversity	Contingent Valuation Method
Fruits excl melons rainfed	Food supply	Productivity valuation method
Fruits excl melons irrigated	Food supply	Productivity valuation method
Vegetables incl melons rainfed	Food supply	Productivity valuation method
Vegetables incl melons irrigated	Food supply	Productivity valuation method
Cereals rainfed	Food supply	Productivity valuation method
Cereals irrigated	Food supply	Productivity valuation method
Other crops rainfed	Food supply	Productivity valuation method

The ecosystem services values are expressed in US$ gross margin/hectares for each land use type, the data are presented in Figure 7.6 for the year 2000 estimations and Figure 7.7 for the year 2050 predictions.

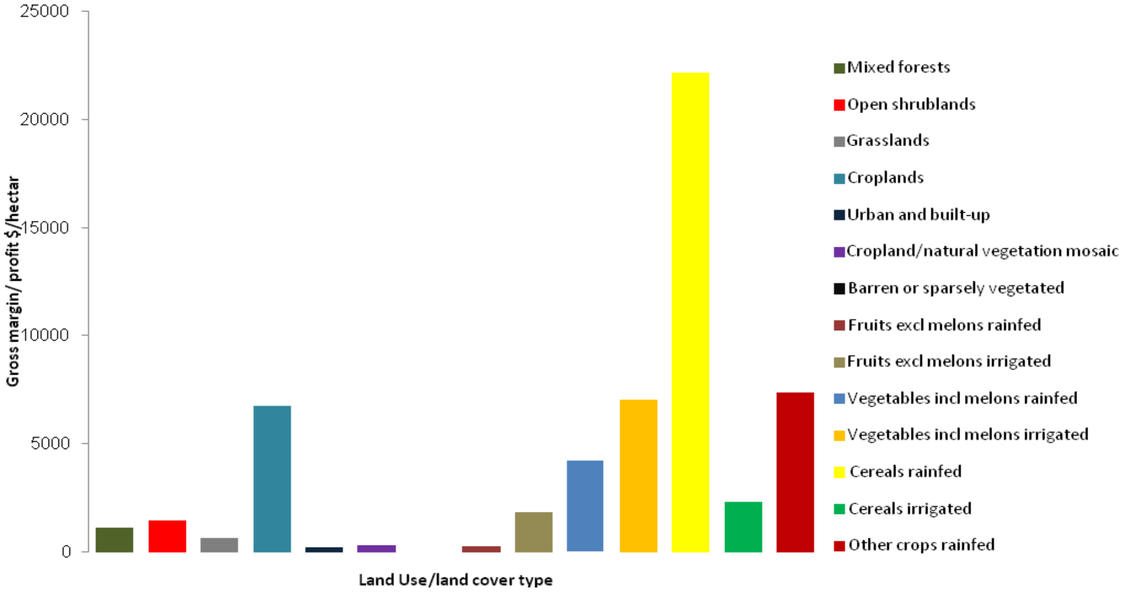


Figure 7.6: Ecosystem services values (year 2000)

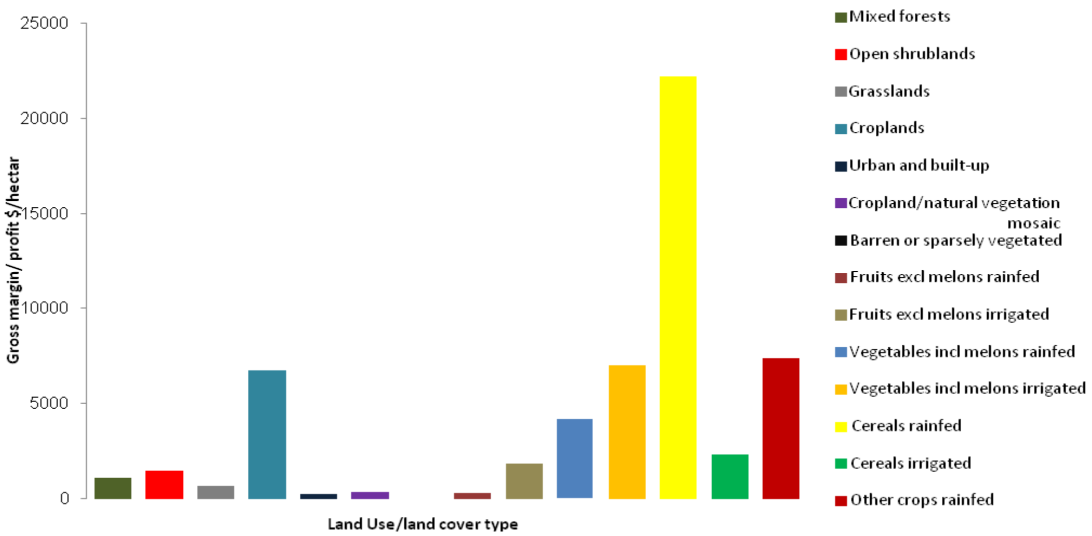


Figure 7.7: Ecosystem services values (year 2050)

7.13.1 Discussion and conclusion of scientific highlights and outlook

Economic valuation of ecosystem services is an evolving discipline. Both the data needed and methods used have shortcomings. Also, some common economic theories and practices do not apply to ecosystem valuation as well as traditional valuations. Finally, there is a conceptual controversy about the use of ecosystem values.

Another limitation of ecosystem service valuation is geographical and temporal specificity. The same type of ecosystem could have very different values in different locations due to differences in economic activities, cultures, and lifestyles of the local people. Values also depend on current market prices and preferences, both of which can change over time. Future generations may value a particular service differently than the current one. The geographical and temporal specificity of any service valuation limits extrapolation of current, local values beyond local or bioregional scales and for all times

7.14 Applied Value of the results

Policy relevant is the data related to the impact of climate change on the present and predicted economic values of ecosystem services for the common land use patterns in the area, and recommendations for adaptation measurements. A stakeholder report of economic values of land use types in Arrabah and Yaabad ecosystems was produced. It was discussed in a workshop with the Palestinian environmental quality authority, the Palestinian water authority, the Palestinian ministry of agriculture and other relevant non-governmental organizations.

7.15 References

Costanza et al. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253-260.

Fleischer, A. and M. Sternberg, 2006: The economic impact of global climate change on Mediterranean rangeland ecosystems: A Space-for-Time approach. Ecological Economics, 59, 287-295.

Fleischer, A. and Tsur Y. (2009). The Amenity Value of Agricultural Landscape and Rural-Urban Land Allocation. Journal of Agricultural Economics, 60(1):132-153.

Freeman A. Myrik 2003: The Measurement of Environmental and Resource Values: Theory and Methods. Rff press.

8 Integrated modelling of land use change and environmental impacts

Rüdiger Schaldach, CESR, University of Kassel
Jan Volland, CESR, University of Kassel
Florian Wimmer, CESR, University of Kassel

In collaboration with:
Mordechai Shechter, University of Haifa, Israel
Mickey Rapaport-Rom, MSc., University of Haifa, Israel
Iddo Kan, Hebrew University, Israel
Aliza Fleischer, Hebrew University of Jerusalem
Jonathan Kaminski, Hebrew University of Jerusalem
Amer Salman & Emad Al Karablieh, ATEEC, Jordan
Thameen Hijawi, AIRD, Palestinian Authority

8.1 Aim

The overall goal of subproject 3.3 comprises four main objectives:

- Development of comprehensive spatially explicit land use scenarios taking into account socio-economic input variables from the story and simulation approach (P1.1) and climate change impacts on irrigated and rainfed agriculture
- Computation of development potentials for agriculture
- Assessment of land-use change effects on ecosystem service values
- Computation of water demands from households and livestock
- Communication of spatial land-use dynamics and its impacts on water demand and ecosystem services to the scenario building process.

8.2 Description of research

In order to develop comprehensive integrated land use scenarios the regional land-use model LandSHIFT.JR, which was developed in phase II of GLOWA JR, was refined. As a preparatory step, the initial land use map for the year 2000 was revised to achieve a detailed representation of the spatial distribution of cropland. Based on the initial map, the algorithms in LandSHIFT.JR were extended to allow for the separate simulation of irrigated and rainfed agriculture. In order to account for climate change impacts on the extent of agricultural area, new algorithms were implemented in the model that simulate changes in irrigated and rainfed crop yields and net primary production of semi-natural vegetation depending on climate conditions. In addition, the model was extended to achieve a more detailed representation of livestock grazing dynamics, including the simulation of different management strategies.

The improved LandSHIFT.JR model was used to calculate land use scenarios for the period 2000-2050, based on socio-economic scenario drivers provided by the subprojects 1.1. (Chapter 2) and 3.2 (Chapter 7), such as population growth and amounts of crop production under rainfed and irrigated agriculture. Based on these land use scenarios and simulated crop yields under climate change, the potential future production in irrigated and rainfed agriculture were assessed. Furthermore, the simulated land use maps were used to estimate future water demand for livestock and settlement areas as well as changes in ecosystem service values, provided by subprojects 3.1 (Chapter 6) and 3.2 (Chapter 7) under the different scenarios.

During the runtime of the project, preliminary results on the spatial land use dynamics and its impacts on water demand and ecosystem services were communicated to stakeholders involved in the scenario building process. This was mainly done by providing maps on land use, population density, livestock density, and ecosystem service value via the GLOWA Jordan River Atlas.

8.2.1 Material and methods

LandSHIFT.JR was applied to generate spatially explicit, mid- to long-term scenarios of land-use and land-cover change for Israel, Jordan and the Palestinian Authority (PA). The model works on a 30 arc seconds grid in 5-year timesteps for the period 2000-2050. Driving forces of LandSHIFT.JR are demands for land intensive commodities (e.g. food crops) and assumptions on policy and socio-economy. The rationale of the model is to regionalize the demands in a consistent and systematic way. Consideration of spatially explicit information on crop yields and productivity of (semi-)natural vegetation enables the inclusion of climate change effect on the spatial distribution and extent of different land uses. Currently, LandSHIFT.JR comprises the land-use activities residential area, both irrigated and rainfed crop cultivation, and livestock grazing. Changes in the extent of (semi-)natural vegetation result from changes in the spatial extent of urban/built-up area, arable land or rangeland. Furthermore, LandSHIFT.JR implements the inclusion of zoning regulations, and different management strategies for the land-use activities. A detailed description of LandSHIFT.JR is given in Koch et al. (2008, 2012).

There were two different sets of scenarios generated within the project. On the one hand, the four GLOWA JR scenarios developed by subproject 1.1, “Poverty and Peace” (PP), “Suffering of the weak and the Envrionment” (SWE), “Willingness and Ability” (WA), and “Modest Hopes” (MH) provide estimates of socio-economic model drivers covering Israel, Jordan, and PA. These scenarios are consistent for all three countries and follow the storylines developed in the stakeholder process. In addition, subproject 3.2 used the economic model VALUE to calculate future crop production in Israeli eco-regions. The resulting water related scenarios “Freshwater Limited” (FL), “Freshwater Double Price” (FDP), “Freshwater Limited Double Price” (FLDP), and “Rain Changes” (RC) are based on assumptions on future development of freshwater availability and prices as well as precipitation. Since these assumptions are not fully consistant with the storylines of subproject 1.1, two separate modelling exercises were carried out with LandSHIFT.JR to calculate the resulting land-use scenarios.

The calculation of wheat yields under varying climate is based on the output of GEPIC (Liu et al., 2007), a combination of the dynamic, process-based crop growth model EPIC (Williams et al. 1989, Williams 1995) and a GIS. For this purpose, we set up a database with GEPIC-results on yield of irrigated and rain-fed wheat as a proxy for cereals, vegetables, and fruits, which is used as input by LandSHIFT.JR. The calculation of net primary production (NPP) of rangeland and natural vegetation under different climate conditions is based on output of WADISCAPE (Köchy et al. 2008).

Simulated crop yields and NPP are based on climate datasets for current (1971-2000) and future (2035-2064) conditions resulting from a dynamical downscaling of general circulation model (GCM) output with regional climate models (RCMs) driven by the IPCC SRES A1B emission scenario. These climate projections comprise the TAU climate data set and four combinations of the GCMs ECHAM5 and HadCM3 and the RCM MM5 in the versions v3.5 and v3.7 (Smiatek et al. 2011). For intermediate time steps, simulated crop yields and NPP are interpolated linearly. Using an ensemble of climate projections for the same emission scenario allows us to analyze the uncertainty in crop yield calculations introduced by different GCMs and RCMs.

In addition to estimates of potential maximum extent of irrigated and rainfed cropland, which can directly be derived from the land-use maps for the different GLOWA JR scenarios, a more detailed analysis of the shift in potential yields was carried out separately for irrigated and rainfed agriculture. In a first step, the quintiles of the value distribution of mean simulated yields for the year 2000 (Y_i) were used to define the five classes of crop yield “very low” ([0, Y_1]), “low” (]Y_1, Y_2]), “medium” (]Y_2, Y_3]), “high” (]Y_3, Y_4]), and “very high” (> Y_4). In a second step, the grid cells values falling into the five classes were counted for the base year and the projections for the year 2050 driven by the different climate projections. Finally, the cells counts in each class for future and current conditions were compared.

The landscape valuation module of LandSHIFT.JR, which maps the value of ecosystem service (ESS) to the land-use classes, was refined to take into account the change of ESS-values over time. For this purpose, a database with ESS-values for the year 2000 and projections of ESS-values for the year 2050 for Israel, Jordan, and the PA is used. During the runtime, the landscape valuation module of LandSHIFT.JR interpolates the ESS-values for each 5-year time step between 2000 and 2050 resulting in dynamically changing maps of ecosystem service values. The ESS-values for Jordan and PA used in this approach were assessed by local GLOWA JR partners. For Israel, the ESS-values in 2000 were developed at the CESR based on former work of our Israeli partners (A. Fleischer and M. Sternberg). Moreover, CESR took on the task to project ESS-values of the Israeli landscapes for 2050.

In order to estimate the water demand for settlements and livestock grazing, country-specific scenario estimates on per-capita domestic water withdrawals from subproject 1.1 and an average drinking water demand of 3.5 l/d per sheep or goat were used, respectively. These assumptions were combined with LandSHIFT.JR output on population density and livestock density, resulting in maps of water demand for settlements and livestock grazing.

8.2.2 Results

In the following, the results of the scenario exercises are shown. In order to reduce the number of maps and tables we only can show a selection of the results in this report. The isolated effect of socio-economic scenario drivers on land-use changes assuming constant climate conditions as in the baseline period can be observed in the land-use maps in Figure 8.1 and the area statistics given in Table 8.1.

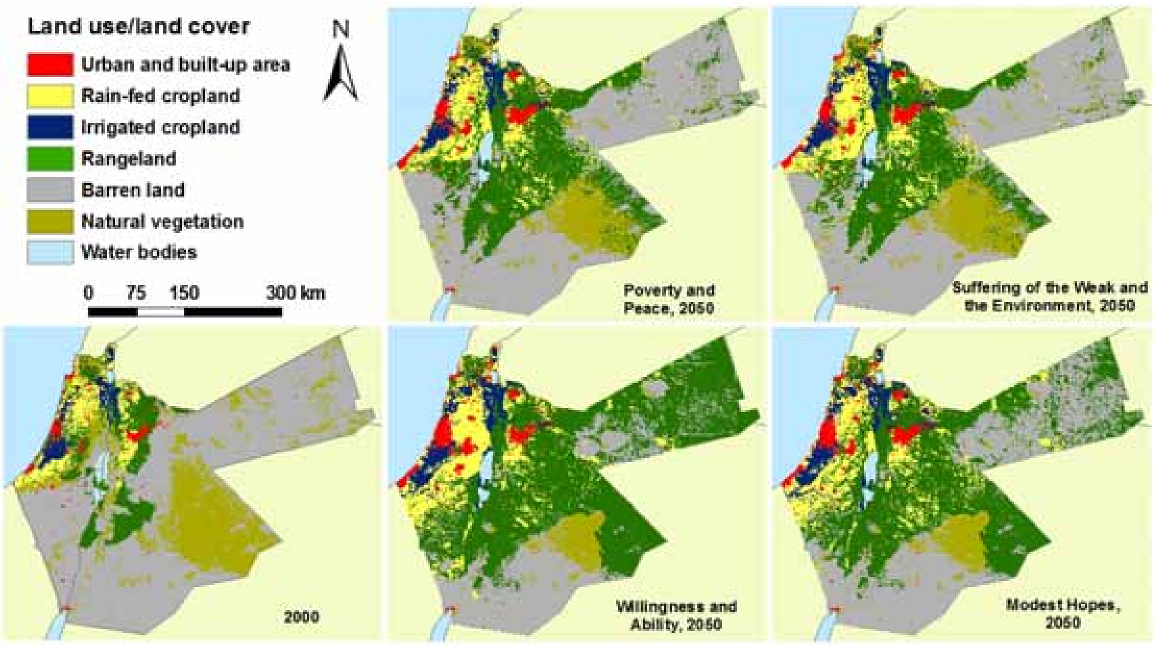


Figure 8.1: Land-use maps for a) the base year 2000 and the four GLOWA JR scenarios in the year 2050 assuming current climate conditions throughout the simulation period.

The simulation results show that urban land area expands by about 44% (SWE) to 59% (WA) in order to fulfill the demands for residential area. Moreover, the scenario assumptions lead to a vast expansion of the simulated area for irrigated agriculture by 36% (PP) to 98% (MH), for rainfed agriculture by 96% (MH) to 184% (WA), and for rangeland by 168% (SWE) to 425% (WA), not considering any adverse effects of climate change (Table 8.1 "Current climate"). The increasing area demand for human activities, mainly rangeland, leads to a strong reduction in the area of semi-natural vegetation. However, it is important to note that land cover on area classified as rangeland still has the character of semi-natural vegetation but is used for livestock grazing with varying but rather low intensity. Nevertheless, in all scenarios the forage production on rangeland is insufficient to meet the feed demand of grazing livestock. By 2050, the failure in forage production ranges between 58 000 t/a (MH) and 364 000 t/a (WA) (Table 8.1).

Table 8.1: Area extent in 2025 and 2050 and percentage change compared to the base year 2000 for different land-use types as calculated by LandSHIFT driven by the GLOWA JR scenario assumptions.

Scenario	Year	Irrigated cropland		Rainfed cropland		Rangeland		Forage failure	Urban area	
		[km²]	[%]	[km²]	[%]	[km²]	[%]	[10³ t/a]	[km²]	[%]
	Base year									
	2000	2350		4522		11027		0	3853	
	Current climate									
MH	2025	3039	29	6587	46	23120	110	7	4713	22
	2050	4650	98	12641	180	45635	314	58	6011	56
PP	2025	2731	16	6123	35	20174	83	14	4790	24
	2050	3188	36	8879	96	32000	190	65	5645	47
SWE	2025	2948	25	6644	47	20143	83	19	4790	24
	2050	3698	57	10416	130	29604	168	81	5561	44
WA	2025	3671	56	8899	97	29945	172	120	5026	30
	[a]2050	4610	96	12819	184	57873	425	365	6145	59
	TAU climate dataset									
MH	2025	3300	40	6910	53	23390	112	10	4713	22
	2050	5601	138	13468	198	47190	328	69	6011	56
PP	2025	2967	26	6250	38	20482	86	17	4790	24
	2050	3797	62	9781	116	32841	198	68	5645	47
SWE	2025	3202	36	6926	53	20334	84	22	4790	24
	2050	4409	88	11182	147	30387	176	83	5561	44
WA	2025	3986	70	9003	99	30976	181	122	5026	30
	[b]2050	5546	136	13251	193	58341	429	398	6145	59
	ECHAM5-MM5 vs. 3.5									
MH	2025	3430	46	7611	68	23649	114	16	4713	22
	2050	6048	157	16034	255	49417	348	124	6011	56
PP	2025	3080	31	7042	56	20154	83	24	4790	24
	2050	4128	76	11622	157	34267	211	85	5645	47
SWE	2025	3329	42	7646	69	20066	82	29	4790	24
	[c]2050	4791	104	12831	184	31946	190	93	5561	44
WA	2025	4137	76	9904	119	32275	193	131	5026	30
	[d]2050	6011	156	15520	243	61190	455	450	6145	59

Failure to meet crop demand by a) 1.77Mio. t/a, b) 2.03 Mio. t/a, c) 0.30 Mio. t/a, d) 2.69 Mio. t/a

Figure 8.2 and Table 8.2 show the results of LandSHIFT.JR for Israel driven by the water related scenarios from subproject 3.2. (Chapter 7) Overall, the differences between the scenarios are small. Here, only minor increase in rainfed cropland and even a reduction in the area of irrigated cropland can be observed. This is due the assumption, that freshwater is limited in these scenarios.

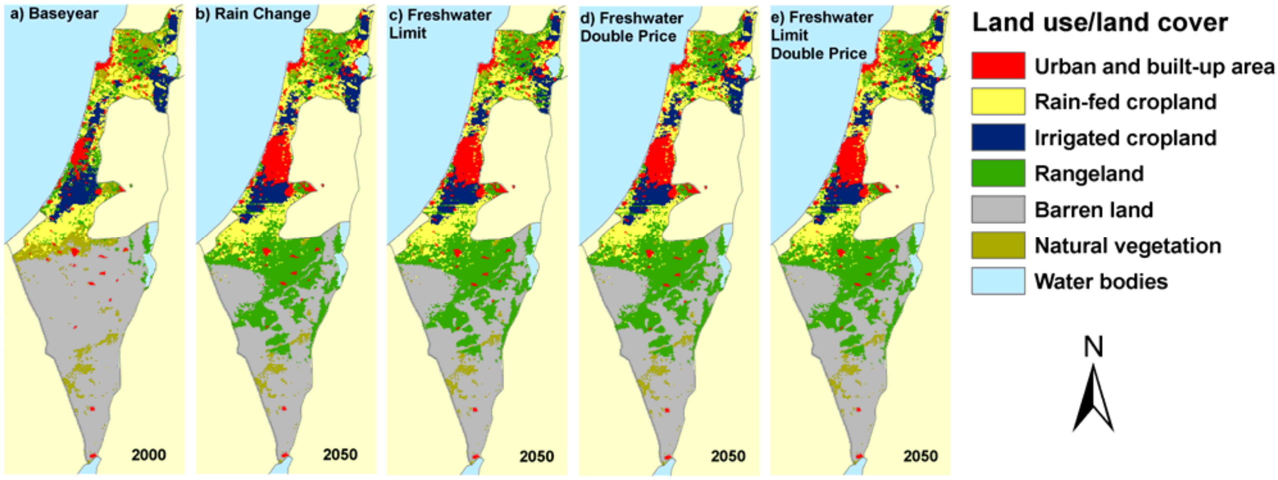


Figure 8.2: Land-use maps for Israel calculated with LandSHIFT.JR driven by VALUE-results on crop production for the base year 2000 and four scenario assumptions on freshwater availability and price.

Table 8.2: Area extent and percentage change in Israel compared to the base year as calculated with LandSHIFT.JR driven by simulation results on crop production from VALUE on eco-region level for four scenario assumptions on freshwater availability and price.

Scenario	Year	Irrigated cropland		Rainfed Cropland		Rangeland		Urban area	
		[km²]	[%]	[km²]	[%]	[km²]	[%]	[km²]	[%]
	2000	1559	0	1392	0	1615	0	1827	0
FDP	2025	1590	2	1473	6	3320	106	2185	20
FDP	2050	1303	-16	1405	1	5800	259	2730	49
FL	2025	1595	2	1474	6	3321	106	2185	20
FL	2050	1189	-24	1378	-1	5800	259	2730	49
FLDP	2025	1590	2	1473	6	3320	106	2185	20
FLDP	2050	1303	-16	1406	1	5800	259	2730	49
RC	2025	1603	3	1482	6	3315	105	2185	20
RC[1]	2050	1328	-15	1427	3	5803	259	2730	49

[1] Failure to meet crop demand by 55 t

As a next step we analysed the impact of climate change on the results for individual socio-economic scenarios. As one example, a comparison of the land-use maps in 2050 for the scenario “Modest Hopes” resulting from different climate projection is shown in Figure 8.3. For all simulations taking into account climate change, i.e. the projections by ECHAM5-MM5 v3.5 (Figure 8.3b), HadCM3-MM5 v3.5 (Figure 8.3c), ECHAM5-MM5 v3.7 (Figure 8.3d), HadCM3-MM5 v3.7 (Figure 8.3e), and the TAU climate dataset (Figure 8.3f), the expansion of irrigated and rainfed cropland as well as rangeland is more pronounced as compared to the simulation assuming constant climate conditions, as in the period 1971-2000 (Figure 8.3a). The overall spatial patterns of land-use do not differ largely between the six simulation runs. However, in some variants agricultural production is allocated in rather remote regions, e.g. in south-eastern Jordan for the TAU climate data set (Figure 8.3f). Urban area is the same in all simulations because its expansion is not sensitive to climate variables but is only driven by population growth. The additional area expansion needed for crop production due adverse effects of climate change on crop yields is lowest for the simulations with the TAU climate data (irrigated: +40%, rainfed: +18%) and highest for ECHAM5-MM5 v3.5 (irrigated: +59%, rainfed: +55%) (Table 8.1). Conversion of (semi-)natural vegetation to land used for human activities is least pronounced for HadCM3-MM5 v3.5 (Figure 8.3c).

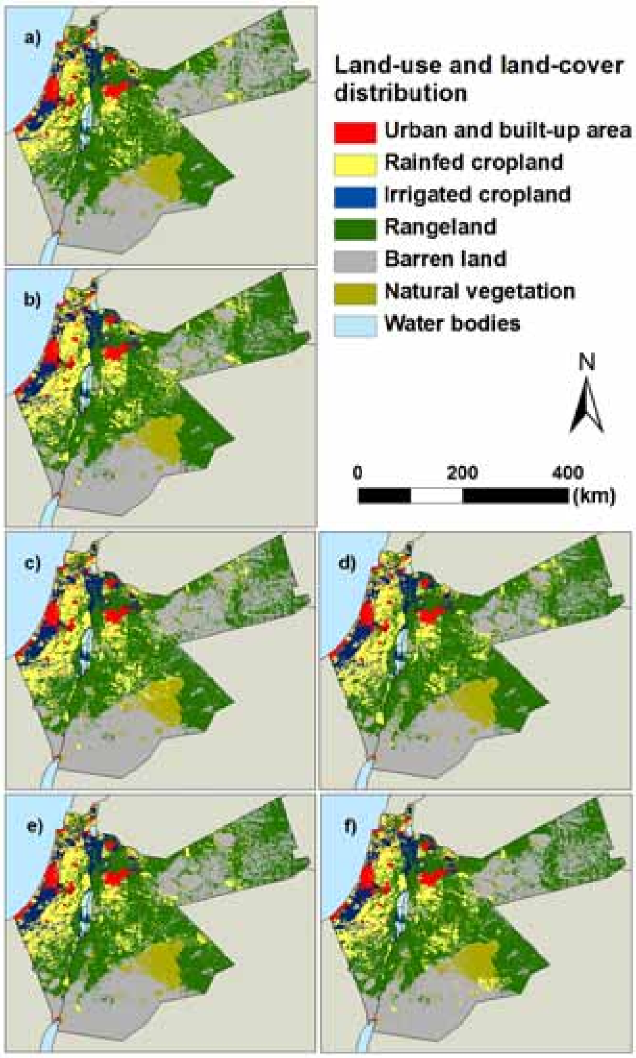


Figure 8.3: Comparison of land-use maps in 2050 for "Modes Hopes" for a) constant climate conditions as in 1971-2000 and the climate projections by b) ECHAM5-MM5 v3.5, c) HadCM3-MM5 v3.5, d) ECHAM5-MM5 v3.7, e) HadCM3-MM5 v3.7, and f) the TAU climate data set.

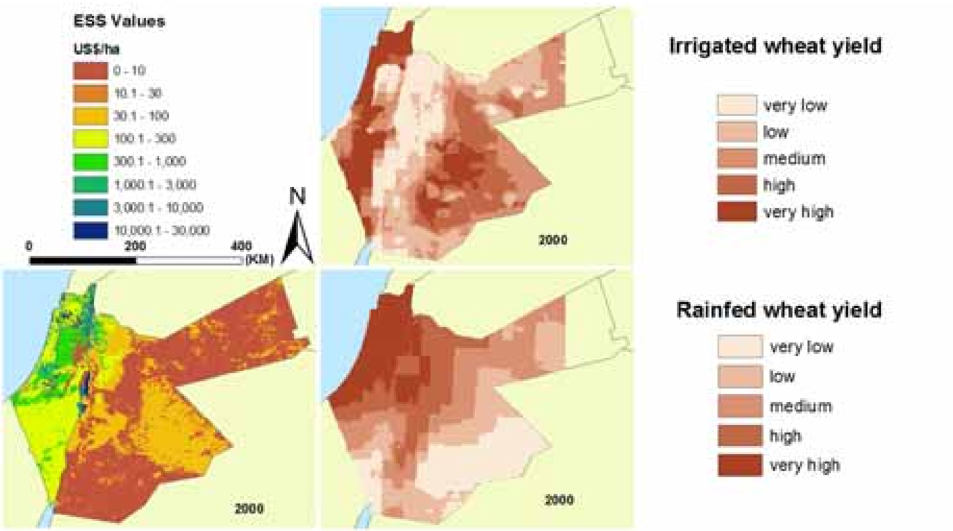


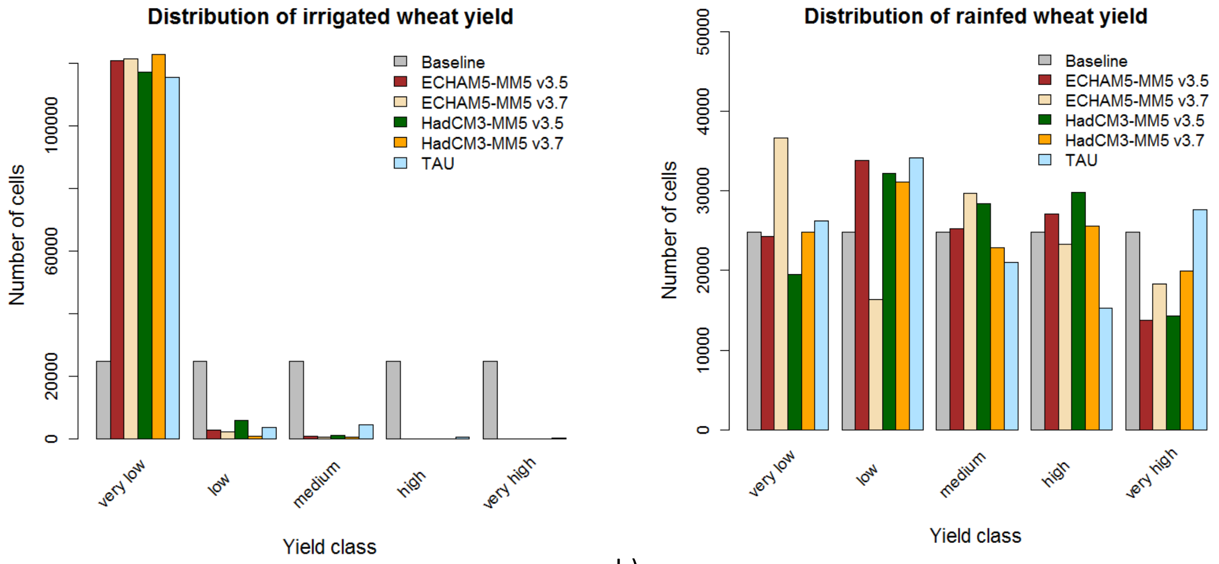
Figure 8.4: Basemaps of the distribution of ecosystem services values and of irrigated and rainfed wheat yield.

In a further step we studied the distribution of irrigated and rainfed wheat yields under the different climate scenarios. Figure 8.4 shows the spatial distribution in year 2000. The classification of the legend is as follows (see.8.1):

Irrigated
0 <very low> 3.68 <low> 3.81 <medium> 4.09 <high> 4.18 <very high> 4.73

Rainfed
0 <very low> 0.08 <low> 0.17 <medium> 0.42 <high> 0.75 <very high> 2.36

It is important to note that irrigated yields are about four times higher than rainfed yields. The areas with the highest wheat yield, whether it is irrigated or rainfed, are located in Israel.



a) b)

Figure 8.5: Shift between the classes of crop yield “very low”, “low”, “medium”, “high”, and “very high” as a result of different climate projections compared to baseline condition for a) irrigated and b) rainfed yield.

The class distribution of wheat yield in 2050 under different climate scenarios is shown in Figure 8.5. For our calculations, we were using the same climate projections as in the scenario experiments described above. Compared to the base year 2000, there is a strong change in the class distribution of irrigated yield (Figure 8.5a). For all climate scenarios, we find a shift from higher classes to the class “very low” on the majority of grid cells. This can be explained by an area-wide increase in temperature stress for crops, i.e., the daily maximum temperature exceeds the heat tolerance of the plants more frequently, which is a robust trend projected by all climate models. On average, the climate projections lead to a reduction of simulated irrigated crop yields by about 25% (Koch et al. 2012).

In comparison, the change in the class distribution of rainfed wheat yield is more heterogeneous, i.e., a shift to both lower and higher yield classes is found (Figure 8.5b). This is because not only temperature is the main driver but also precipitation. Among the ensemble of climate projections, the patterns of regions with increasing and decreasing precipitation are highly variable, leading to considerable differences in the class distribution. For example, a strong shift to the class “very low” can be observed for the ECHAM5-MM5 v3.7 simulation, while the cell count in class “very high” increases for the TAU climate data set. Nevertheless, climate change leads to an average reduction of simulated rainfed crop yield in the region. Compared to current climate conditions, the number of cells in the classes “very low” and “low” is, on average, about 5.1% higher for the future climate projections, while the cell counts in the classes “high” and “very high” are about 5.4% lower.

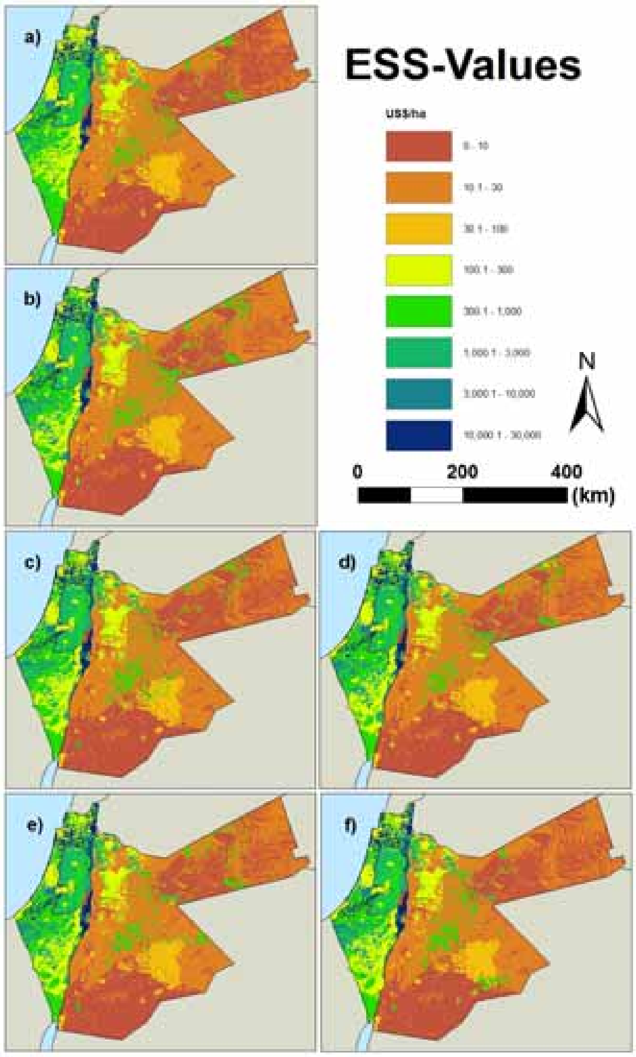


Figure 8.6: Comparison of ecosystem service maps in 2050 for "Modes Hopes" for a) constant climate conditions as in 1971-2000 and the climate projections by b) ECHAM5-MM5 v. 3.5, c) HadCM3-MM5 v. 3.5, d) ECHAM5-MM5 v. 3.7, e) HadCM3-MM5 v. 3.7, and f) the TAU climate data set.

Based on the results of the land use maps we then analysed the distribution of ecosystem service values in the GLOWA Jordan River region. In chapter 8.2.1 the method for calculating the ecosystem service values is explained. The basemap of the ecosystem service values in 2000 is presented in Figure 8.4. It indicates that high valued areas are located in Israel, Palestina and the north-west of Jordan.

The comparison between the different climate scenarios in 2050 is shown in figure 8.6. All scenarios show an increase in higher valued areas. These areas are predominantly located in the southern part of Israel and in some parts of Jordan. The highest valued areas in 2050 are lakes and cities. Only small differences in low valued areas between the climate scenarios can be observed.

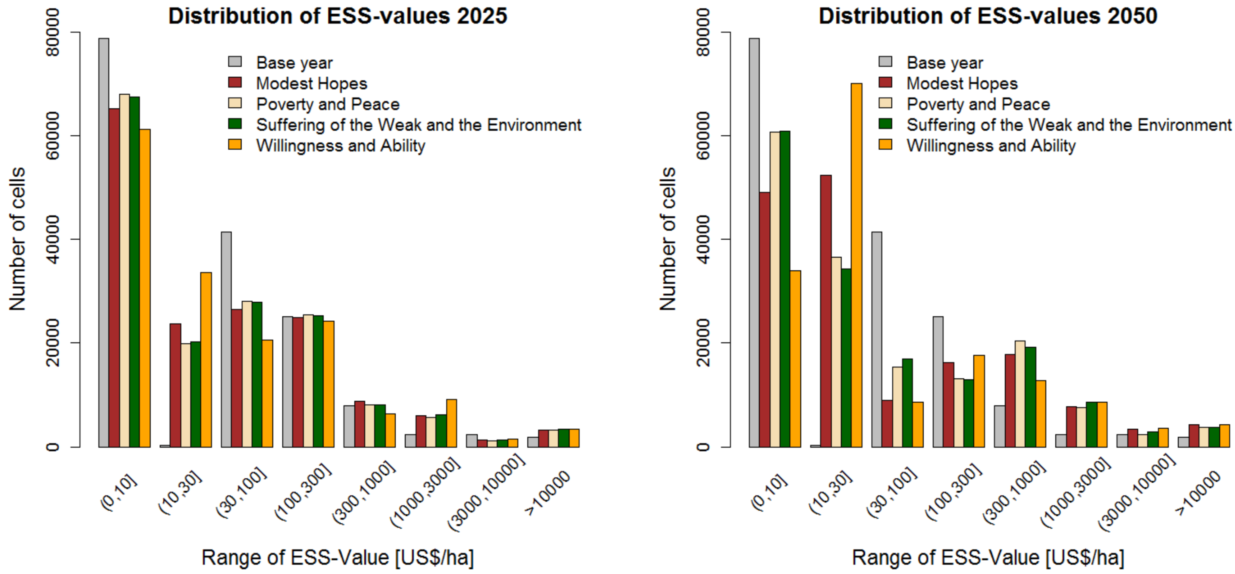


Figure 8.7: Shift between the ESS-values of the base year 2000 and the four GLOWA JR scenarios in the year 2025 and 2050 assuming current climate conditions throughout the simulation period.

More differences become visible when we compare the four GLOWA JR scenarios without climate change in 2025 and 2050 (Figure 8.7). The grey bar shows the distribution of ESS-values in the base year. In 2025 there are two main changes: Firstly, the number of grid cells in the second class (10 to 30 US$/ha) increases over all scenarios. With regard to the land use changes, this is due to an increase of the ESS-value of rangeland. Secondly, there is a trend to higher values, for example the increase of values in the highest class. There are only small differences between the scenarios in 2025. In 2050, differences between the scenarios are larger. In particular the “Willingness and Ability” scenario shows significantly different result. The trend of increasing ESS-values over all scenarios, which could be observed for 2025, no longer exists. There are more cells grouped in the three lowest classes, but at the same time there is a strong decrease of cells with values between 30 and 1000 US$/ha and a high increase of cells with values between 10 and 30 US$/ha. Reasons are a decrease of the values for rangeland and the change from agricultural area to set-aside area.

In a last step we analysed the water demand of livestock (Figure 8.8) and households (Figure 8.9). Overall, the total household water demand is about 200 times higher than the livestock water demand.

In 2000, the highest water demand for livestock is located near the Dead Sea and in the north west of Jordan. In 2050, the area for livestock grazing increases in all scenarios with the highest increase in the “Modest Hopes” and “Willingness and Ability” scenarios. This development is also shown in the land use maps (Figure 8.3). Due to the lower stocking densities, the livestock water demand on the newly allocated rageland areas is smaller than on the areas in the basemap. However, the increase of livestock numbers leads to a higher total water comsumption by livestock which might contribute to regional water stress.

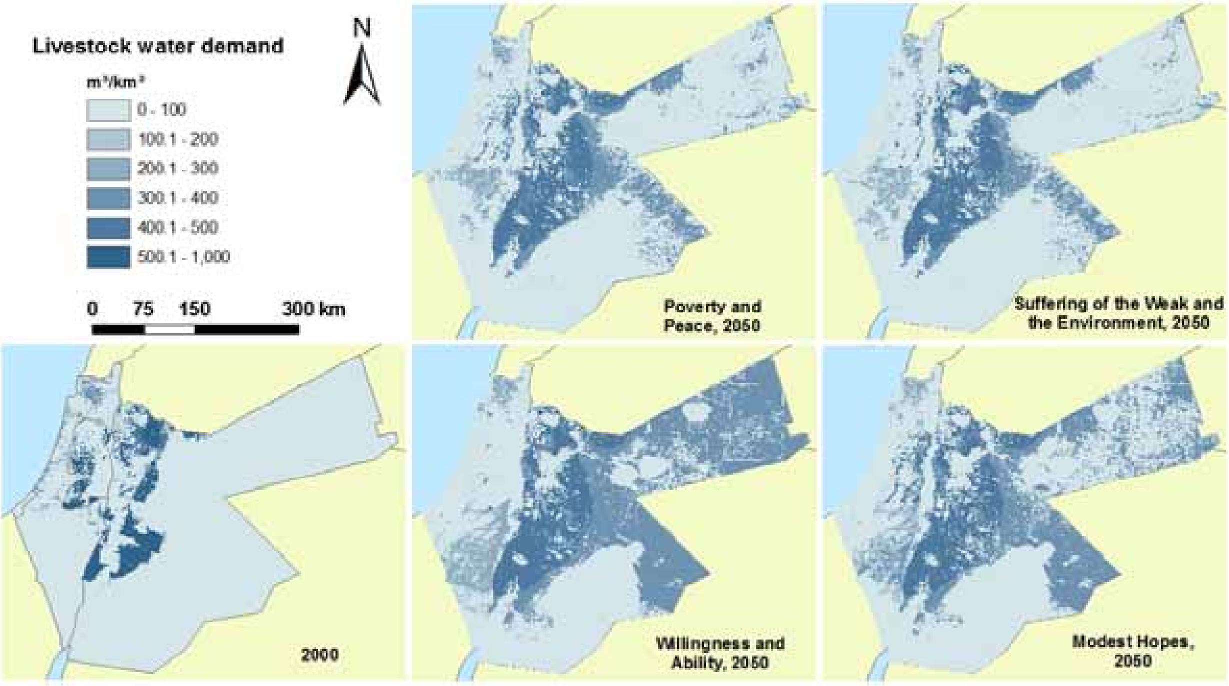


Figure 8.8: Livestock water demand of the base year 2000 and the four GLOWA JR scenarios in the year 2050 assuming current climate conditions throughout the simulation period.

The spatial distribution of the domestic water demand is shown in Figure 8.9. In 2010, the areas with the highest domestic water demand are cities, like Jerusalem, Amman, or Tel Aviv. Future domestic water demand will increase rapidly, because of the population growth projected within the GLOWA Jordan River scenarios. In all scenarios, the highest water demand is about 1.5 millions m^3/km^2. Differences between the scenarios are smaller than between the scenarios of livestock water demand.

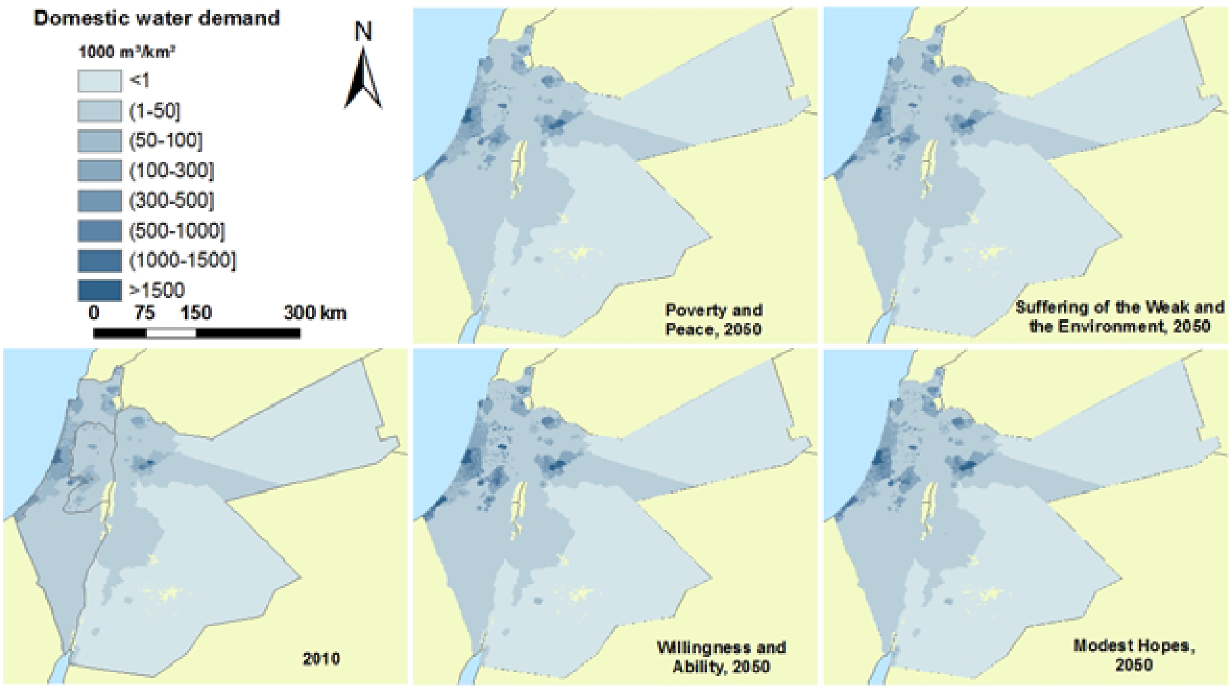


Figure 8.9: Domestic water demand of the base year 2010 and the four GLOWA JR scenarios in the year 2050 assuming current climate conditions throughout the simulation period.

8.2.3 Discussion and conclusion of scientific highlights and outlook

The main conclusions from our research are that climate change as well as the anticipated socio-economic changes will have strong impacts on land resources in the region. On the one hand, this imposes a threat to biodiversity because large areas of semi-natural vegetation will be used for human activities. On the other hand, it is highly questionable whether the growing demand for agricultural and livestock products can be satisfied locally. In particular, the increasing irrigation water requirements and the increasing demand for rangeland may exceed the limits of water and land resources in the Jordan River Region.

In a further step after the end of the project, we will analyse the water demand for irrigation vs. Water availability in the Jordan River region.

8.3 Applied value of results

Our model-based analysis explores scenarios of land- and water-use within the project region under climatic and socio-economic change. Therefore, the results have relevance for regional stakeholders and decision makers involved in land and water resources management. As the majority of the generated maps are freely available via the GLOWA JR atlas, they provide an information source to support the development of strategies for sustainable regional development. In particular, the land-use scenarios and ecosystem service maps might contribute to regional land-use planning and to stimulate discussions about future development goals. Moreover the information on water use in the agricultural and household sectors might help resource managers and authorities to investigate future hot spots of water stress and water scarcity.

8.4 References

Koch J, Schaldach R & Köchy M 2008. Modeling the impacts of grazing land management on land-use change for the Jordan River region. Global and Planetary Change, 64, 177–187.

Koch J, Onigkeit J, Schaldach R, Alcamo J, Köchy M, Wolff H-P & Kan I 2011. Land-use change scenarios for the Jordan River region. Intl. J Sust Wat Env Sys 3(1), 25-31.

Koch J, Wimmer F , Schaldach R, Onigkeit J & Folberth C 2012. Modelling the impact of climate change on the demand for irrigation area in the Jordan River region. Proceedings of the International Congress on Environmental Modelling and Software - Managing Resources of a Limited Planet, 6th Biennial Meeting, Leipzig, 2012, Germany.

Koch J, Wimmer F, Onigkeit J & Schaldach R (in press). An integrated land-use system model for the Jordan River region. In: S Appiah-Opoku (Ed.) Environmental Land Use Planning. InTech Open Science, Rijeka, ISBN 979-953-307-943-0.

Köchy M, Mathaj M, Jeltsch F & Malkinson D 2008. Resilience of stocking capacity to changing climate in arid to Mediterranean landscapes. Regional Environmental Change 8, 73–78.

Liu J, Williams JR, Zehnder AJB & Yang H 2007. GEPIC – modelling wheat yield and crop water productivity with high resolution on a global scale, Agricultural Systems, 94(2), 478-493.

Smiatek G, Kunstmann H & Heckl A 2011. High-resolution climate change simulations for the Jordan River area. Journal of Geophysical Research (116), doi:10.1029/2010JD015313.

Williams JR 1995. “The EPIC Model.” In Computer Models of Watershed Hydrology. Edited by V.P. Singh. Highlands Ranch, CO: Water Resources Publications. pp 909-1000.

Williams JR, Jones CA, Kiniry JR & Spanel DA 1989. The EPIC crop growth model, Transactions of the American Society of Agricultural Engineers, 32(2), 497-511.

9 Water productivity in agriculture

Berliner Pedro, Blaustein Inst. For Desert Research, Ben Gurion Univ. of the Negev, Israel
Arazi Adit, Blaustein Inst. For Desert Research, Ben Gurion Univ. of the Negev, Israel
Peters Aviva, Blaustein Inst. For Desert Research, Ben Gurion Univ. of the Negev, Israel
Ben-Asher J., Blaustein Inst. For Desert Research, Ben Gurion Univ. of the Negev, Israel

9.1 Aim

There are several aspects to be considered in the future climate-agriculture productivity issue. One of the aspects is how to increase the agricultural productivity of rain- fed crops. This was the focus our sub project within GLOWA phase II, where a wheat model was developed to estimate wheat yields reduction due to future increase in air temperature, and decrease in precipitation.

Under GLOWA phase III, our research focuses on irrigated crops (specifically fruit orchard), which are one of the major crops within the Upper Jordan Valley. The main goal of this research is to evaluate future change in demand for irrigation water for the main crops within the upper Jordan valley. Two sub-goals were defined in order to achieve the main goal:

- Determine the spatial agricultural crop distribution within the upper JR basin
- Evaluate the change in water usage due to future climatic changes for the main crops

9.2 Description of research

To acheive these goals, as a first step, a land-use map had to be produced. In order to produce a reliable land-use map, we have developed a procedure based on a thematic classification using RGB aerial images of the area, with a spatial resolution of 1.0 m, and in-situ ancillary data for validation.

Next goal, i.e., to evaluate the change in water usage due to future climatic change, daily values of Potential Evapo-Transpiration (PET) were calculated based on daily values of atmospheric parameters obtained by two GCM's simulations;

- ECHAM5 (A1B Scenario), RegCM3 (25 km resolution), for the years 2020-2050.
- ECHAM4 (Scenario B2)' Regional Model MM5 by IMK-IFU (18 km resolution) for the years 2070-2099.

Last, irrigation coefficients for the main agricultural crops (obtained from agricultural authorities) were used to calculate the change in irrigation water demands per crop and for the entire Upper Jordan Valley.

9.2.1 Material and methods

9.2.1.1 Landuse classification of the upper Jordan valley

To quantify past and present water usage as well as predict future water demand a thematic land use classification was carried out. The process consisted of several steps:

- A supervised classification was applied on a set of RGB aerial images of the area with a spatial resolution of 1.0 m. 16 classes were pre-defined, based on the spectral properties of the classes, to allow the differentiation between sub-classes, for example between different types of agricultural fields. A Maximum Likelihood Classification (MLC) was used as a classification method.

- The classified images were then reclassified in GIS to develop a thematic map with seven classes of land-use: agricultural fields, orchards, forest, water, urban, undeveloped land and roads. A majority filter was applied to the reclassified image. The final classification was evaluated statistically for its accuracy with satisfying results (Fig. 9.1).

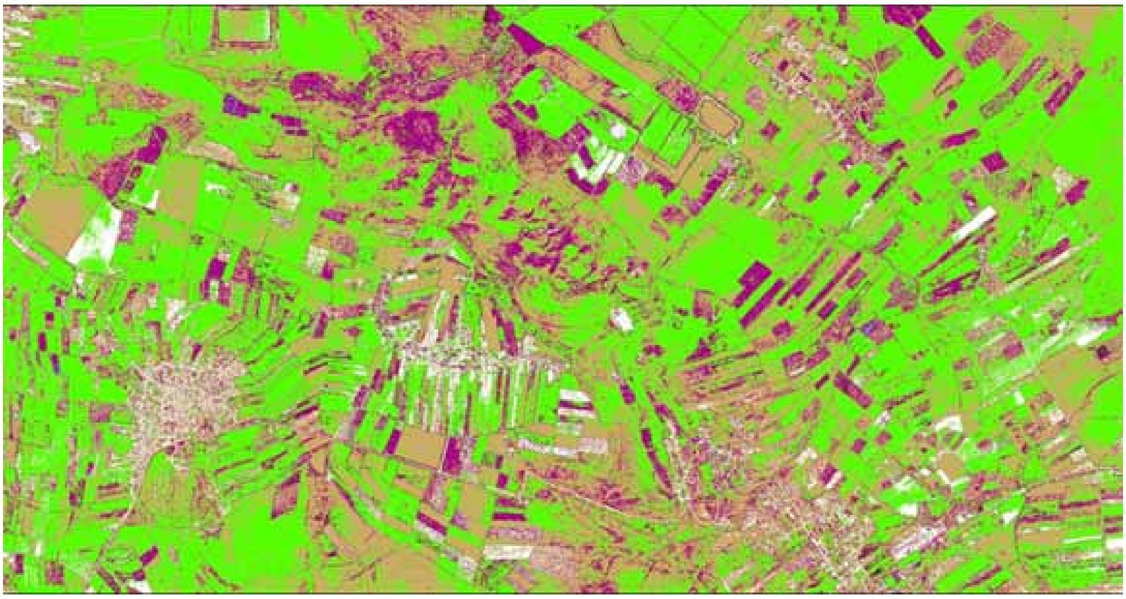


Figure 9.1: Section of classified images after reclassification and applying a majority filter, resulting in 7 classes (green representing agricultural fields).

- While the received classes are rather robust, they lack specific information regarding the types of orchards (sub-classes). RGB images are not sufficient to allow the differentiation between the sub-classes (types of crops). Therefore, additional data was required to make-up for the various types of orchards as well as to validate the classification. These data were collected based on: in-situ field trips, data gathered from several agricultural-societies, local farmers, governmental agricultural instructors, and the Israeli Central Bureau of Statistics (CBS). The data consisted of digitized layers of sub-classes, for example, crop types and tabular data, and were used to update the original maps. The classified images were combined with collected data using GIS methods of queries and transformations to construct the complete database of the different land use and their characteristics (Fig. 9.2).

Figure 9.2: A detail of the updated classification illustrating sub-classes of orchards such as: citrus, olive groves, vines, apples and bananas.

- To simplify the database, for the water usage analysis, the classes were reclassified again. For example, sub-classes such as apples, pears and plums were joined into one class named *deciduous*. This resulted in a set of 12 classes: *bananas, citrus, deciduous, olives, palms, tropical, vines, unspecified orchards, agricultural fields, open space*, *forest* and *other* (Fig. 9.3 and Fig. 9.4 in results section).

9.2.1.2 Quantitative analysis of sub-clases

A zonal analysis was performed to analyze the various classes. Zones were based on the climatological grid. The outputs are tables of summary statistics for each grid such as the average, sum, max, min, std. and variance values of the different landuse types (table 9.1. and table 9.2.).

Table 9.1: A sample of the summary statistics. Calculations are based on a zonal analysis applied on the sub-classes of orchards in one of the climatological grids (grid #6).

OID	REC_ NAME	Cnt_ REC_NA	Min_ AREA	Max_ AREA	Ave_ AREA	Sum_ AREA	SD_ AREA
0	citrus	160	843,17	113359,04	15135,73	2421717,27	16137,15
1	olives	270	362,48	321117,88	13530,56	3653251,53	36441,87
2	orchards	2924	180,18	465810,81	14650,35	42837611,64	25065,05
3	vines	14	9793,04	223028,44	50423,93	705934,98	60877,57

Table 9.2: A sample of the summary statistics. Calculations are based on a zonal analysis applied on the sub-classes of orchards in one of the climatological grids (grid #7).

OID	REC_ NAME	Cnt_ REC_NA	Min_ AREA	Max_ AREA	Ave_ AREA	Sum_ AREA	SD_ AREA
0	citrus	127	3067,49	100603,59	18044,02	2291590,45	14632,61
1	deciduous	985	161,00	44356,89	4012,46	3952274,10	4887,71
2	olives	818	121,97	2085605,03	43773,53	35806745,18	150311,52
3	orchards	1899	37,80	1114495,32	15332,42	29116273,16	40806,43
4	other	3	441,22	842,02	591,85	1775,56	218,15
5	tropical	81	755,23	21119,67	7502,00	607661,76	4271,02
6	vines	86	359,68	66210,38	6822,55	586739,08	10794,96

9.2.1.3 Evaluation of the change in water demand for irrigation for the main crops within the upper jordan valley

This parameter was calculated based on daily calculation of the Potential Evapotranspiration (PET) derived from daily atmospheric parameters given by the global and regional models. The annual values were averaged over a period of 30 years past (1961-1990) and future (2020-2050) / (2070-2099).

In addition to the daily PET values, irrigation coefficients for the different agricultural crops were used according to the agricultural classification; these values were obtained from agricultural authorities, and averaged over the harvesting periods (shown in table 9.3).

Table 9.3: Irrigation coefficients for the major agricultural crops within the Jordan valley.

	Deciduous	Olive	Grape	Palm	Tropic	Banana	Citrus
March				0.75		0.40	
				0.75		0.40	
				0.75		0.40	
April	0.20	0.20	0.20	0.75	0.40	0.40	0.30
	0.21	0.20	0.20	0.75	0.40	0.40	0.30
	0.34	0.20	0.20	0.75	0.40	0.40	0.30
May	0.44	0.30	0.20	0.75	0.45	0.48	0.37
	0.48	0.30	0.20	0.75	0.45	0.57	0.37
	0.53	0.30	0.25	0.75	0.45	0.63	0.37
June	0.57	0.20	0.25	0.75	0.55	0.68	0.43
	0.61	0.20	0.25	0.75	0.55	0.75	0.43
	0.58	0.20	0.30	0.75	0.55	0.79	0.43
July	0.51	0.20	0.35	0.75	0.60	0.87	0.48
	0.55	0.20	0.40	0.75	0.60	0.94	0.48
	0.65	0.20	0.50	0.65	0.60	1.01	0.48
Augost	0.64	0.30	0.60	0.65	0.65	1.01	0.53
	0.65	0.30	0.65	0.65	0.65	1.03	0.53
	0.70	0.30	0.75	0.65	0.65	1.06	0.53
September	0.55	0.40	0.65	0.65	0.65	0.98	0.57
	0.28	0.40	0.60	0.65	0.65	1.04	0.57
	0.24	0.40	0.50	0.65	0.65	1.03	0.57
October	0.23	0.40	0.40	0.60	0.65	0.98	0.60
	0.16	0.40	0.30	0.60	0.65	0.94	0.60
	0.12	0.40	0.15	0.60	0.65	0.85	0.60
November		0.15		0.50			0.63
		0.15		0.50			0.63
		0.15		0.50			0.63

9.2.2 Results

9.2.2.1 LAND-USE MAP

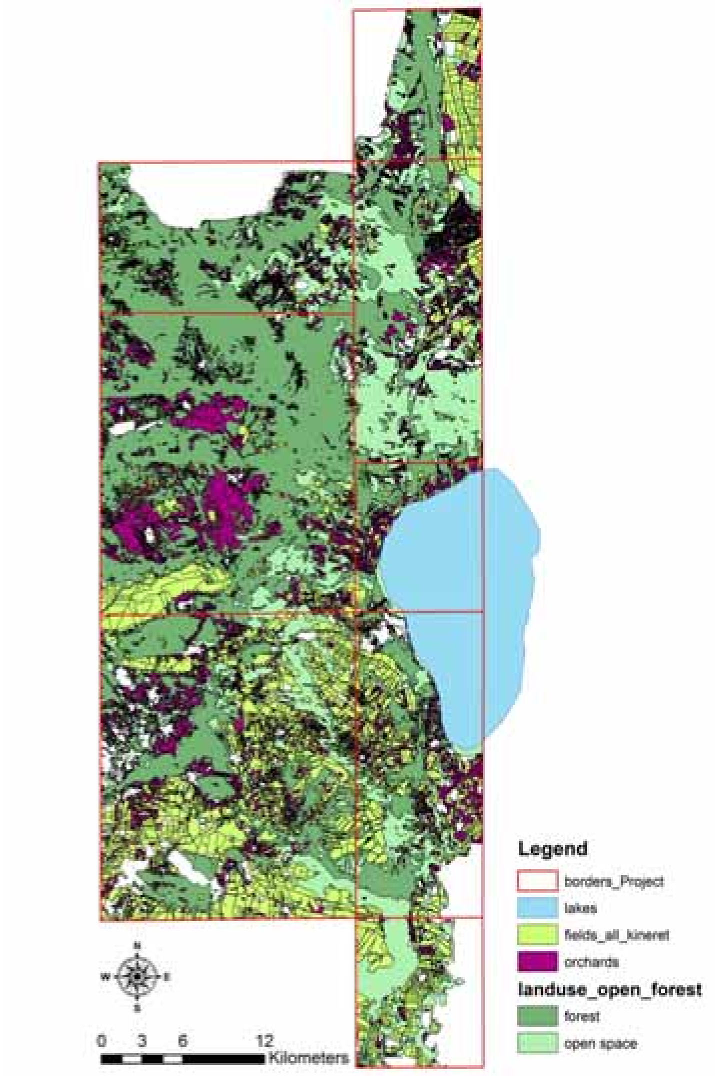


Figure 9.3: Final classification results of agricultural land-use for the entire region illustrating the main classes: agricultural fields, orchards, open space and forest. Region borders (climatological grid) are in red.

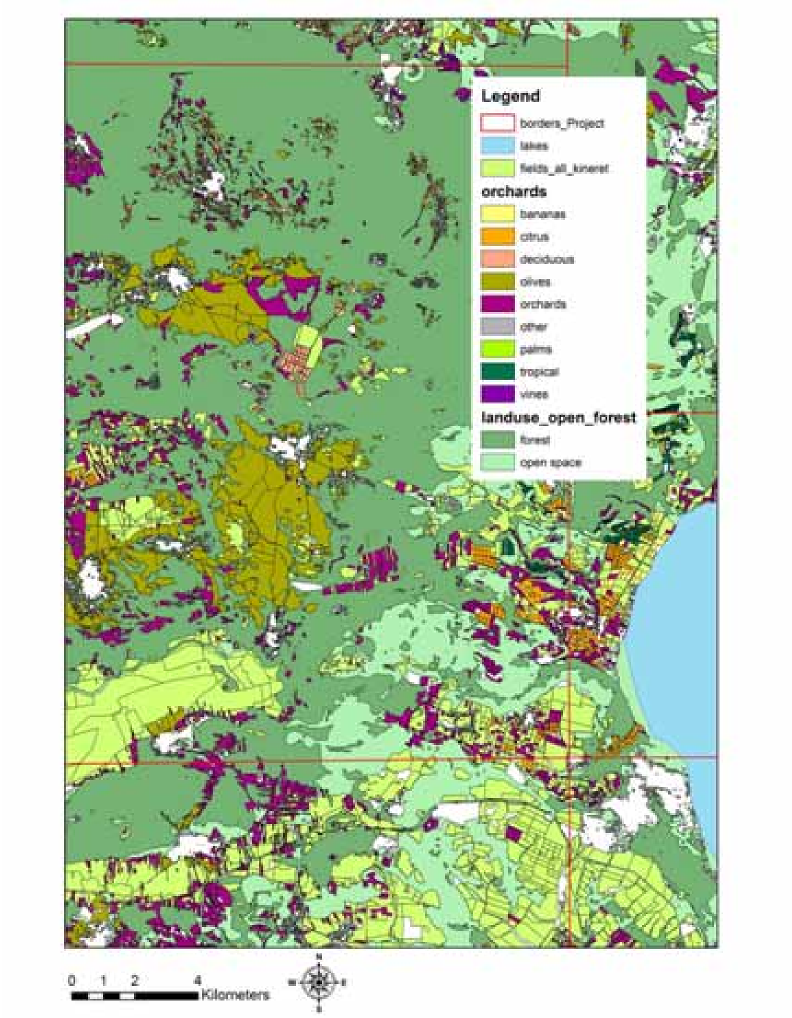
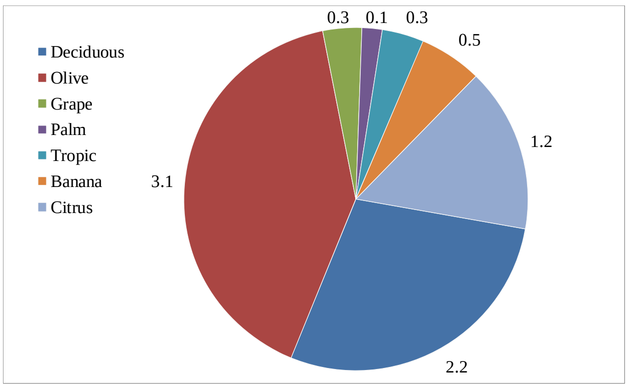


Figure 9.4: Detail of the final sub-classes within the climatological grid cell. The total change in water demand for agriculture were calculated for each climatic grid cell, and for each type of crop multiplied by its area's size, and finally summed for all the grid cells within the upper Jordan valley.

9.2.2.2 Change in water demands for irrigation

Results for the climatic simulation are shown in Figure 9.5. It is clear that the two scenarios show different results; this is primarily due to the period of simulation and also due to the parameterization of the physical "heating" process. The change in irrigation demands between the two scenarios is about half an order in magnitude.



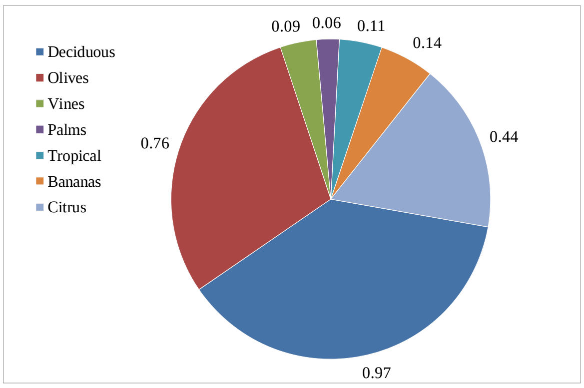


Figure 9.5: Change in annual water for irrigation (Mil-m^3) per crop. Left ECHAM4 (Scenario B2) / (2070-2099), right ECHAM5 (A1B Scenario) /(2020-2050)

9.2.3 Discussion and conclusion of scientific highlights and outlook

The spatial distribution of vegetation within of the Upper Jordan Valley based on the land-use maps, produced within this sub project shown that 60% of the area is occupied by natural forests & open area, 20% by field crops (mainly wheat), 5% olive groves, 8% irrigated orchards.

Due to the predicted increase in water stress and in order to minimize damage to the natural forests, thinning actions should be considered.

The simulations of the regional & GCMs differ not only by their simulated periods, but also on other parameters like, initial conditions and assumptions. Therefore the resultant calculations of the future change in irrigation demand are strongly affected by the climatic simulations. In the cases tested in this sub project the irrigation water demand for different crops may change by a factor of 2-3according to the different climatic simulations.

According to climatic simulations tested within sub-project, the increase in PET during the irrigation period (summer) is app. 60mm (2020-2050) & 100mm (2070-2099), causing an increase in water for irrigation of 10-40 mm & 40-110mm, respectively, depending on the crop type. Note that such increase in PET will consequently cause water stress for natural forests and non-irrigated crops.

9.3 Applied value of results

One of the major tasks of this sub project is to produce a reliable, detailed land-use map. A lot of efforts were made to develop a method to classify the different land uses, using aerial images. This method can be applied elsewhere. The agricultural land-use map produced in this project is the only detailed reliable map known to us.

The second major task was to evaluate the future change in demand for irrigation water. It was shown that such evaluations are strongly dependent on the global and regional climatic model simulations. Therefore any decision on future action will have to rely on a range of scenario simulations.

10 Regional based land evaluation for effluent irrigation

Marschner B, Ruhr-Univ. Bochum, Dept. of Soil Science and Soil Ecology
Abed Rabbo A, Univ. of Bethlehem, Water & Soil Environmental Research Unit (WSERU)
Almasri M, An-Najah National Univ., Water and Environmental Studies Inst. (WESI), Nablus
Chen Y & Tarchitzky J, Hebrew Univ. of Jerusalem Dept. of Soil and Water Sciences, Rehovot
Salman A & Karablieh E, Arab Technologist for Economical and Environmental Consultation (ATEEC), Amman

10.1 Aim

Wastewater is the most important non-conventional water resource in the Jordan River catchment. The use of treated and blended wastewater in irrigated agriculture on the Jordanian side amounts to about 20% of the natural annual inflow and estimations are that wastewater flows into the Jordan Valley will exceed the annual natural inflow before 2025. Israel replaces nationwide currently about 35% of its water for agricultural production by treated wastewater and targets a rate of 50% in 2020. Potential wastewater resources in the West Bank are estimated to equal about 50% of the current Palestinian freshwater withdrawal. Climatic change is likely to accelerate this process of replacement, if freshwater resources become scarcer.

However, depending on site characteristics, land use, irrigation technology and effluent quality, certain ecological on- and off-site risks like soil salinization, soil structural deterioration, erosion, accumulation and transfer of pollutants have to be considered when effluent irrigated areas are to increase, in order to prevent the long-term degradation of soils and groundwater resources.

The objectives of this project were

- to assess the effects of effluent irrigation on soil properties and groundwater quality;
- to develop and apply predictive tools for the evaluation of adverse environmental effects of effluent irrigated agricultural production under different climatic and land-use scenarios,
- to develop and provide a uniform region-wide GIS compatible database of land suitability for sustainable effluent irrigated agricultural production.

10.2 Description of research

During the course of the 10 years of research within the project, objectives, hypotheses and methodologies underwent various changes and adaptations based on the continuous acquisition of new scientific results and insights and on the increasing number of partners involved in the activities. At the onset of the project, only little was known about the effects of long-term irrigation with treated wastewater on soil properties although this had been practiced for several decades in Israel. Therefore, the initial methodological approaches covered soil biological, chemical and physical investigations on experimental fields and in the laboratory. This led to the identification of an array of soil properties for which changes had been observed under TWW irrigation. This included increased runoff due to soil slaking (Agassi, Lado, Levy), reduced infiltration due to water repellency (Tarchitzky, Nadav) and enhanced soil organic matter degradation due to priming effects from TWW-borne organic compounds (Jueschke, Hamer). Since various other studies had shown that groundwater in the region was already affected by anthropogenic inputs, the groundwater vulnerability had also to be considered (Almasri). While the mechanisms for the observed soil property changes under TWW irrigation were continuously investigated in field and laboratory studies and experiments, a large part of the activities during the last 5 years of the project focused on developing a GIS-based land evaluation system for the suitability for TWW irrigation (Schacht, Almasri).

10.2.1 Material and methods

For the study of long-term effects of TWW irrigation on soil properties, numerous field plots with up to 35 years of TWW irrigation history and adjacent freshwater irrigation were identified in Israel. At these sites, field experiments were carried out to determine infiltration rates, soil slaking, run-off, wettability and soil respiration. Soil samples collected from selected plots were used for laboratory investigations and greenhouse experiments to determine soil microbial activity, composition of dissolved and solid soil organic matter, nutrient and heavy metal availability to plants. Detailed descriptions of the applied methods are found in the respective scientific publications listed at the end of this report.

For the assessment of soil suitability for TWW irrigation, digital soil maps were joined with spatial data on soil properties using Geographic Information Systems (GIS). Six major risks of primarily agricultural significance were defined. The changes in specific soil and groundwater properties as a result of irrigation with low water quality were evaluated and discussed. Based on the local soil parameters, the specific sensitivity and suitability grades were assessed for the respective soil unit concerning irrigation with treated wastewater (TWW) using standard and specially developed methods.

10.2.2 Results

10.2.2.1 Effects of TWW irrigation on seal formation, infiltration, and soil loss during rainfall

The use of TWW for irrigation could affect the chemical and hydraulic properties of soils due to its high salt and organic matter (OM) content, and, consequently, the rainfall–infiltration–runoff–erosion relationships during the subsequent rainy season. TWW irrigation increased the total OM content and the exchangeable sodium percentage (ESP) of the soils. The cumulative infiltration in FW- and TWW-irrigated clay soils was 6.5 and 5.6 mm, respectively, in the initially dry soils, and 52.3 and 51.5 mm, respectively, in the prewetted soils. In the FW- and TWW-irrigated sandy soils, the corresponding values of cumulative infiltration were 79.5 and 44.7 mm, and 85.0 and 56.3 mm, respectively. In the sandy soil, the higher sodium adsorption ratio (SAR) values in the leachate of effluent-irrigated soil led to greater clay dispersion, which enhanced seal formation, reduced infiltration, and increased soil loss. In the clay soil, slaking was the main process involved in seal formation, neglecting the possible deleterious effect of effluent irrigation. When slaking was prevented, the SAR values in the leachate of the TWW-irrigated soil decreased during rainfall and were similar to those of the FW-irrigated soil at the end of the applied rainfall amount. This was probably due to the exchange of adsorbed Na with soluble Ca, which minimized the differences in clay dispersion, infiltration, and soil loss. Therefore, in the clay soil, aggregate slaking might be the main process involved in seal formation and affecting infiltration and erosion. These results show that the effect of TWW irrigation on infiltration, runoff, and soil loss depends on the soil type (amount of clay and $CaCO_3$) and the dominant mechanisms of seal formation. Therefore, to prevent a possible deleterious effect on soil structure, it is necessary to identify sensitive areas and soils before the application of effluents for irrigation.

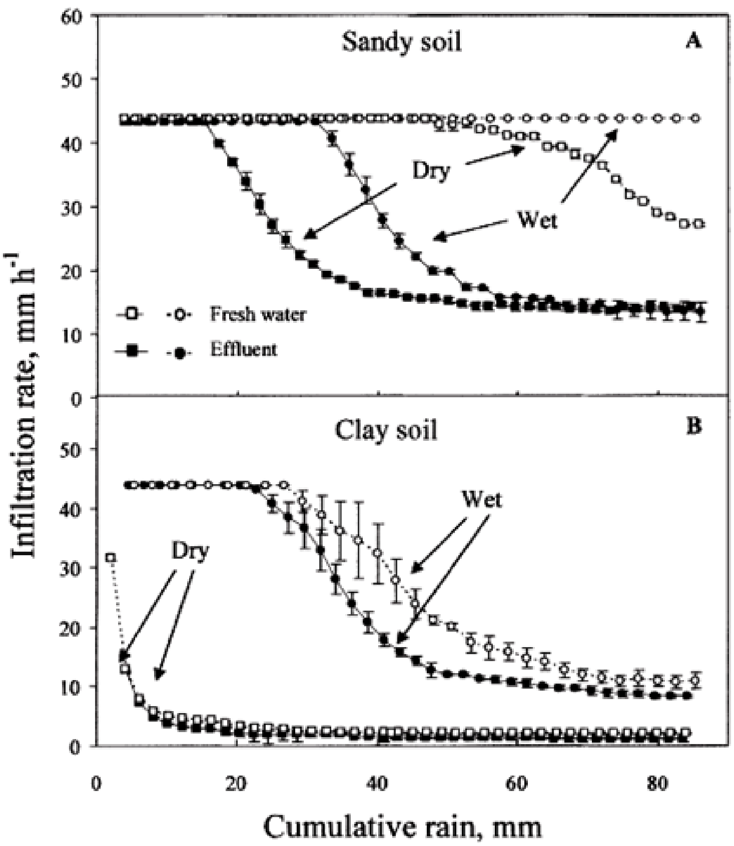


Fig. 10.1: Mean infiltration rates as functions of cumulative rainfall for the two soils irrigated with fresh-water or effluent at two initial conditions. Bars indicate one standard deviation (Lado et.al. 2005).

In a laboratory experiment, soils were packed in mini-lysimeters. This experiment was planned to simulate two consecutive years of irrigation with TWW, each including a seasonal (summer) period (TWW 1) followed by a rainy season (Irrigation with deionized water; Rain 1) then a second year (TWW 2; Rain 2).

The clay soil (Fig. 10.2) exhibited similar initial and final HC after the two irrigation cycles using TWW. The two irrigation cycles using DW (Rain) decreased the initial and final HC in comparison with the TWW treatments. This difference was similar for all the water qualities and is a consequence of an increased soil swelling as a result of the reduced electrolyte concentration. A significant difference between the HC according to the water qualities was observed after the TWW treatments. The higher the water quality the higher the HC maintained. All the soils exhibited sealing conditions and a sharp decrease of the HC during the last cycle (rain 2) apparently as a result of the strong swelling of the clay soil.

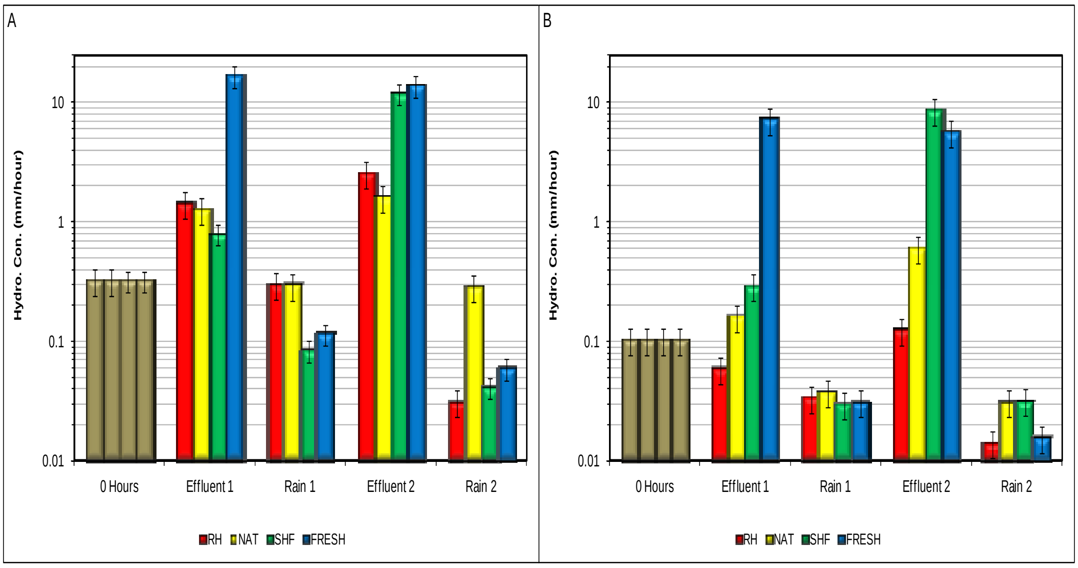


Fig. 10.2: Saturated hydraulic conductivity of the clay soil (Grumosol) irrigated with different water qualities (RH= Ramat Hakovesh; Nat= Natanya; SHF= Shefdan; FRESH= fresh water). A= initial HC and B= final value (Tarchitzky, unpublished).

10.2.2.2 Water distribution pattern in treated wastewater irrigated soils: hydrophobicity effect

Frequently, farmers utilizing reclaimed wastewater (TWW) report a unique type of water distribution regime in drip-irrigated soils, as follows: (i) limited wetted area on the soil surface; and (ii) small saturated areas around and below the dripper, in TWW irrigated soil as opposed to an even, onion-like wet profile, formed under fresh water (FW) irrigation. Following this observation in the field and after conducting preliminary tests in the laboratory, we hypothesized that TWW irrigation introduces water-repellent organic constituents into the soil. Tests characterizing the water distribution showed the diameter of the saturated area on the soil surface and its water content (at a depth of 0–10 cm) was smaller with TWW than with FW irrigation. The TWW accumulated on the soil surface in small lenses and then flowed rapidly into the ground. The repellency of soils irrigated with FW and TWW was measured with the water drop penetration time test. Soils irrigated with FW were hydrophilic, whereas those irrigated with TWW exhibited hydrophobicity. Fourier transform infra-red spectroscopy (FTIR) and 13C-NMR analyses of organic components extracted from the soils with organic solvents indicated differences in composition only at a depth of 0–2 cm. Extracting soils with a methanol + chloroform (1:1, by volume) mixture was found to be very effective in the removal and extraction of hydrophobic aliphatic components from soils irrigated with TWW.

Fig. 10.3: Water repellency in treated-wastewater-irrigated soils: (a) lenticular water drop formation below the dripper on the surface of a Rehovot-red-brown soil; (b) rapid disappearance of the water, without formation of the characteristic ponded area below the dripper on the soil surface of a Rehovot-red-brown soil; (c) lenticular water drop formation below the dripper on the surface of a Hatzerim-loess soil; and (d) lenticular water drop formation below the dripper on the surface of an Magal-alluvium soil (Tarchitzky et al. 2006).

In a lysimeter experiment where 3 different soils receive 4 different irrigation water qualities (secondary TWW, tertiary TWW, ultrfiltrated TWW, FW) elemental analysis of the organic matter from the top 0-2 cm of the soil showed consistently higher C/O ratios in the TWW irrigated soils compared to the UF and FW treatments (Fig. 10.3). A higher C/O ratio means more C-C bonds and less oxygen-containing functional groups, such as carboxylic groups, which are more polar and hence more hydrophilic. In all soil types, the highest C/O ratio was observed for the rich OM-containing S-TWW, while the lowest value of this ratio was found for the low OM-containing FW. This increased C/O ratio was observed in all soil types along the water-quality axis from FW to S-TWW, which is in accordance with the increasing water-repellency potential of the OM.

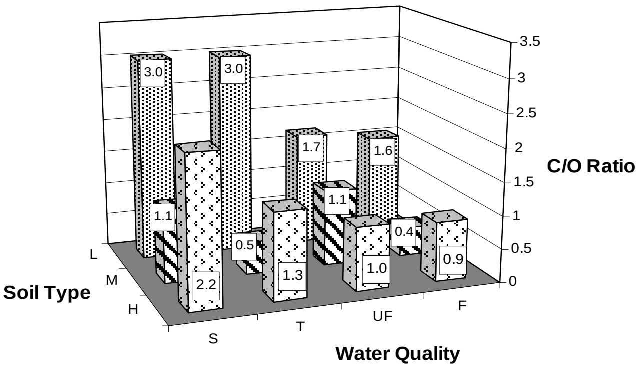


Fig. 10.4: C/O ratio of organic matter extracted from the different soil types irrigated with the different water qualities. L, M, H = light, medium and heavy soil, respectively; F, freshwater irrigation; UF, T, S = ultrafiltered, tertiary and secondary treated wastewater irrigation, respectively. Numbers represents C/O ratios. (Tarchitzky, unpublished).

10.2.2.3 Effects of TWW irrigation on soil organic carbon pools

As it can be seen in Figure 10.1, in the first 20 cm the SOC content is generally similar or higher in the TWW irrigated soils compared to the freshwater controls. A trend of SOC accumulation of the TWW irrigated soil in the topsoil can be pointed out. These results are similar to the results from other studies were after long-term irrigation an accumulation of organic matter could also be seen in the topsoil. In the soil profiles shown in Figure 10.5 the SOC decreased below ~50 cm in the TWW irrigated soils. The SOC content of the HaMa´pil avocado orchard soil, does not show a clear difference between freshwater and effluent irrigated soils in the depth of 100 cm but a decrease of SOC in both irrigation variants which is stronger in the TWW irrigated soil. Based on these different SOC contents in the subsoil of the investigated sites a SOC loss caused by TWW irrigation could be calculated for the soils. It ranges between 5 and 30 t ha^{-1} and the highest values were observed at sites with the longest TWW irrigation history.

The organic carbon content of TWW irrigated soils seems to become depleted in the subsoil compared to freshwater irrigated fields. This is in contrast to the topsoils where the content of organic carbon is similar or even higher under effluent irrigation, which could also be found in the literature (Friedel et al., 2000, Ramirez-Fuentes et al., 2002, Meli et al., 2002). The pronounced effect seems to be relevant in deeper soil horizons with continuously input of OM which percolates in the soil. According to our hypothesis the SOC in these horizons gets depleted because of stimulated microbial activity due to substrate inputs from the effluents. The effect has no direct influence on the fertility of the soils in the rooting zone. But, due to enhanced mineralization of organic material a greater amount of CO_2 is released from the soil which changes the C-balance and may therefore contribute to climate change.

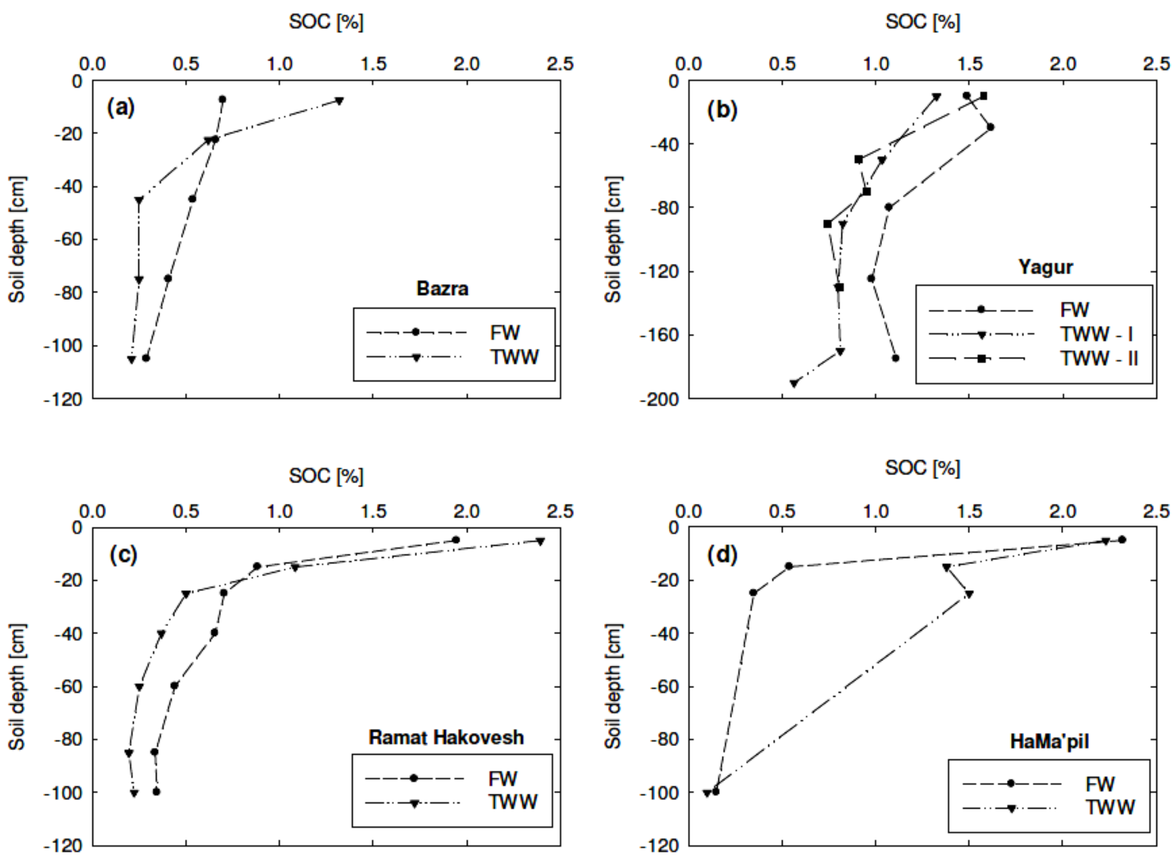


Fig.10.5: Soil organic carbon (SOC) content in % of the soil profiles in freshwater (FW) and treated wastewater (TWW) irrigated soils in Bazra (a), Yagur (b), Ramat Hakovesh (c) and HaMa'pil (HM) site. (Jüschke et al. 2006).

10.2.2.4 Soil suitability for irrigated vegetables and fruit trees in the lower Jordan Valley

A digital soil map was prepared and provided the principal investigators to work on soil suitability for TWW. The map included the main soil properties (CaCO3, CEC, ECe, pH, Hydraulic conductivity, AWHC, ESP, Gypsum, soil depth and texture). Analysis of soil map showed that soil salinity is a problem when soil becomes deeper than 60 cm. Soil layers of 0-30 and 30-60 do not suffer from serious salinity problem. Regarding soil carbonate (on the form of CaCO3), soil maps showed high contents of carbonate in all soil layers. This was considered as a positive factor that mitigates the impacts of the reuse of TWW in irrigation in the Jordan Valley.

Soil maps were also used to assess soil suitability for irrigated vegetables and fruit trees. Suitability maps were generated from the soil map using the land suitability approach of Food and Agriculture Organization (FAO, 1976). The suitability classes represented the following:

- S1, highly suitable (Land having no, or insignificant limitations);
- S2, moderately suitable (Land having minor limitations);
- S3, marginally suitable (Land having moderate limitations) and
- N, a non-suitable land (Land having severe limitations that might not be alleviated).

The criteria for suitability ratings for drip irrigated vegetables and fruit trees are shown in Tab.10.1 and 10.2, respectively.

Tab. 10.1: Ratings of land suitability criteria for drip irrigated vegetables.

Land Characteristic	Highly Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Not Suitable (NS)
Soil depth (cm)	> 45	> 25	≤ 25	≤ 25
$CaCO_3$ (%)	< 40	< 50	< 60	≥ 60
Hydraulic Conductivity (cm/hr)*	> 1	> 0.36	> 0.036	≤ 0.036
Electrical Conductivity (dS/m)	< 3	< 5	< 6.5	≥ 6.5
Moisture Availability (mm/m)	> 100	> 80	> 50	≤ 50

***: According to (Soil Survey Division Staff. 1993. Soil survey manual. U.S. Department of Agriculture Handbook 18): >1: moderately high; >0.36: Moderately low; >0.036: low.**

Tab. 10.2: Ratings of land suitability criteria for drip irrigated fruit trees.

Land Characteristic	Highly Suitable (S1)	Moderately Suitable (S2)	Marginally Suitable (S3)	Not Suitable (NS)
Soil depth (cm)	> 90	> 45	> 25	≤ 25
CaCO3 (%)	< 40	< 50	< 60	≥ 60
Hydraulic Conductivity (cm/hr)*	> 1	> 0.36	> 0.036	≤ 0.036
Electrical Conductivity (dS/m)	< 4	< 4.7	< 6	≥ 6
Moisture Availability (mm/m)	> 120	> 100	> 70	≤ 70

***: According to (Soil Survey Division Staff. 1993. Soil survey manual. U.S. Department of Agriculture Handbook 18): >1: moderately high; >0.36: Moderately low; >0.036: low.**

Results of soil suitability (Fig.10.6) can be summarized in the following points:

- Suitability for vegetables is more than fruit trees as salinity starts to appear after 60 cm depth.
- Main limitations for irrigated vegetables are the low hydraulic conductivity (water logging problem) and the moisture storage which is related to soil texture.
- Limitations to irrigated fruit trees are mainly the salinity of subsurface soil and the low water holding capacity.
- Limitations coincided with the short irrigation interval practiced in JV.
- Limitations are also overcome by the management practices followed by farmers.

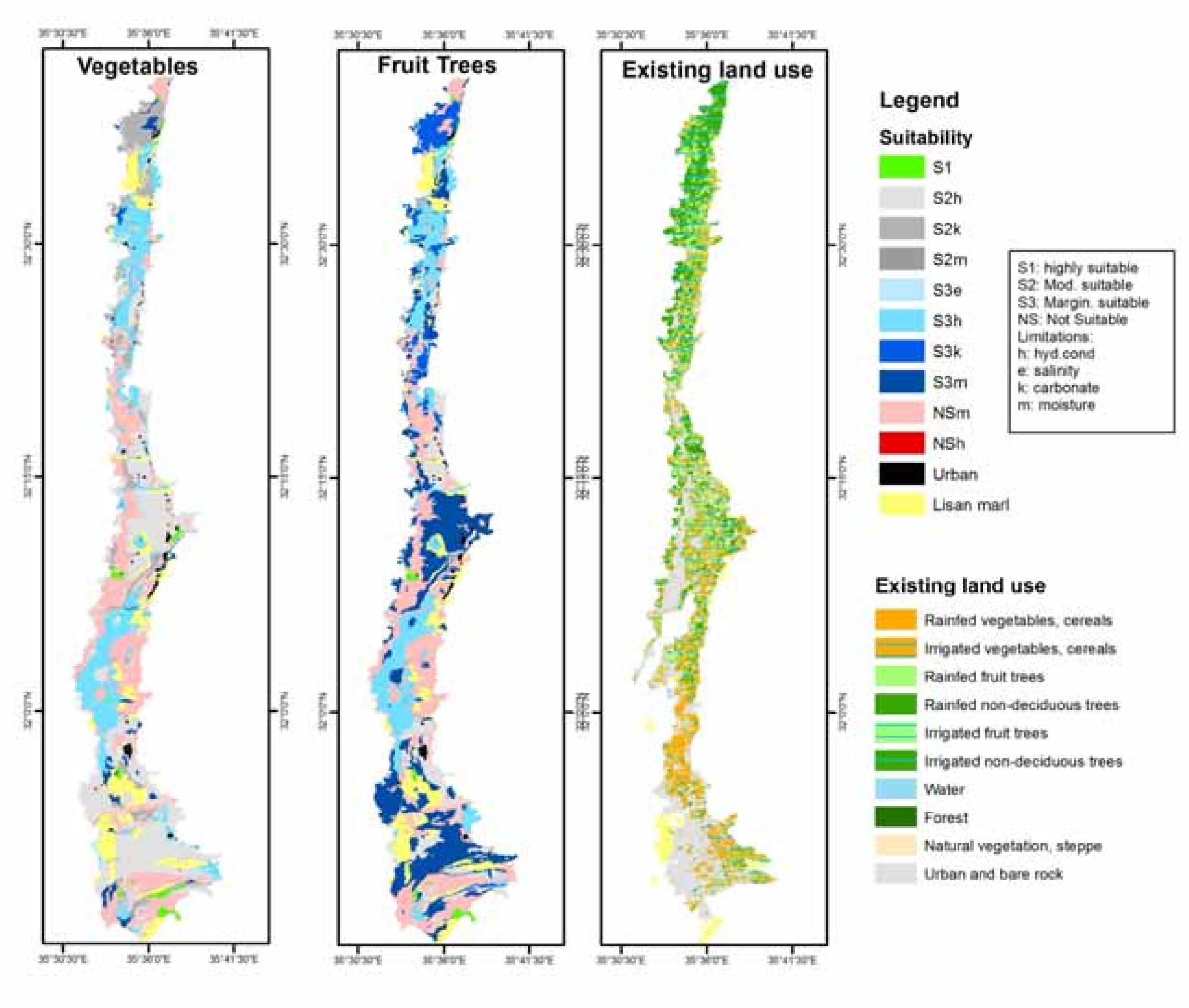


Fig. 10.6: Maps of soil suitability for irrigated vegetables and fruit trees (Middle) and existing land use in JV.

10.2.2.5 Evaluation of soil sensitivity towards the irrigation with treated wastewater

The methodical approach consisted of two parallel processes. As there was no supraregional spatial data about soil properties available, a new set of data was created. Available national soil maps were taken or digitized and matched with a small-scaled transboundary map. The soil units of these maps were subsequently attributed with allocated soil properties, e.g., regarding soil texture, organic matter content

(OM), pH. The other process was the definition of major agricultural and environmental risks, their assessment and visualization.

The environmental risks of irrigation with TWW mainly depend on the local soil properties and the water quality. There is no spatially up-to-date inclusive and comprehensive information about water qualities used in the different countries available. The soil sensitivity is more an inherent characteristic of the soil, independent of the water quality. In a next step, the most important soil-related risks associated with TWW irrigation were defined based on the assumption that TWW is generally of poorer quality than fresh water regarding several properties like salinity, total dissolved solids, total suspended solids, dissolved organic matter or heavy metals and other pollutants. The soil sensitivity was related to these risks using specific criteria which had to be evaluated based on the available soil data (Tab.10.1). Finally, the particular sensitivities were weighted, aggregated and displayed as total sensitivity. The results of each assessment are the respective sensitivity grades, which were given on a three-step scale: 1—low sensitivity; 2—medium sensitivity; and 3—high sensitivity. From this, the respective suitability grades are derived in the way that a low sensitivity area has a high suitability for irrigation with TWW and vice versa. The sensitivity and the derived suitability grades are displayed in maps according to a traffic light labeling (red/yellow/green).

Tab. 10.3: Overview of the defined risks, criteria, methods and the parameters used.

Risks		Criteria	Parameters (required and derived)	Methods
A	Mobilization of inorganic adsorbable pollutants	Buffering capacity for inorganic adsorbable pollutants (e.g., heavy metals)	Texture, OM, pH	Blume & Brümmer 1991 [19]; modified
B	Slaking of the upper soil layer	Slaking of the upper soil layers	Texture, OM	Ad-hoc-Arbeitsgruppe Boden 2005 [16]; modified
C	Salinization of soils	Salinization of soils	Texture, bulk density, depth of root zone, soil depth, field capacity, saturated hydraulic conductivity, leaching rate	Own method
D	Mobilization of boron	Buffering capacity for boron	Texture, OM, pH	Own method
E	Groundwater pollution	Buffer capacity for non-adsorbable substances (e.g., nitrate)	Texture, bulk density, depth of root zone, field capacity, leaching rate	DIN 19732: 1997-06 [20]
F	Hydrophobicity	Soil surface area	Texture	Own method

For compiling an aggregated sensitivity, the single sensitivities were given relative weights according to their relevance in consultation with all regional partners as the impact of the sensitivities could not been valued equally. It was generally agreed, that sensitivity C (salinization) and E (groundwater pollution) are given a higher weight since they have a high relevance for assessing the total sensitivity. The aggregation of the single weighted sensitivities values resulted in the presentation of the total sensitivity grade by means of the three-step scale (Fig. 10.6).

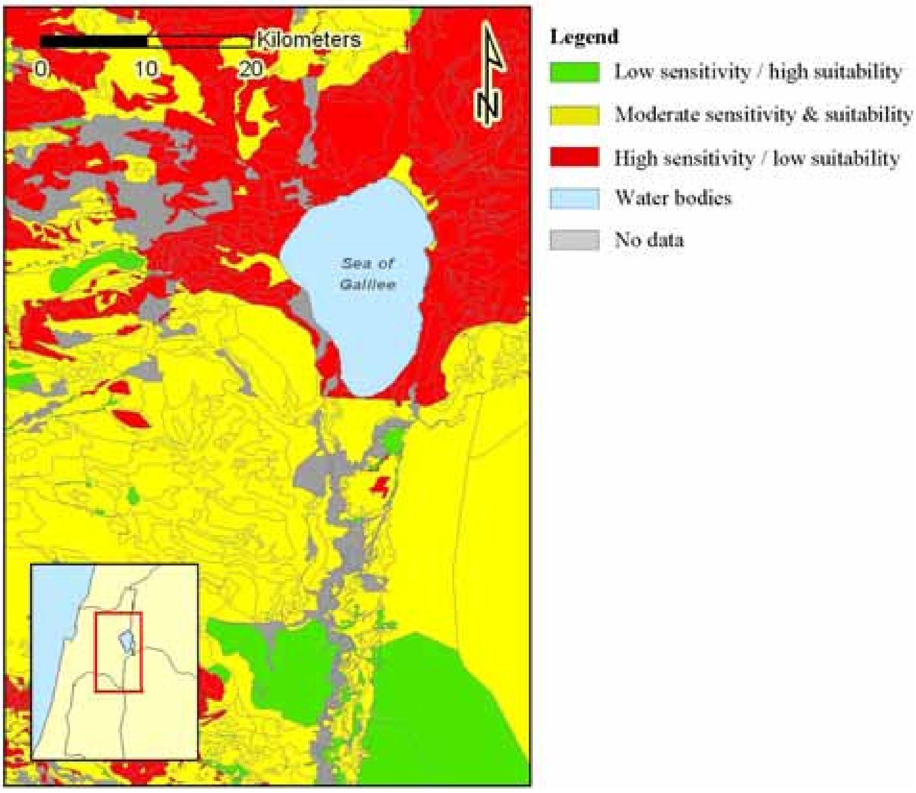


Fig. 10.7: Cut-out of the assessment map visualizing the aggregated total sensitivity (Schacht et al. 2011).

Using this approach, the available spatial soil information of major parts of the project area has been brought together for the first time in order to assess the soil sensitivities towards the potential risks associated with TWW use for agricultural irrigation. The database offers a comprehensive and transboundary overview about soil properties and their distribution in the region. Comparable transboundary soil maps displaying the soil units and their properties have not been available previously. However, the resolution and the quality of information regarding the spatial assessment of the particular sensitivities towards TWW irrigation depend on the basic data. Although this assessment has been conducted using the best available data, it is not adequate for displaying the large-scale soil heterogeneities that occur within the mapping units. Moreover, due to averaging of soil property data from different sources while matching them to certain soil units, possible information of spatial heterogeneity have necessarily been equalized.

For regional and supraregional planning purposes, the sensitivity maps are well suited to provide reasonable information regarding sustainable infrastructural development, but they are not yet suited for farm level decision making. However, the methods presented in this work can be applied to any spatial scale if soil data is available at the desired scale of resolution. On the farm level, for example if a farmer has to decide about the distribution of irrigation water of different quality, large-scale mapping and designation of soil units would be needed. More detailed information about the spatial distribution regarding for example soil texture, pH and OM-content would significantly enhance the quality of the maps.

The methods applied in this assessment have been chosen as they are simple enough to be conducted and understood not only by professionals. They are based on the evaluation of soil properties which are, in most cases, easy to handle, except the generation of leaching rate data, which has to be derived differently. Therefore, the methods presented are transferable to other arid and semiarid regions. The weighting of the particular sensitivities can then be adjusted to the regional requirements.

The weights given to the particular sensitivities A-F for estimating the total sensitivity are based on the personal expertise of local experts and the authorship, reflecting their personal experience. During the alignment process it became clear that certain particular sensitivities were weighted differently. Sensitivity B (slaking of the upper soil layer) has been given higher impact, for example by the expert from the West Bank due to the fact that erosion processes are of major significance there. Boron mobilization is more threatening when TWW of poorer quality is used. Due to this fact, this risk is more of an issue in countries with less sophisticated treatment infrastructure and legislative regulation, like Jordan and the PA. So the final decision was a compromise between different expertises, shared within the authorship.

This assessment was conducted independently from the effective TWW quality, as there was no supraregional spatial information available. The possible adverse impacts on soil and groundwater quality are dependent on quality of the irrigation water used, though. In the three observed countries, the quality of the reused water is very different. Israel has a well-developed infrastructure for wastewater treatment and its reuse and only in a few sites orchards (e.g., dates) are irrigated with only primary treated wastewater. The situation is very different in the PA, where sufficient treatment capacities are currently not available. Therefore, raw or diluted wastewater is often used in the PA for irrigation, The quality of the water reused for irrigation in Jordan, mainly for agriculture located in the Jordan Valley, varies enormously in time and space, depending on the performance of the As-Samra treatment plant and the further dilution of the treated wastewater (TWW) while flowing down the river Zarqa and mixing with water coming from the King Abdullah Canal. There are some farms in the vicinity of the As-Samra treatment plant that use undiluted TWW for irrigation near-by. Even if there are progressive legislative limiting values (Israel, Jordan), the quality of the reused water for irrigation does not match these limits in every case. Due to this fact, we decided not to cite “typical” quality parameters of fresh water (FW), wastewater, treated wastewater, as the parameters are essentially highly variable in space and time. Simplified, we regard fresh water in its chemical composition as a case of TWW without organic matter, inorganic pollutants and usually with lower concentrations of salts. Since other waters with poor quality parameters, such as brackish water, are also used for irrigation in some parts of the region, the assessment can be generalized to reflect the soils' sensitivities towards irrigation with other "marginal waters". Especially when working on the farm level, it would be advisable to include information on irrigation water quality for further decision-making. Information about previous impacts and initial levels of soil contamination should then also be taken into account.

10.2.3 Discussion and conclusion of scientific highlights and outlook

The studies have shown that irrigation with TWW can lead to profound changes in soil chemical, biological and physical properties. Many of the observed effects can be attributed to the TWW's organic load and its specific composition. While some effects appear to be ephemeral, such as the reduced wettability which is removed by the winter rains, other effects are more long-lasting, such as the reduction in SOC pools in the deeper soil layers. So far, none of the observed effects are so pronounced that severe reductions in soil fertility or other ecosystem services have to be expected. However, since soils only react slowly to such perturbations, but possibly irreversibly, a risk of long-term soil degradation exists, unless TWW quality is greatly improved.

10.3 Applied value of results

This is the first comprehensive supranational study assessing the soil sensitivity and suitability towards the risks of irrigation with TWW. It provides a comprehensive overview and identifies sensitive regions. This information will be important for sustainable agriculture and strategic infrastructure planning. The assessment methods are kept simple to provide usability and easy performance. The results are displayed in maps which can be used with common GIS systems. Moreover, the particular sensitivity maps can be distributed analogically. This also contributes to strategic water reuse management and could be implemented in integrated water resource management.

10.4 References

Ad-hoc-Arbeitsgruppe Boden. Bodenkundliche Kartieranleitung, 5th ed.; Schweizerbart: Stuttgart, Germany, 2005, (in German).

Blume, H.P.; Brümmer, G. Prediction of heavy metal behavior in soil by means of simple field tests. Ecotoxicol. Environ. Saf. 1991*, 22, 164-174.*

DIN 19732: 1997-06 (1997) Soil Quality—Determination of the Site Specific Potential for Translocation of Non-Sorbable Substances, DIN Deutsches Institut für Normung e. V.: Berlin, Germany.

Friedel, J. K., T. Langer, C. Siebe and K. Stahr (2000). Effects of long-term wastewater irrigation on soil organic matter, soil microbial biomass and its activities in central Mexico. Biol Fertil Soils 31, 414-421.

Meli, S., M. Porto, A. Belligno, S. A. Bufo, A. Mazzatura and A. Scopa (2002). Influence of irrigation with lagooned urban wastewater on chemical and microbiological soil parameters in a citrus orchard under Mediterranean condition. The Science of the Total Environment 285, 69-77.

Ramirez-Fuentes, E., C. Lucho-Constantino, E. Escamilla-Silva and L. Dendooven (2002). Characteristics, and carbon and nitrogen dynamics in soil irrigated with wastewater for different lengths of time. Bioresource Technology 85, 179-187.

11 Regional climate scenarios

Prof. Harald Kunstmann, Institute of Meteorology and Climate (IMK-IFU), Karlsruhe Institute of Technology, Germany
Dr. Gerhard Smiatek, Institute of Meteorology and Climate (IMK-IFU), Karlsruhe Institute of Technology, Germany
Dr. Andreas Heckl, Institute of Meteorology and Climate (IMK-IFU), Karlsruhe Institute of Technology, Germany

IMK-IFU working group

11.1 Aim

The aim of the sub-projects is the dynamical downscaling of global climate scenarios from global climate models (GCM) for the area of EM with highly resolved regional climate models (RCM).

11.2 Description of research

11.2.1 Material and methods

Transient runs of the regional climate model MM5 driven with boundary forcings from the ECHAM5 (MPI, Hamburg) and HadCM3 (Hadley Centre) general circulation models (GCM) are used to simulate the climate change signal in the EM region. In order to account for regional and local climate patterns resulting from the sharp climatic gradient in the region, global climate scenarios have to be downscaled to higher spatial resolutions.

Two versions of the NCAR/ Penn State University model MM5 were employed: MM5 version 3.5 (MM5V35) and version 3.7_4 (MM5V37). They differ in the applied soil-vegetation-atmosphere-transfer model (SVAT) one of the key sub-models in a climate model. Version 3.5 utilizes the four layer Oregon State University (OSU-Model) while version 3.7 was driven with the Noah Land Surface Model. The approach with two RCMs driven with various GCM forsings allows for consideration of model ensembles.

The spatially highly resolved dynamic downscaling approach covers the period from 1960 to 2100 and the spatial resolutions of the nested simulations are 50 km and 18.6 km. The main focus is set on the delineation of uncertainty ranges and the statistical analysis of extreme events as well as on provision of highly resolved meteorology data from the RCM run as input data for subsequent impact analysis.

Table 11.1: Performed dynamical downscaling experiments.

Nr.	RCM	Dx	Period	Scenario	GCM
1	MM5V35	18.6 km	1960-2100	A1B	ECHAM5
2	MM5V35	18.6 km	1960-2099	A1B	HadCM3
3	MM5V37	18.6 km	1960-2100	A1B	ECHAM5
4	MM5V37	18.6 km	1960-2099	A1B	HadCM3

All results were evaluated for the period 1961-1990 against the observational reference from GLOWA JR precipitation data set (Menzel et al., 2009) and the third version of the European daily high-resolution gridded data set for surface temperature and precipitation (Haylock et al., 2008; van den Besselaar et al.,2011) both at daily temporal resolution.

Smiatek et al. (2011) (http://dx.doi.org/10.1029/2010JD015313) and Samuels et al. (2011) (http://dx.doi.org/10.1029/2011JD016322) present a detailed evaluation of the RCM data.

11.2.2 Results

Results of the four RCM simulations presented by Smiatek et al. (2011) (http://dx.doi.org/10.1029/2010JD015313) show that the applied models reproduce the mean temperature and precipitation patterns in the EM area with some limitations in reproducing the precipitation seasonality. The bias in the annual mean precipitation for the period 1961 -1990 was in the range from −20% to +17%, with an ensemble mean of −3%. Figure 11.1 illustrates the spatial correlation with the observed reference for several variables indicating reasonable reproduction of the key climate variables in the area.

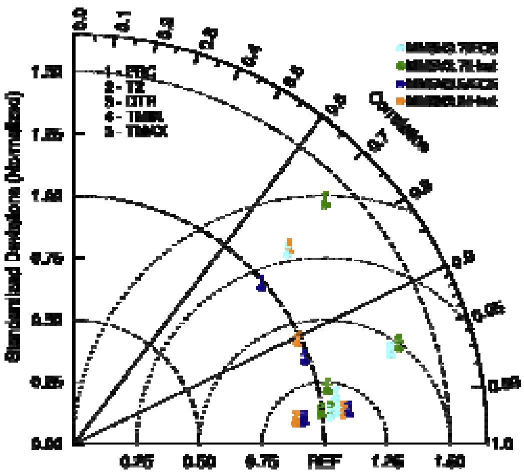


Figure 11.1: Spatial correlation between modeled annual mean and the observational E-OBS reference and the period 1961–1991. Abbreviations are as follows: PRC - precipitation; T2 - mean 2 m temperature; DTR – diurnal temperature range, TMIN -minimum temperature and TMAX -maximum temperature.

Related to the 1961-1991 mean, simulations of the future climate signal with the four available RCM models reveal an ensemble mean increase of the annual mean temperature of approximately 2.1°c for the period 2031-2060 and 3.7°C for the period 2070-2099. For the same periods, the annual mean precipitation is simulated to decrease by approximately −11.5% and −20%. Figure 11.2 illustrates the simulated changes in a set o climate variables and the winter season (DJF). The results show to a large extend a reasonable agreement between the models run with ECHAM5 and with HadCM3 boundary forcing.

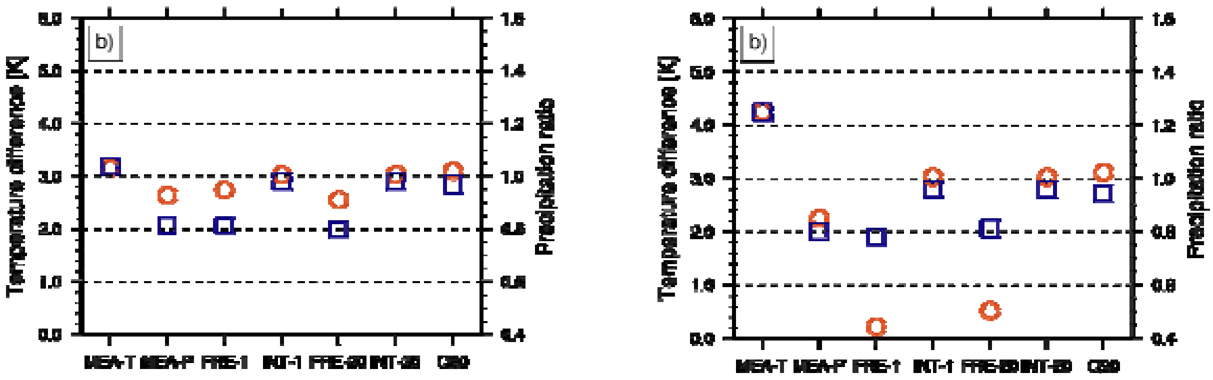


Figure 11.2: Simulated Change for the winter season (DJF). (a) 2031-2060 to 1961- 1990 and (b) 2070-2099 to 1961 - 1990 and MM5V3.5/Had (red) and MM5V3.5/EC5 (blue) models. MEA-T – mean 2m temperature, MEA-P – mean precipitation, FRE-1 – frequency of days with precipitation of at least 1 mm, INT-1 precipitation intensity on days with at least 1mm precipitation, FRE-20 frequency of days with precipitation of more than 20 mm, INT-20 - 1 precipitation intensity on days with more than 20mm precipitation and Q90 – 90 quantile of the precipitation distribution on days with at least 1mm precipitation.

11.2.3 Discussion and conclusion of scientific highlights and outlook

Detailed investigations of the future climate change signal revealed a significant elevation dependency: areas at higher elevation are simulated to experience higher temperature increase and larger precipitation decreases. Future precipitation reduction in an area with average annual mean precipitation of 255 mm together with higher inter-annual variability has a large potential to increase the pressure on the water management in the region.

11.3 Applied value of results

Projections of future climate conditions, particularly of future spatial and temporal distribution of temperature and precipitation, are a central requirement for the development of adaptation and mitigation strategies.

11.4 References

Haylock, M., N. Hofstra, A. K. Tank, E. Klok, P. Jones, and M. New(2008), A European daily high-resolution gridded dataset of surface temperature and precipitation for 1950–2006, J. Geophys. Res., 113, D20119, doi:10.1029/2008JD010201.

Menzel, L., J. Koch, J. Onigkeit, and R. Schaldach (2009), Modelling the effects of land-use and land-cover change on water availability in the Jordan River region, Adv. Geosci., 21, 73–80, doi:10.5194/adgeo-21-73-2009.

Smiatek, G., H. Kunstmann, and A. Heckl (2011), High-resolution climate change simulations for the Jordan River area, J. Geophys. Res., 116, D16111, doi:10.1029/2010JD015313.

Samuels, R., G. Smiatek, S. Krichak, H. Kunstmann, and P. Alpert (2011), Extreme value indicators in highly resolved climate change simulations for the Jordan River area, J. Geophys. Res., 116, D24123, doi:10.1029/2011JD016322.

van den Besselaar, E., M. Haylock, G. van der Schrier, and A. M. G. Klein Tank (2011), A European daily high-resolution observational gridded data set of sea level pressure, J. Geophys. Res., 116, D11110, doi:10.1029/2010JD015468.

Tel Aviv University working group

Prof. Pinhas Alpert, Dept. of Geophysics, Atmospheric and Planetary Sciences, Tel Aviv University, Israel.
Dr. Shimon Krichak, Dept. of Geophysics, Atmospheric and Planetary Sciences, Tel Aviv University, Israel.
Dr. Rana Samuels, Dept. of Geophysics, Atmospheric and Planetary Sciences, Tel Aviv University, Israel.
Haim Shafir, Dept. of Geophysics, Atmospheric and Planetary Sciences, Tel Aviv University, Israel.
Yosef Breintgand, Dept. of Geophysics, Atmospheric and Planetary Sciences, Tel Aviv University, Israel.

11.5 Aim

The aim of this sub-project is to run RCMs over the EM, and to find what the projected changes are in the 21st century in the EM climate as resulted from the "greenhouse effect".

11.6 Description of research

Evaluations of climate change trends due to effects of anthropogenic emission of greenhouse gases (GHG) are usually performed with the help of Atmosphere-Ocean Global Climate Models (AOGCM) using specially designed projections of future GHG emissions (IPCC, 2001, 2007). Most of the contemporary AOGCMs are characterized by relatively coarse (~200 km or more) spatial resolution, precluding them from accounting for the contributions of small-scale atmospheric and land surface effects. Therefore, regional climate model (RCM) downscaling of the AOGCM results is often performed to deeper understand the AOGCM results over specific areas.

In this research, a determination of the climate change projections for the EM region during the first half of 21st century using an optimally configured RCM models RegCM3 (Giorgi et al., 2004b; Alpert et al., 2008, Krichak et al., 2009; Pal et al., 2007) has been performed to downscale results of one global climate simulation experiment performed at the Max-Planck Institute for Meteorology, Hamburg with emission of greenhouse gases from 2001 according to A1B and B1 SRES scenario during 1961-2060 employing spatial resolutions of 25 km/18L. Time variations of the differences in the space distributions of simulated climate parameters were analyzed to evaluate the role of smaller scale effects. Both least-square linear and non-linear trends of several characteristics of the EM climate were evaluated.

11.6.1 Material and methods

The RCM models used is the third generation RegCM3 model (Pal et al., 2007) of the International Center for Theoretical Physics (ICTP). The top of the model's atmosphere is defined at 80 hPa. The model domain used covers southern Europe, the eastern part of the Mediterranean region and the Middle East. The size and configuration of the model domain have been selected to allow a representation of main synoptic processes important for description of the to EM climate (Krichak et al. 2009b). The domain includes 160x160 grid points (25 km resolution). The physical options used are discussed separately (Krichak et al., 2007, 2008, 2009a,b; Samuels et al., 2010).

The driving data adopted are from a transient climate change simulation experiment performed with the fifth-generation global atmosphere-ocean ECHAM5 / MPI-OM model of the MPI-M (Muller and Roeckner, 2008). The ECHAM5 atmosphere model is hydrostatic with spectral T63 truncation (1.875°x1.875° spatial resolution) and 31 hybrid vertical levels. The ocean model MPI_OM uses a conformal mapping grid with a horizontal grid spacing of 1.5° and 40 vertical levels. The ECHAM5/MPI-OM experiment is initiated from the pre-industrial period (~1850). For the future climate projection, the ECHAM5 experiment employed greenhouse gases (GHG) emission scenarios A1B and B1 (IPCC 2007).

Within the full range of the IPCC GHG anthropogenic emission scenarios, the A1 (IPCC 2007; Raupach et al. 2007) family of scenarios is characterized by (a) rapid economic growth; (b) a global population reaches 9 billion in 2050 and then gradually declines; (c) the quick spread of new and efficient technologies; (d) a convergent world - income and way of life converge between regions; (e) extensive social and cultural interactions worldwide. The subset A1B in the A1 family assumes a balanced emphasis on all energy sources. Another family (B1) of the GHG scenarios assumes a world as more integrated, and more ecologically friendly. The B1 scenarios are characterized by (a) rapid economic growth as in A1, but with rapid changes towards a service and information economy; (b) population rising to 9 billion in 2050 and then declining as in A1;(d) reductions in material intensity and the introduction of clean and resource efficient technologies; (e) an emphasis on global solutions to economic, social and environmental stability.

11.6.2 Results

We have realized a transient regional climate change simulation experiment using a double resolution approach. Another series of RCM simulations for GLOWA JR has been also performed. The computations were performed at High Performance and Grid Computing Center TUBITAK, ULAKBIM (http://blog.grid.org.tr, http://wiki.grid.org.tr, http://www.grid.org.tr,) as an informal cooperative effort with Prof. Dr. Sevilay Topcu (Cukurova University, Agricultural Faculty Department of Agricultural Structures and Irrigation, 01330 Adana/TURKEY) and Dr. Burak Sen (Turkish State Meteorological Service, Department of Weather Forecasting, Numerical Weather Prediction Division, 06120 Kalaba/ANKARA/TURKEY).

An ensemble of RCM simulations with RegCM3 model has been designed focused on determination of the climate change projections for the EM region during the first half of 21st century (1960-2060) (Table 11.2). Results of three global climate simulation experiments (EH5A1B_3; EH5B1_1) performed at the Max-Planck Institute for Meteorology, Hamburg (according to A1B and B1 SRES scenarios) and HadCM3 model of the Hadley Center for Climate Research, UK (A1B scenario – one ensemble member – HC_A1B) have been adopted for the downscaling. The RegCM3 simulations have been performed using 25 km/18L resolution.

In general, evaluations of the different simulations show a statistically significant positive trend in near-surface air temperature during the four seasons of year over the whole EM region during 2001-2060. They also include a notable, significant negative precipitation trend during DJF and SON. The experiment also consistently projects a minor positive precipitation trend during MAM. The trends are not significant over the area however. The result is a consequence of relatively low frequency of rainy events during MAM and practically absolute absence of rains during JJA. Also projected are the rises in the air temperature extremes as well as in relative contribution of convective processes in the region during 2020-2060 as a result of projected decline in amount of total precipitation but a zero trend in that of convective one. Projected multi-decadal variations of air-temperature and its extremes, maximum wind speed and solar incident radiation flux over the EM are clearly controlled by those in total precipitation.

More specifically, results of the climate simulation with GHG emission according to the AIB scenario indicate a decrease of 15% annually in rainfall and an increase of 1.5-2.5 degrees Celsius in the 2031-2060 period, as compared with the 1961-1990 period, with a more dramatic increase inland as opposed to the coastal areas. The simulations also project an increase in extreme events. Changes in extreme precipitation events are shown in Figure 11.3. Number of extreme rain days decreases both for days with over 20 mm and days with over 50 mm of rainfall. However, since much of the country, especially the south, does not receive many days with that much rainfall, we also looked at the number of days where the daily precipitation amount is over the 90th and 99th percentile of the 1960-1990 values. For this metric we see that for places specifically in the central/south east, there is an increase in days above the 90th percentile and in the north there is an increase in the number of days above the 99th percentile. This suggests that the general decrease in rainfall will be accompanied by an increase in extreme rainfall events in these areas. This fits our earlier study of observations during the 2nd half of the 20th century over the Mediterranean (Alpert et al., 2002).

Table 11.2: An ensemble of RCM simulations with RegCM3 model has been designed focused on determination of the climate change projections for the EM region during the first half of 21st century (1960-2060).

Num. of exp.	RCM	Space/ Time Resolution	Data for time period	Time resolution	Emission scenario	Driving AOGCM	AOGCM Spatial resolution	No. of ensemble member
1	Reg CM3	25 km	1960-2060	1 day (3 hr)	A1B	ECHAM/MPI	~220 km	1
2	Reg CM3	25 km	1960-2060	1 day (3 hr)	A1B	ECHAM5/MPI	~220 km	2
3	Reg CM3	25 km	1960-2060	1 day (3 hr)	A1B	ECHAM5/MPI	~220 km	3
4	Reg CM3	25 km	1960-2060	1 day (3 hr)	B1	ECHAM5/MPI	~220 km	1
5	Reg CM3	25 km	1960-2060	1 day (3 hr)	A1B	HadCM3Q	~300 km	0

11.6.3 Discussion and conclusion of scientific highlights and outlook

- RCM runs were performed in the EM for the first time.
- 5 ensemble RCM simulation with different climate scenarios and high-resolution were performed.
- Increase of 1.5-2.5°C in the summer temperature for the 21st century was found.
- Decrease of 15% in the annual rainfall for the 21st century.
- Increase in extreme events.
- Preliminary evaluations of results of the RCM simulations according to A1B and B1 scenarios show a more intense increase in summer temperature in the future climate developing in accordance with A1B scenario with a lower reduction in annual rainfall as compared with the B1 scenario case (Figure 12.2).

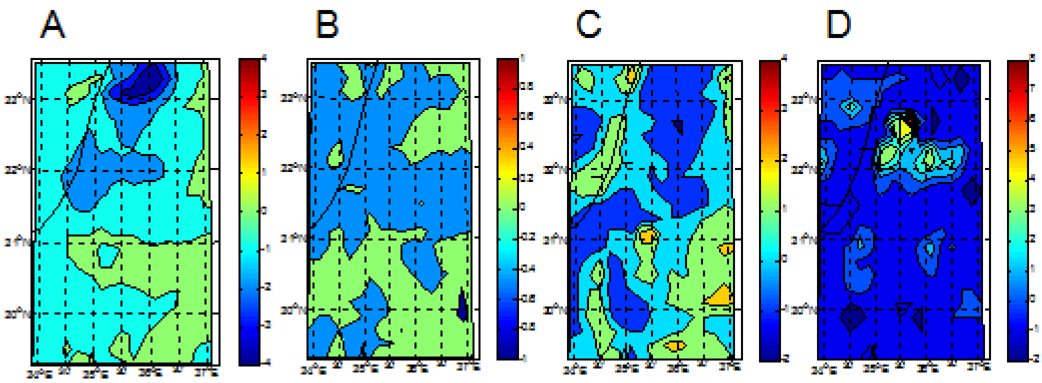


Figure 11.3: Changes in extreme precipitation events between the future 2031-2060 period and past 1961-1990 period. Extreme events include: (A) Number of days/year where the daily precipitation amount is at least 20 mm; (B) Number of days/year where the daily precipitation amount is at least 50 mm; (C) Number of days where the daily precipitation amount is over the 90%; and (D) Number of days where the daily precipitation amount is over the 99%.

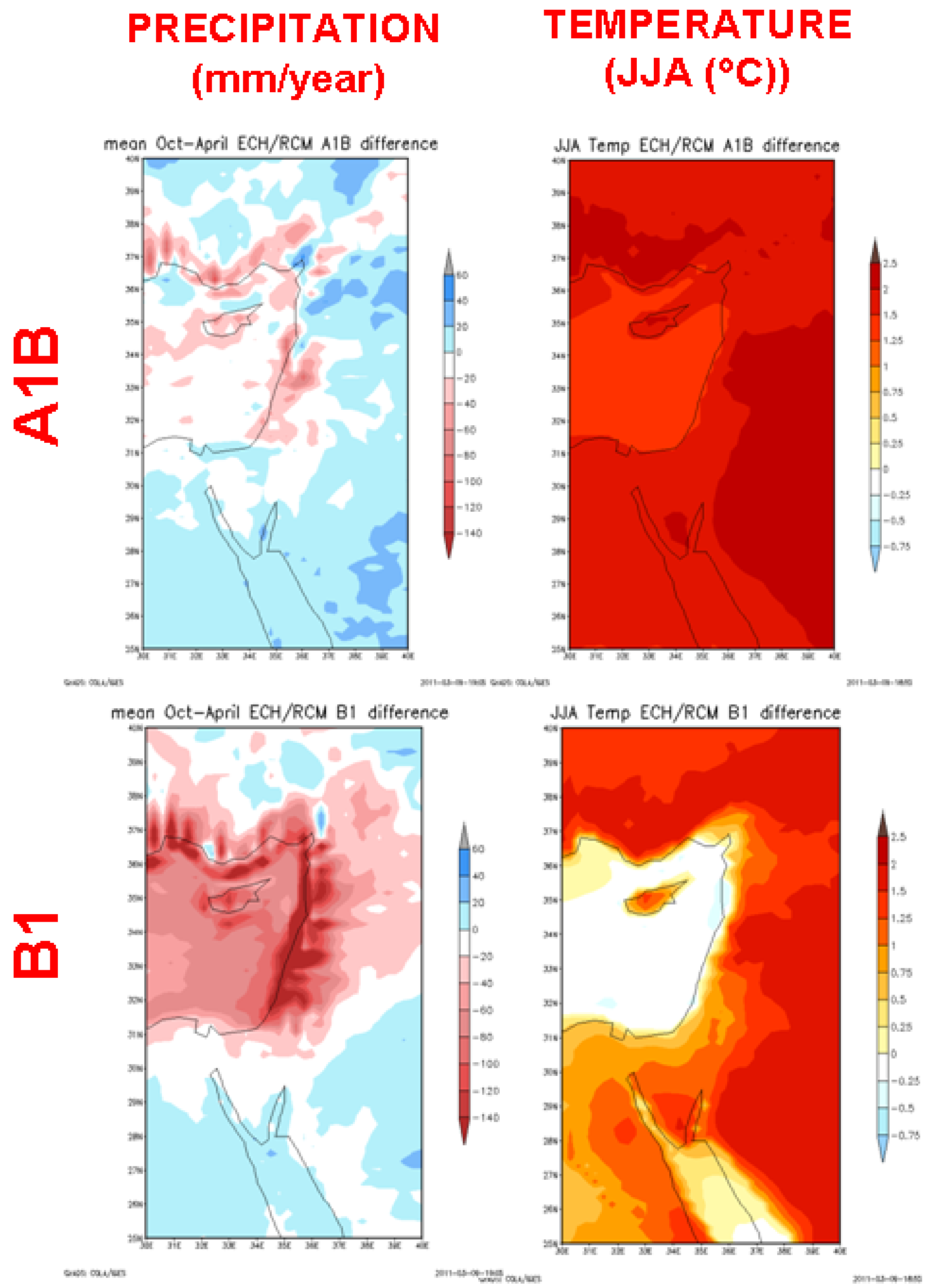


Figure 11.4: Changes in temperature and precipitation between the future and past period for A1B and B1 scenarios.

11.7 Applied value of results

The projected climate changes for the 21st century will help the decision makers in the EM in preparing a water policy.

11.8 References

Alpert P., T. Ben-Gai, A. Baharad, Y. Benjamini, D. Yekutieli, M. Colacino, L. Diodato, C. Ramis, V. Homar, R. Romero, S. Michaelides and A. Manes, The paradoxical increase of Mediterranean extreme daily rainfall in spite of decrease in total values, Geophys. Res. Lett., 29, 11, 31-1 – 31-4, (June issue), 2002.

Alpert P., Krichak S. O., Shafir H., Haim D., Osetinsky I., Climatic trends to extremes employing regional modeling and statistical interpretation over the E. Mediterranean, Global and Planetary Change, 63, 163–170, 2008.

Giorgi F., Interdecadal variability of regional climate change: implications for the development of regional climate change scenarios Meteorol Atmos Phys 89, 1–15, DOI 10.1007/s00703-005-0118-y, 2005.

IPCC (2007), Climate change - the physical science basis. Contribution of working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp., 2007.

Krichak S. O., Alpert P., Bassat K., Kunin P., The surface climatology of the eastern Mediterranean region obtained in a three-member ensemble climate change simulation experiment, Advances in Geosciences Adv. Geosci., 12, 67–80, 2007, www.adv-geosci.net/12/67/2007.

Krichak S.O., Alpert P., Kunin P., Numerical Simulation of Seasonal Distribution of Precipitation over the Eastern Mediterranean with a RCM. Climate Dynamics, DOI 10.1007/s00382-009-0649-x, 2009.

Krichak S. O., Alpert P., Projection of climate change during first half of twenty-first century over the Easter Mediterranean region according to results of a transient RCM experiment with 25 km resolution. Geophysical Research Abstracts, 12, EGU2010, 2010.

Krichak S. O., J. S. Breitgand, R. Samuels, P. Alpert, A double-resolution transient RCM climate change simulation experiment for near-coastal eastern zone of the Eastern Mediterranean region, Theor Appl Climatol 103, 167-195, DOI 10.1007/s00704-010-0279-6 2011.

Muller W. A., Roeckner E., ENSO teleconnections in projections of future climate in ECHAM5/MPI-OM. Clim Dyn. doi:10.1007/s00382-007-0357-3, 2008.

Raupach M. R., Marland G., Ciais P. H., Le Quéré C., Canadell J. G., Klepper G., Field C. B., Global and regional drivers of accelerating CO2 emissions. Proc of the Nat Acad Sci USA. doi:10.1073/pnas.0700609104, 2007.

Samuels R., A. Rimmer, A. Hartmann, S. Krichak, and P. Alpert, Climate Change impacts on Jordan River flow: Downscaling application from a Regional Climate Model, Journal of Hydrometeorology, 11, 4, 860-879, 2010.

12 Impact of environmental change on water resources

J. Lange (Freiburg University)
L. Menzel (Heidelberg University)
T. Grodek, E. Morin, Y. Enzel (Hebrew University of Jerusalem)
D. Yakir (Weizmann Institute of Science)
I. Oroud (Mu'tah University)

12.1 Aim

This project analyses current and future hydrological conditions for both the entire Jordan River

Region (JRR) as well as for the Lower Jordan River Basin (LJRB). It investigates the impact from land use and climate change and evaluates mitigation options in order to optimize water use and water availability on different spatial scales. The major aims are:

- to carry out a detailed assessment of the water resources and of the green / blue water fluxes for the JRR, based on refined land-use and soil maps
- to investigate the combined impact of land-use and climate changes on the water situation in the JRR
- to assess hydrological droughts, their current and future frequency and intensity, their impact on land-use and irrigation, and to evaluate mitigation options
- to produce hydrological information as input for SAS, and
- to translate hydrological information from various spatial scales (including current conditions and scenarios) into a regional WEAP model to produce sound options for water management.

Thereby, the hydrological models TRAIN and TRAIN-ZIN serve as principal tools, the latter was developed in phase 2 of the GLOWA JR project. Droughts are a special focus, because during drought seasons a sound management of the scarce water resources is especially important.

12.2 Description of research

The hydrological conditions of the JRR and LJRB are addressed. Focus is on drought, a hydrological extreme triggered by rainfall deficits. Based on observed climate data, the hydrological fluxes evapotranspiration, surface runoff and deep percolation are simulated and quantified. To furthermore address the hydrological impacts of environmental change, both land-use and climate scenarios are applied. The land-use scenarios are based on the SAS approach and delivered from sub-project 3.3 (Chapter 8) A range of climate scenarios are delivered from sub-project 4.1 (Chapter 11) Based on these scenarios the future hydrological conditions are assessed; the water balance components are simulated and droughts are characterised.

12.2.1 Material and methods

Within this sub-project, the TRAIN and the TRAIN-ZIN models are the major tools. The models have during phase 3 continuously been further developed. For example, certain sub-modules have been incorporated and the tempo-spatial parameterization of vegetation has been improved by using data from remote sensing. Other tools include the widely used drought indices Standardized Precipitation Index (SPI) and the Palmer Drought Index (PDI). In this study, the indices have been applied on both the point- and the large scale to characterize droughts under current and future climates.

12.2.2 Results

12.2.2.1 Water balance investigations in the Jordan Valley and the Jordanian highlands – contribution of Mu'tah University

The modelling of green and direct evaporation (bare surface) fluxes in the mountainous areas of Jordan and along a climate gradient was carried out. In this experiment we used both point stations and spatially distributed modelling with a spatial resolution of 1 km^2 and with a daily time step. GIS was used to integrate the simulation results and to produce spatial attributes such as soil moisture, surface runoff, deep percolation (groundwater recharge), actual evaporation, etc. Figure 12.1 shows the linkage between bare surface evaporation fractions as influenced by precipitation changes. Figure 12.2 displays transpiration of a wheat crop grown under rain-fed conditions.

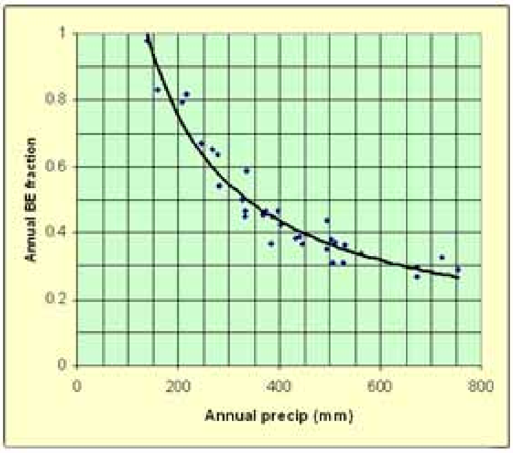


Figure 12.1: Linkage between direct evaporation ratio and annual precipitation in the mountainous areas of Jordan

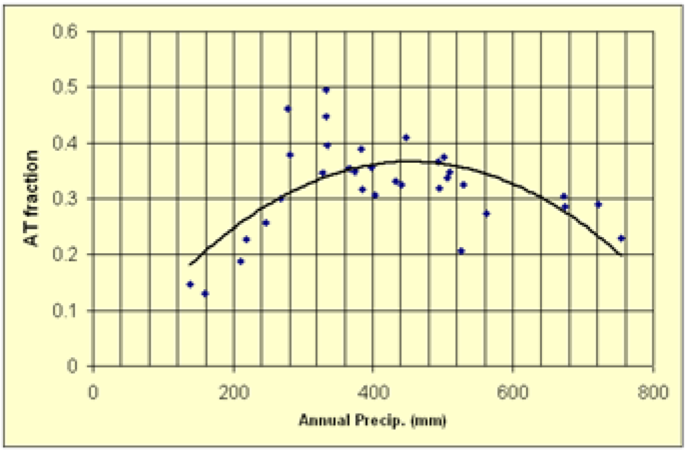


Figure 12.2: Green water fluxes (transpiration) as influenced by annual precipitation in the mountainous areas of Jordan.

For the determination of irrigation water requirements we used the FAO56 method with a daily time step to investigate water needs for vegetables and trees. Tables 12.1 and 12.2 show calculated water deficits for vegetables and trees in the northern and central Jordan Valley under current and future climates. In the scenarios it was assumed that temperature would increase by 2 °C and monthly precipitation would drop by 15% with no other climatic changes (e.g., relative humidity, wind speed, sunshine duration, and cloud cover would remain unchanged).

Table 12.1: The irrigation water demand for the current conditions as well according to two climate change scenarios in the central Jordan Valley.

Central J.V.	Current conditions	Temperature increase of 2 °C	A 2 °C increase along with a 15% reduction in precipitation
Annual ET	1250	1320	1320
Deficit (annual)	1080	1140	1155
ET (Nov-May)	495	535	535
Deficit (Nov-May)	335	360	375

Table 12.2: Same as Table 12.1 but for the northern Jordan Valley.

Northern J.V	Current conditions	Temperature increase of 2 °C	A two °C increase along with a 15% reduction in precipitation
Annual ET (mm)	1175	1255	1255
Deficit (annual)	930	990	1015
ET (Nov-May)	485	530	530
Deficit (Nov-May)	250	280	300

With a 2 °C temperature increase, annual crop reference evapotranspiration would increase by about 5-7% in the Jordan Valley. If we assume that 40% of the Jordan Valley is planted with trees (≈ 14000 hectares), the additional water needed to compensate for this climate change would then be around 12-14 million m^3. The climate change impact on irrigation water needs for vegetables is relatively less than that for trees. The additional irrigation water needed for vegetables grown in the Jordan Valley in the period November through May **following** a climate change of 2 °C and 85% of current normal annual precipitation will increase by about 8 million m^3. The combined irrigation water amount is sufficient to provide domestic water supplies for about 800 thousand to one million people with the current water consumption rates (≈ 0.1 m^3/day).

12.2.2.2 Water balance projections for the Jordan River Region – contribution of Heidelberg University

Hydrological fluxes

The evapotranspiration, water availability (surface runoff and deep percolation resp. groundwater recharge) and irrigation water demand was simulated on the point scale as well on the spatial scale within the whole JRR and neighboring regions. The simulations were conducted for the current situation and by considering several land use and climate change projections.

On the point scale, the physically based hydrological model TRAIN was set up and calibrated to simulate the water balance of the semi-arid Yatir forest in Israel, at the edge of the Negev. The model applications aimed at improving and validating TRAIN, based on high quality data measured by the Weizmann Institute of Science (within the FLUXNET programme). The hydrological model was able to successfully represent the overall behaviour of observed latent heat (evapotranspiration) at the Yatir site, with a mean difference between observed and simulated data of only 11.1% (Fig. 12.3). TRAIN successfully represented canopy interception, simulating an amount of approx. 6% of total precipitation, which is in agreement with previous studies on interception.

To validate TRAIN at the spatial scale, the simulated surface runoff was compared with observed runoff in three catchments draining the Jordanian Highlands towards the Jordan Valley and the Dead Sea. The comparison was conducted on monthly values and the results show that TRAIN is able to simulate a realistic runoff in the region (not showed). Only one catchment had a poor performance. Possible reasons may be due to dams and other anthropogenic activities like water usage that impact the runoff within the wadis.

The successful validation and application of TRAIN enables us

- to demonstrate the credibility of the results for the scientific community as well as for the stakeholders of the SAS group and beyond
- to further improve large-scale applications with this model for the whole JRR and neighboring regions (see below) on a 1x1 km grid

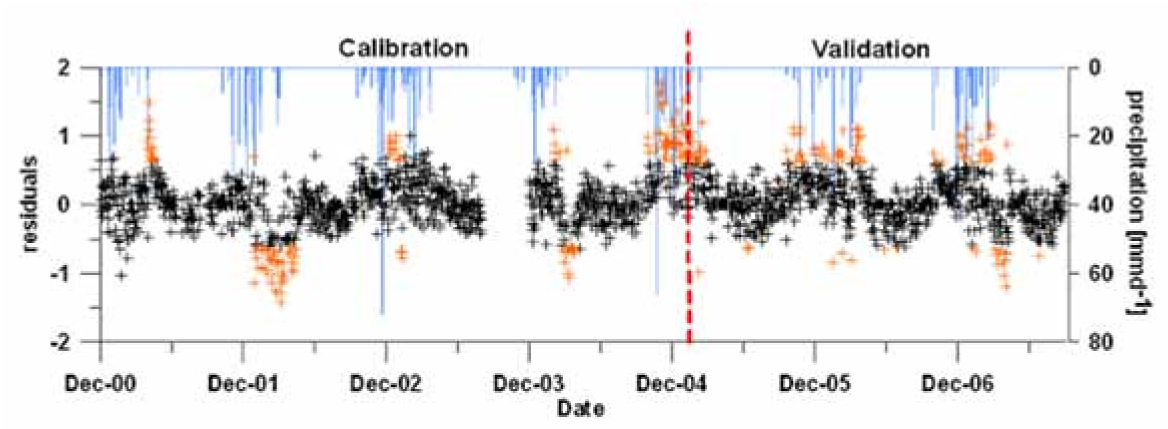


Figure 12.3: Residuals (daily differences between simulated and observed evapotranspiration, in mm) for the years 2000 to 2007 at the Yatir site. Orange dots denote intervals where TRAIN has a low performance, mainly due to shortcomings in the observed data as a consequence of rainfall (compare the synchronism between the orange dots and the blue bars, the latter representing rainfall).

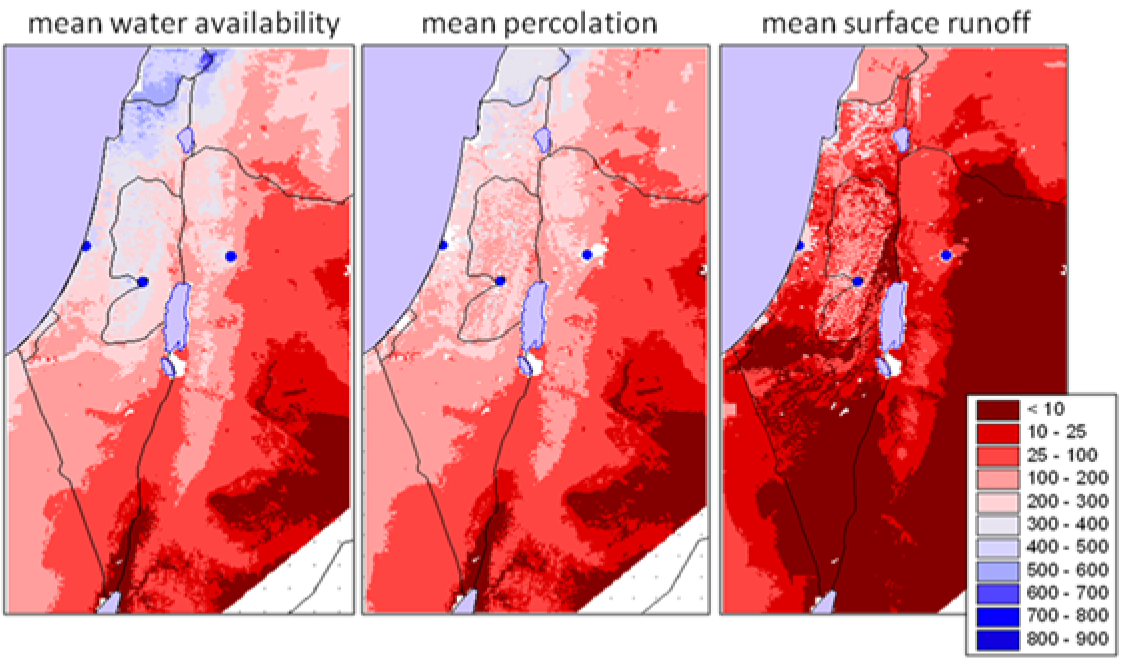


Figure 12.4: Results from the application of TRAIN give a spatially detailed view on the water resources of the Jordan River Region and its broader environs. The figure shows mean simulated annual data (1961-1990) for water availability (left), deep percolation (center), and surface runoff (right). The results demonstrate the scarcity of water resources in major parts of the area investigated, with very low values of mean surface runoff. All data are given in [mm]. Blue dots mark the location of major cities (Tel Aviv, Jerusalem, Amman).

After validation on the point and local scales, TRAIN was applied to cover the whole JRR and neighboring regions. A redefined soil map of Israel, delivered during project phase 2 by the University of Bochum (group of B. Marschner), was applied. The model first simulates the water balance components and water availability for current climate conditions (1961-1990) on a daily time step, taking into account the varying physiographic conditions (soils, vegetation, land use) on a 1x1 km grid (Fig.12.4). In a next step, data from the available climate scenario runs for the period 2031-2060 were used to determine the projected changes of selected water indicators with reference to current conditions (with land-use remaining unchanged). For a refined consideration of sub-regional changes, the project region was subdivided into three precipitation zones, representing sub-humid (> 450 mm), semi-arid (250-450 mm) and arid (< 250 mm) conditions. For each of the three regions, relative changes [%] for three of the most important indicators, namely water availability, evapotranspiration (green water fluxes) and irrigation water demand, have been computed. Figure 12.5 shows an aggregated view for the entire JRR, while Figure 12.6 represents sub-regional changes. The climate projections show that precipitation is predicted to drop considerably both over the entire JRR as well as within the three sub-regions. As a consequence, water availability shows an over-proportional decrease, with percentage changes in a range between ca. -10% and >-30% (according to the respective climate scenario and selected sub-region). Hence, in order to sustain agriculture at its current extent and intensity, an additional amount of between 15% and nearly 50% of water (with reference to current conditions) would be required. In order to integrate the simulated water fluxes in a greater context, the results were also delivered to WEAP.

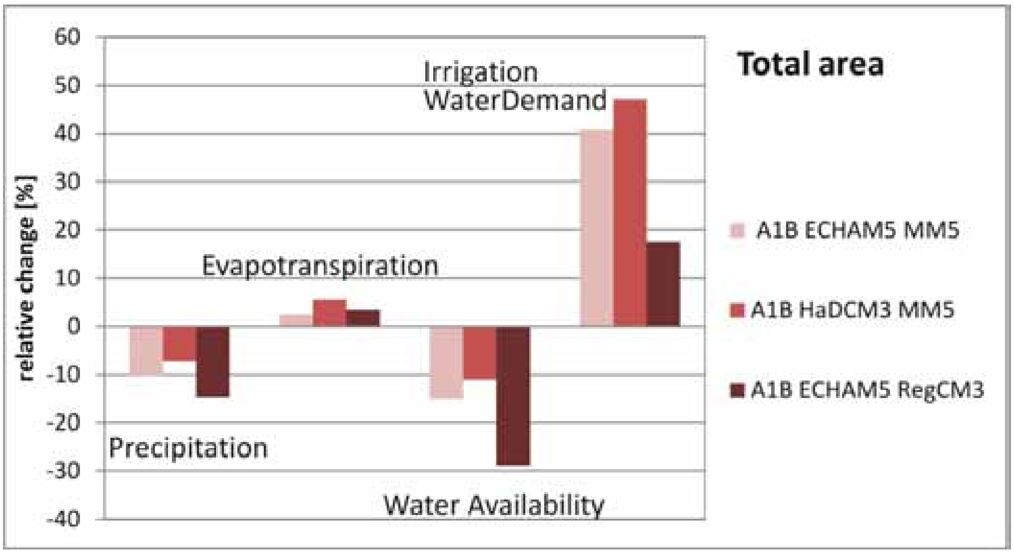


Figure 12.5: Relative changes [%] in precipitation, evapotranspiration, water availability and irrigation water demand between current (1961-1990) and future (2031-2060) conditions, representing the impact of the three climate scenarios. The model results refer to the entire JRR.

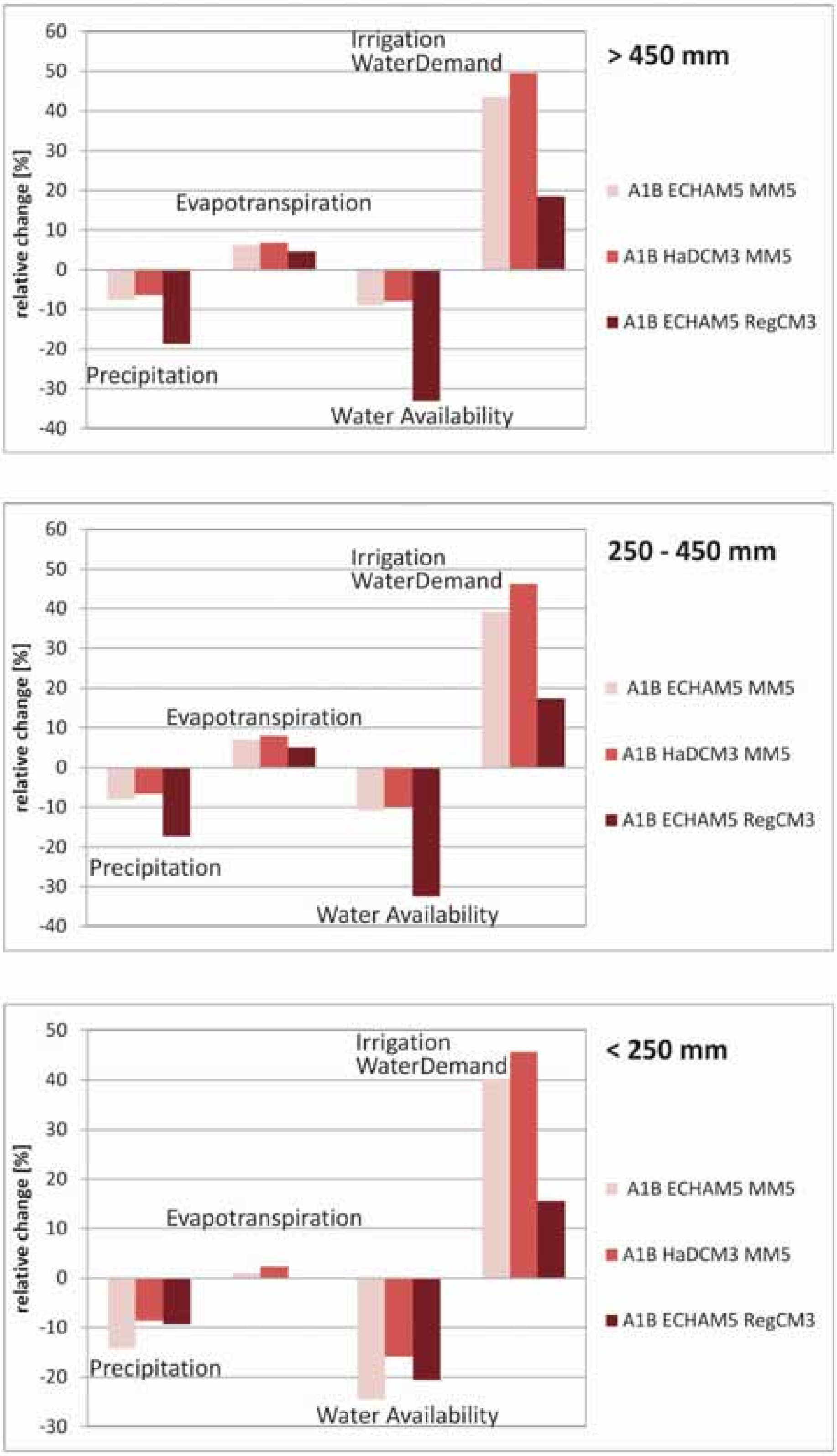


Figure 12.6: Relative changes [%] in precipitation, evapotranspiration, water availability and irrigation water demand between current (1961-1990) and future (2031-2060) conditions, representing the impact of the three climate scenarios. The model results refer to three different precipitation zones within the Jordan River Region.

Improved parameterization of TRAIN

During the third project phase, the availability of updated meteorological data made it possible to extend the reference period of the TRAIN simulations from 1961-1990 to 1961-2005. The model itself was also further developed. One important parameter when modelling the water balance is the Leaf Area Index (LAI). LAI is defined as the one-sided leaf area per unit ground area. In TRAIN, the parameter is essential regarding plant transpiration and interception and therefore acts as an interface between the land and atmosphere. During the previous project phases, LAI was parameterized with standard values from literature. During the third phase, LAI was successfully simulated as a function of precipitation. The simulated LAI shows very good agreement with observed LAI derived from the Normalized Difference Vegetation Index (NDVI) obtained from the Advanced Very High Resolution Radiometer (AVHRR). The highest correlation between simulated and observed LAI is obtained for the comparable vegetation rich land uses like cropland (correlation coefficient r 0.92), and mosaic (a combination of cropland and natural vegetation) ($r = 0.94$) but also for barren land ($r = 0.78$) and shrubland ($r = 0.85$) the simulated values can reproduce the temporal- and spatial variation of vegetation (Fig. 12.7 and Fig. 12.8, respectively). Since vegetation in the model now responds to the amount of rainfall, the model parameterisation of LAI is more realistic than before and improves the hydrological modelling in general. The greatest benefits are however observed during comparable dry and wet weather events where a clear response in vegetation and simulated transpiration can be observed with the improved LAI parameterisation.

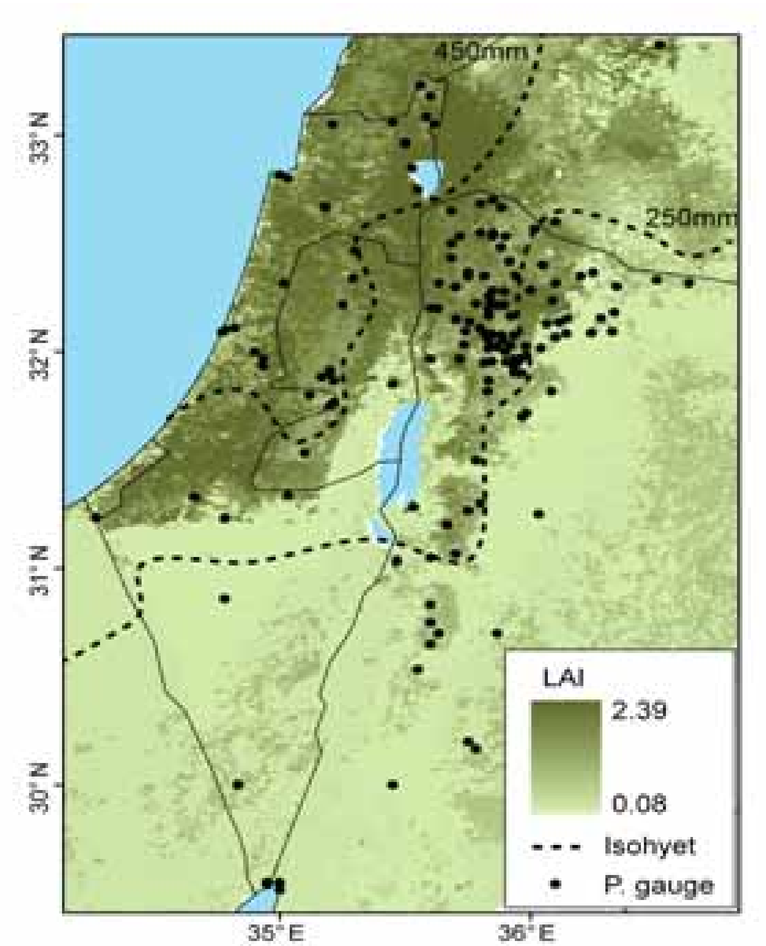


Figure 12.7: Simulated maximum LAI. The parameter LAI was simulated as a function of precipitation and has been implemented in TRAIN in order to better account for the regional vegetation dynamics.

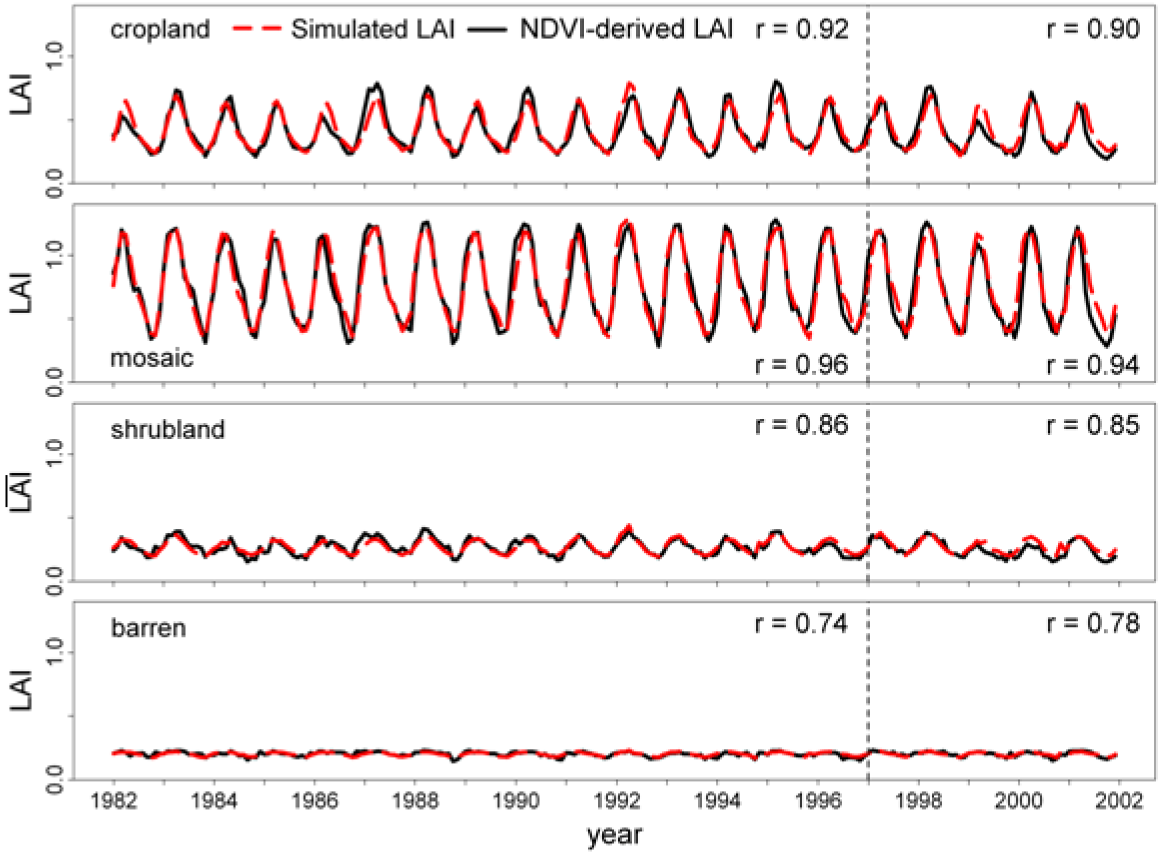


Figure 12.8: Observed (black line) and simulated (red dashed line) LAI for selected land-use classes where r is the correlation coefficient between the series. The time period 1982-1996 was used for calibration and the years 1997-2001 for validation.

12.2.2.3 Assessing daily rates of evapotranspiration in the Jordan River basin by remote sensing data– contribution of University of Trier and Heidelberg University

In co-operation with the Dept. of Geography, University of Trier (Prof. Michael Vohland; now at the University of Leipzig), remote sensing data have been applied in order to determine areal evapotranspiration for selected sub-regions of the Jordan River Region. These activities aim at comparing the TRAIN based simulations with independent data in order to validate TRAIN output on the large scale. Based on both reflective and thermal data, evapotranspiration was determined at the pixel scale. Thermal data allows the retrieval of land surface temperature which provides the necessary link between radiation budget (heat fluxes) and water budget. Reflective data were used for the quantification of shortwave albedo, vegetation coverage (quantified as scaled vegetation index as NDVI) and also emission coefficients (which all are auxiliary quantities in the remote sensing approach).

The thermal sensors of Landsat-5 TM and Landsat-7 ETM+ provide spatial resolutions of 120 m and 60 m, respectively. The Landsat scenes used for the computations were acquired at 29 May 2000, 21 March 2001, 24 May 2001 and 03 March 2002.

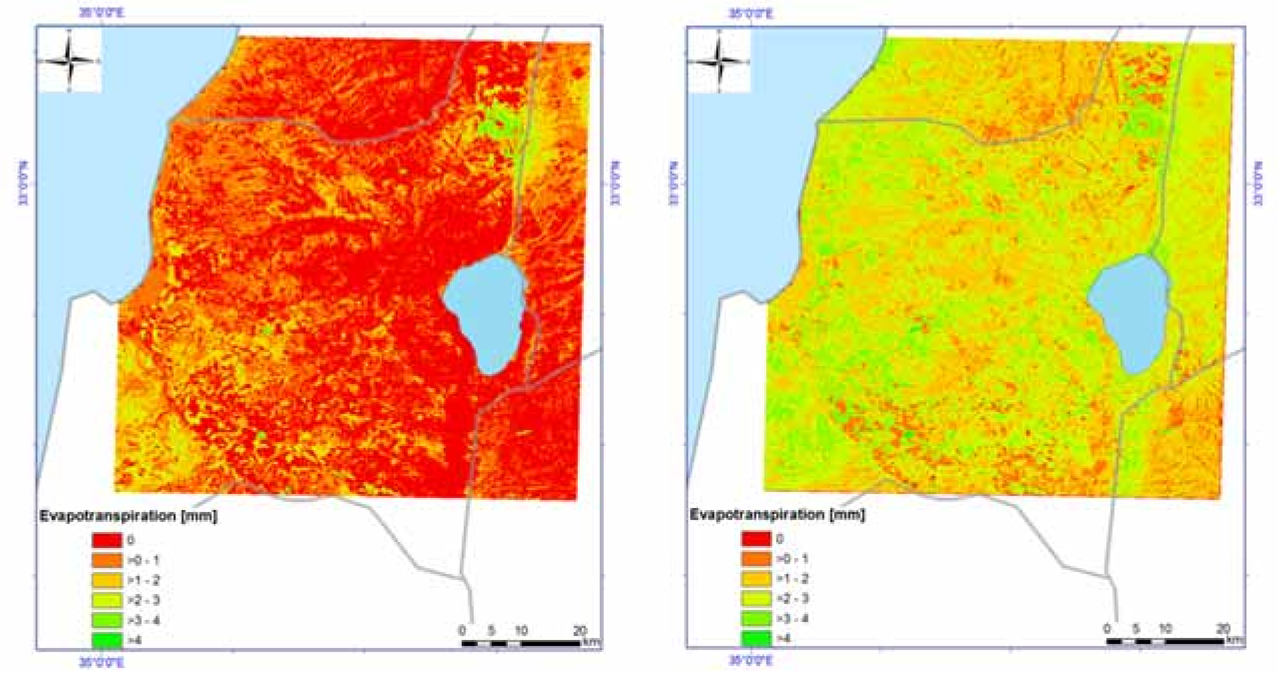


Figure 12.9: Evapotranspiration derived with the gradient method (left) and the hot-cold pixel approach (right) for 21. March 2001.

The rate of actual evapotranspiration (ET) was derived with two methods: 1) the gradient method and 2) the hot-cold pixel approach. In the former method the evapotranspiration is computed as an integral over 24 hours by considering the net radiation, the soil heat flux and the sensible heat flux. To calculate the net radiation for each pixel, the shortwave and longwave radiation have to be known. The estimation of global radiation values for each day is based on a digital elevation model (grid size 90 m). Surface orientation, shading and limitations of horizon are considered for the pixel-wise computation of the global radiation values. The short-wave radiation balance was derived by using short-wave albedo and spatially interpolated global radiation. The calculation of the long-wave emission of the surface was based on Stephan-Boltzmann law. The conversion of land surface temperatures to mean daily surface temperatures was performed by using an algorithm of LAGOUARDE & BRUNET (1993). The soil heat flux was defined as a fraction of global radiation.

In the latter method, the hot-cold pixel approach, the near-surface vertical air temperature difference can be regarded as the core of the sensible heat flux determination. A linear regression is executed between the two pairs of hot and cold pixels. The hot pixel is an area where the land surface temperatures reach its maximum over bare soil or similar surfaces. At this point, the latent heat flux is regarded to be zero. On the contrary, the cold pixel is found over wet surfaces like irrigated fields. There, the assumption is made that the sensible heat flux is zero. The estimation of the air temperature differences is done by using the values of net radiation, soil heat flux and aerodynamic resistance to heat transport at the hot pixel.

When comparing the gradient method and the hot-cold pixel approach, the results show that evapotranspiration is generally lower with the gradient method than with the hot-cold pixel approach. Figure 12.9 shows the derived evapotranspiration for the 21 March 2001, the figure is also representative for other dates. Comparable high ET rates are shown in irrigated agricultural regions like Hula Valley and Jesreel Valley. Both methods calculate high ET rates for this regions but the hot-cold pixel approach seems to be more exact. Mountainous regions that are covered with forest or shrubs also exhibit high ET rates. Less vegetated areas are characterized by lower rates of actual evapotranspiration. In these regions, the hot-cold pixel approach shows a more differentiated and detailed picture compared to the gradient method.

A pixel-wise comparison of the remote sensing calculations shows a shift due to the minimizing algorithm of the hot-cold pixel approach (which causes higher ET rates) and the limitation of fixed coefficients used by the gradient method. A linear relationship exists between both approaches with R^2=0.38 and RMSD=0.34.

Because of the different spatial scales, comparisons with TRAIN were done by selecting 40 areas which represent different land use types. Furthermore, the LANDSAT data were aggregated to a resolution of 960 m. This allows the plotting of the remote sensing approach against those of the hydrological model on pixel scale (Fig. 12.10). The comparison of the results from TRAIN simulations and the gradient method indicate no accordance (R^2=0.02, RMSD=0.53). However, the results of the hot-cold pixel approach match much better with the values calculated by TRAIN (R^2=0.23, RMSD=0.68).

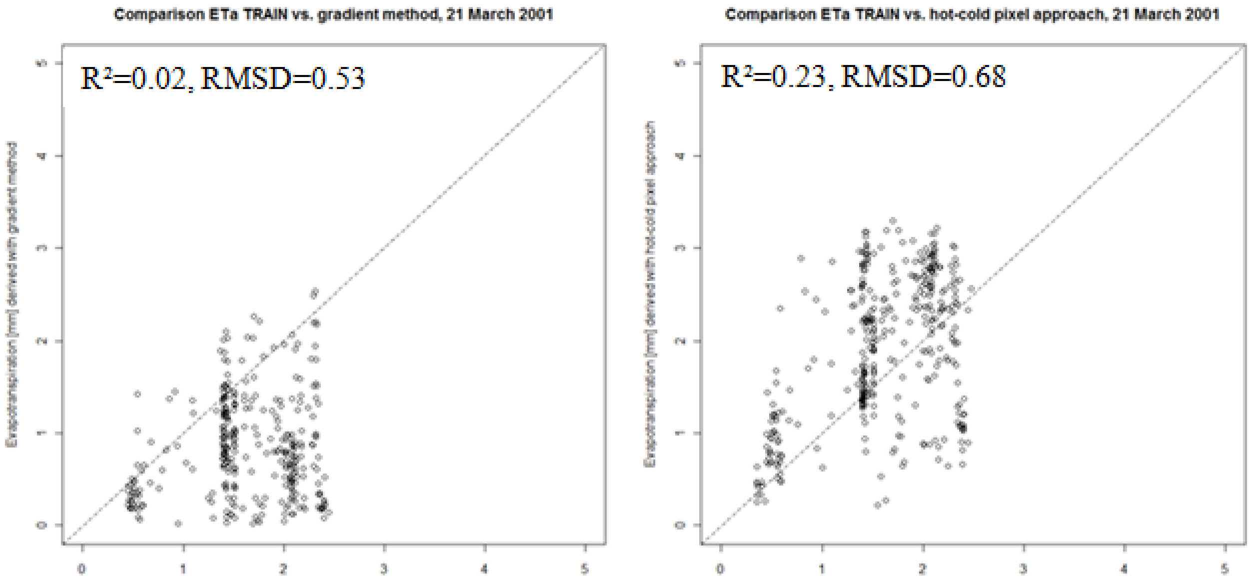


Figure 12.10: Evapotranspiration [mm] derived with the gradient method (left; y-axis) and the hot-cold pixel approach (right; y-axis) in comparison to the results from TRAIN (x-axis), given here for 21 March 2001.

12.2.2.4 Ecohydrology of a semi-arid forest – contribution of Weizmann Institute

Forests in dry regions use most of the available precipitation water, limiting both runoff and recharge. The forest transpiration (T) water is used mainly for carbon sequestration, but this is associated with large losses to soil evaporation (E), accounting for a significant part of total ET. However, E greatly varies with conditions, such as between shaded and exposed areas. We quantified the links between factors such as canopy structure and precipitation patterns, and the losses to E, using pine afforestation in Israel as a model system.

The seasonal trend in E had a reoccurring pattern defined by climatic conditions. Peak rates were measured during early and late winter (combination of high soil water content and high temperatures), and lower rates were measured both during mid-winter (low temperatures and low radiation) and summer (low soil water content). Flux partitioning was controlled by soil moisture partitioning to different depths. Figure 12.11 shows that the seasonal trend in E (top panel, diamonds) correlated with that of soil water content at the upper soil layer (θ5 cm, top panel, line). The seasonal pattern of tree transpiration (T, bottom panel, diamonds) differed from that of E and correlated with soil water content in the main root zone (θ15 cm, bottom panel, line).

Water use efficiency of the ecosystem (WUEe, ratio of carbon assimilation to water loss) was affected by precipitation patterns more than by total precipitation. P is annual precipitation while P30/P is the contribution of the large storms (≥ 30 mm) to P. Larger storms infiltrate deeper and are less susceptible to E. They increase moisture at the root zone and therefore selectively improve conditions for the trees.

The hydrological budget of Yatir (Table 12.3) shows that ET balance most of precipitation (P). ET was partitioned into canopy interception (EI), transpiration (ET) and soil evaporation (ES) showing the importance of E in this system. Soil moisture storage (Δθ) and adsorption (A) during the dry summer were measured but canceled out on annual time scale. Losses to runoff (Q), subsurface flow (F), and drainage below the root zone (D) were small.

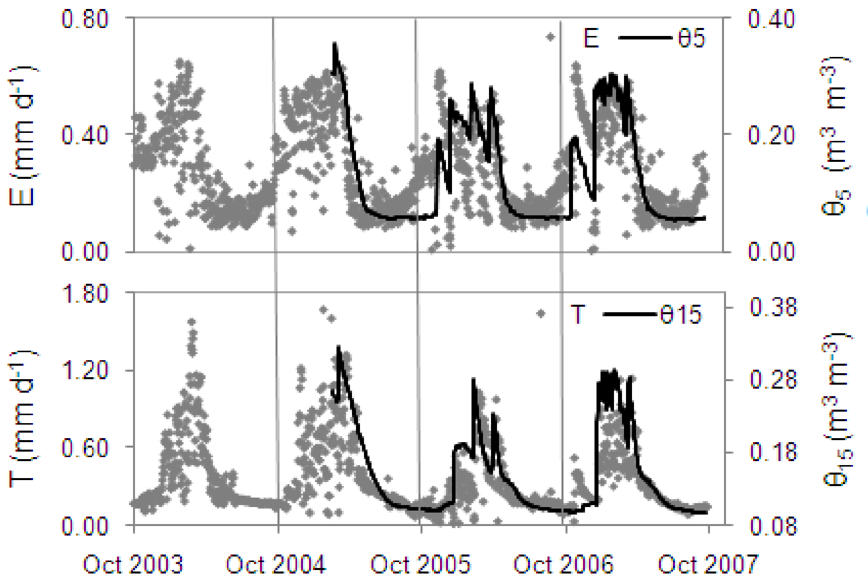


Figure 12.11: Fluxes of transpiration T and soil evaporation E versus soil moisture recordings at different depths. Data from Yatir forest.

Table 12.3: Hydrological budget of the Yatir forest (in mm yr^{-1}).

	P	ET	E_T	E_S	E_I	Δθ	L
2003/4	231	235	134	99	27	-8	4
2004/5	377	343	156	112	39	11	23
2005/6	224	227	111	93	26	-10	7
2006/7	308	263	115	106	33	-1	46
Avg.	285	267	129	103	31	-2	20
SD	72	53	21	8	6	9	19

Canopy cover increases with age or management, increasing leaf and shaded ground area, in turn reducing E and increasing T. This influences the “excess” water available for runoff, re-charge, or for planting more trees. Under current precipitation, P, the forest is unsustainable above canopy cover of ~65% when E, T and interception add up to more than P. Such analysis along the climatic gradient in Israel can provide a useful management tool both for forester (forest density, carbon sequestration potential) and hydrologists (controlling runoff/consumption/recharge).

Recent simulations based on allometric equations and solar altitude for the Yatir ecosystem indicated that increasing canopy cover from an undeveloped canopy (10% cover) to a fully developed canopy (100% cover) could decrease soil evaporation, E_s, from 150 to 86 mm yr^{-1}, potentially improving tree water usage. However, according to our assessments, above 65% canopy cover the forest will not be sustained under the current precipitation regime, due to the increasing demand of tree water use with canopy cover (and to a lesser extent, the increase in intercepted precipitation). The results demonstrate, first, the importance of high-resolution E measurements for forest management in water-limited environments; second, that the current forest density likely provides some excess moisture for tree transpiration that can be critical for forest survival in the face of predicted climate change for this region. Alternatively, reducing tree density will create excess that can be channeled / harvested to other purposes. These tradeoffs (see Fig.12.12) will be further explored.

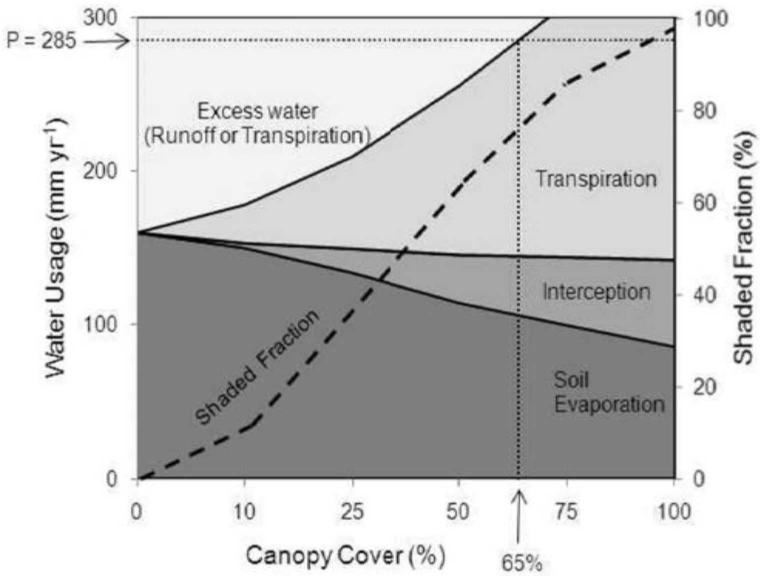


Figure 12.12: Relationship between canopy cover, shaded fraction and forest water usage for the Yatir forest. The different components strongly influence the magnitude of the individual evaporation components as well as the formation of excess water.

12.2.2.5 Agricultural Survey based on Satellite Imagery Analysis and the Examination of Test Sites – contribution of Heidelberg University

A survey of agriculture in Israel was conducted during a Master thesis (Henning Götz) at Heidelberg University. The objective was to improve the input data used for modeling the spatially and temporally varying patterns of agricultural irrigation water demand with TRAIN. More specifically, this input data related to agriculture are (1) the distribution of agricultural areas throughout the country; (2) the number of growing cycles per year; (3) the types of crops cultivated and (4) whether and when these crops are irrigated in the course of a year. In order to update or gather this information, medium-resolution satellite imagery was analyzed; two selected test sites in Israel were examined (and partly mapped via GIS) and Israeli key persons engaged in agriculture (representatives of the Ministry of Agriculture and Rural Development's Extension Service and MIGAL Galilee Technology Center; farmers from the visited kibbutzim/moshavim within the test sites) were interviewed on prevailing cropping and irrigation practices in Israel.

So far, the TRAIN model has been run based on relatively coarse (1000 x 1000 m) land cover and land use information and summer cropping has not been accounted for due to the lack of reliable data. In this analysis, two Landsat-scenes of Israel with a spatial resolution of 30 x 30 m, one taken in March and the other in late June 2002, allowed for a much more precise identification of agricultural areas throughout the entire country and the differentiation of these areas according to the season when crops were grown on them. The results show that an area of about 4000 km² was devoted to agricultural usage (fields and orchards), this matches well with the data provided by the Israeli Central Bureau of Statistics (CBS) for the same year (4300 km², including areas for agricultural infrastructure; CBS Statistical Abstract 2012, Table 19.1). Out of these 4000 km², 90 % were open fields and 10 % orchards, or 80 % and 20 % according to the results of this study and CBS data, respectively. The analysis revealed that 57 % of the fields were cultivated during winter/spring, 28 % during summer, 6 % during both seasons and 8 % left idle for the whole year.

In TRAIN, major crop types that are taken into account for different coefficients for transpiration include orchards, cereals, vegetables and any other kind of open field crops. However, information regarding double cropping and detailed irrigation practices have been lacking. The field trip to Israel in March 2012, i.e. the examination of the two test sites (Hula Valley in northern Israel and the area around Ofakim in the northern part of the Negev) and the interviews revealed that most commonly, shifting cultivation is practiced with wheat, potatoes, peas and carrots being the major winter crops and corn, cotton and tomatoes, peppers and herbs the dominating summer crops. The irrigation patterns are complex and differ from crop to crop with regards to the irrigation interval and period, as well as the amount of water given. All crops except wheat (which is only grown during the winter season and usually irrigated just upon seeding) appear to receive irrigation water during both growing seasons, i.e. not only in summer when irrigation is mandatory for growing any kind of crop, but also from autumn to spring.

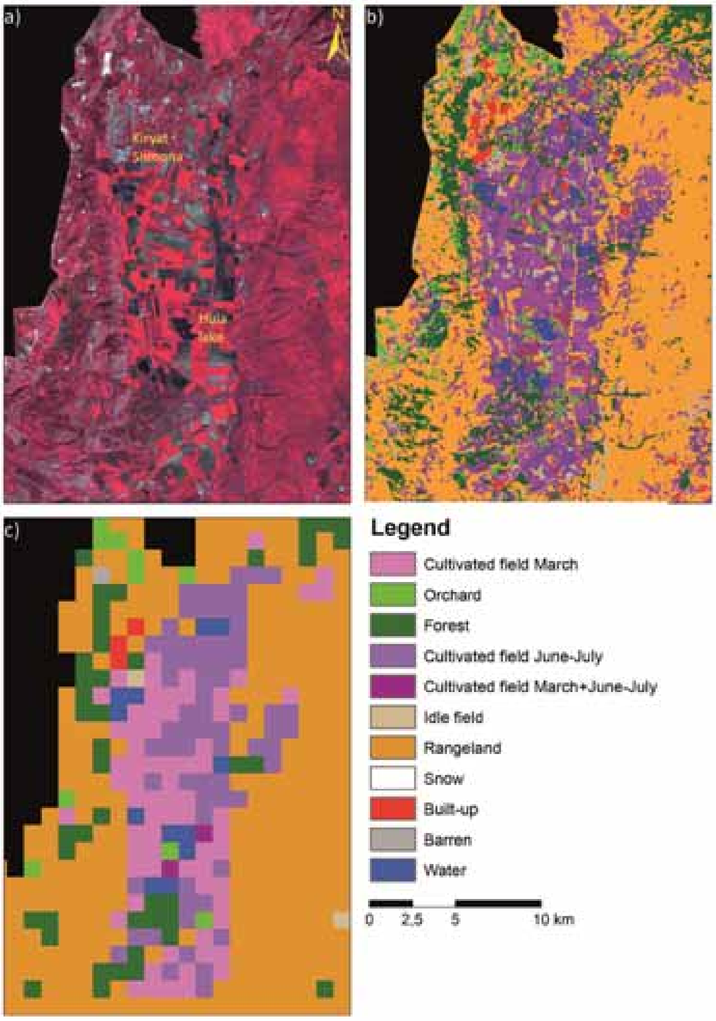


Figure 12.13: Map samples of the Hula Valley in Northern Israel and parts of the Golan Heights: a) Landsat false-color composite of the area from March 2002; b) land cover/ land use classification in 30 m spatial resolution and c) resampled to 1000 m, i.e. the original TRAIN resolution.

12.2.2.6 Susceptibility of land erosion – contribution of Heidelberg University

MENZEL et al. (2009) carried out an analysis regarding the impact of land-use and land-cover changes on water availability in the Jordan River Region. For two scenarios, a notable increase in simulated water availability for major parts of Jordan occurred. This has been correlated with a projected increase in grazing land. In TRAIN, the category grazing land is similarly treated as shrub land, but with a lower LAI. That implies lower transpiration rates which lead to higher amounts of water availability (or, to be more precise, in surface runoff) simulated by the model. However, MENZEL et al. (2009) reported that the effects of grazing require better reproduction in TRAIN, for example with a description and quantification of the susceptibility of grazing land against erosion. Therefore, a module has been developed which shall help to assess the erosivity of the landscape as a consequence of changes in precipitation, land-use / land-cover, and water availability (surface runoff). The determination of erosivity is based on the Universal Soil Loss Equation (USLE), but the rainfall factor has been adopted from the MedREM-model (Rainfall Erosivity Model for the Mediterranean Region). The necessary slope length and inclination factors have been determined from GIS analysis. Since the spatial scale of TRAIN applications is based on 1x1 km grid cells, it is not envisaged that the erosion risk of the landscape will be determined in detail, but it is graded into three different classes (high, moderate, low). The erosion module will be deployed in combination with TRAIN simulation runs.

12.2.3 Hydrological drought analysis

12.2.3.1 Drought in the Eastern Mediterranean – contribution of Mu'tah University

Drought indices are useful tools in identifying and predicting many environmental and natural hazard features such as dust storm frequency and intensity, wind erosion, agricultural yield, water availability and stress, grazing conditions, and many other economic and environmental issues. Within the framework of GLOWA Phase 3, we identified and evaluated several drought indices (Palmer, SPI, and water budgeting methods) using daily time steps. Figure 12.14 shows soil moisture as presented by Palmer method for three locations with a distinct climate gradient: Amman airport (aridity index ~ 5), Rabbah (aridity index ~ 3.8), and Irbid (aridity index ~ 2.7).

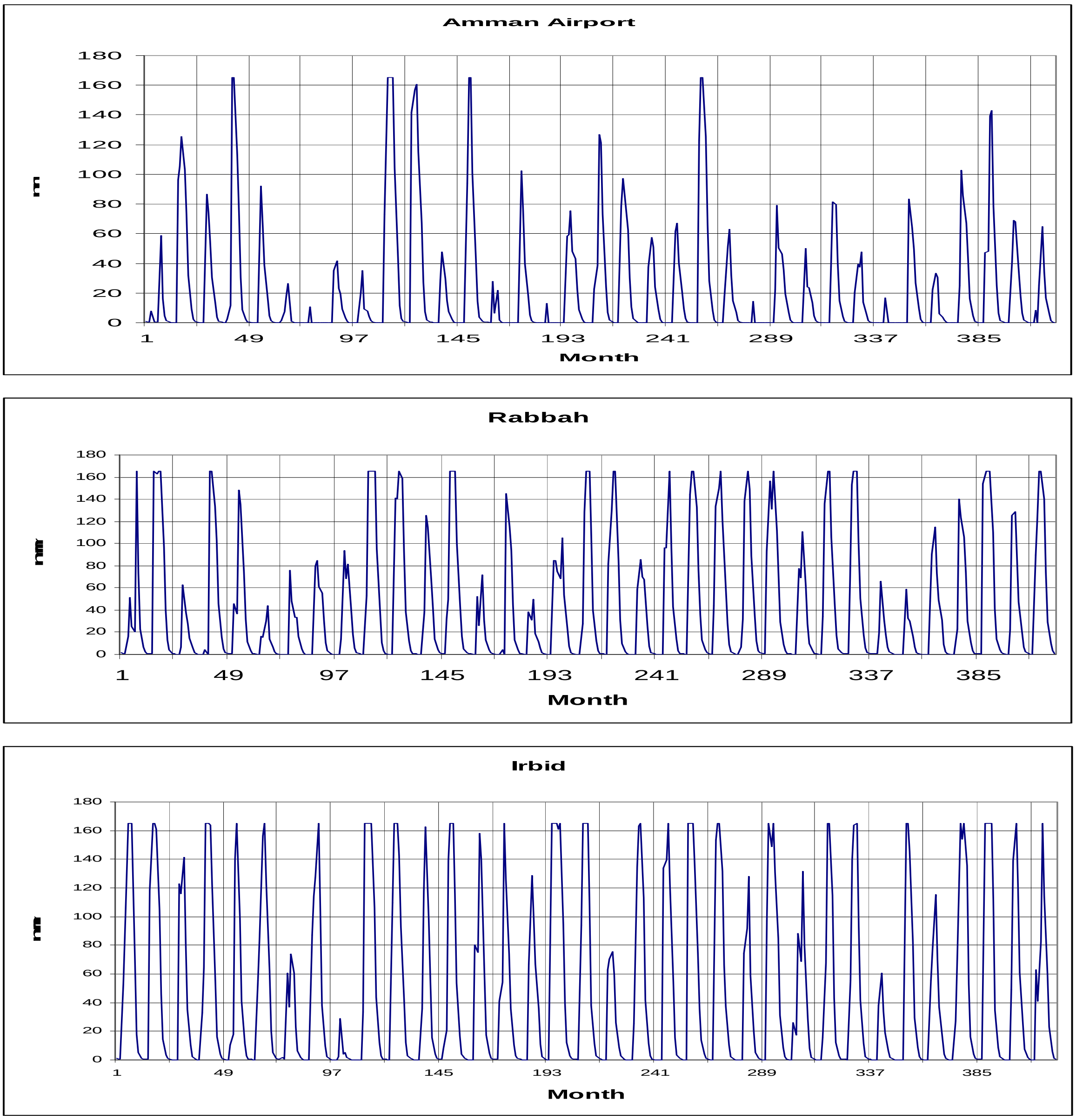


Figure 12.14: Annual soil moisture curves for three locations during the period 1970 through 2005 as calculated by the Palmer procedure.

The Palmer method was compared to a daily time step and results are congruent (Fig.12.15). Results indicate a close agreement between Palmer results which is based on monthly climatic data and a more elaborate model which takes into account several soil layers, plant transpiration coefficient, root distribution, and albedo changes. It can be concluded that the Palmer method, although it has a very coarse temporal resolution compared to daily moisture budgeting, provides reliable results and can be used successfully to identify agricultural drought.

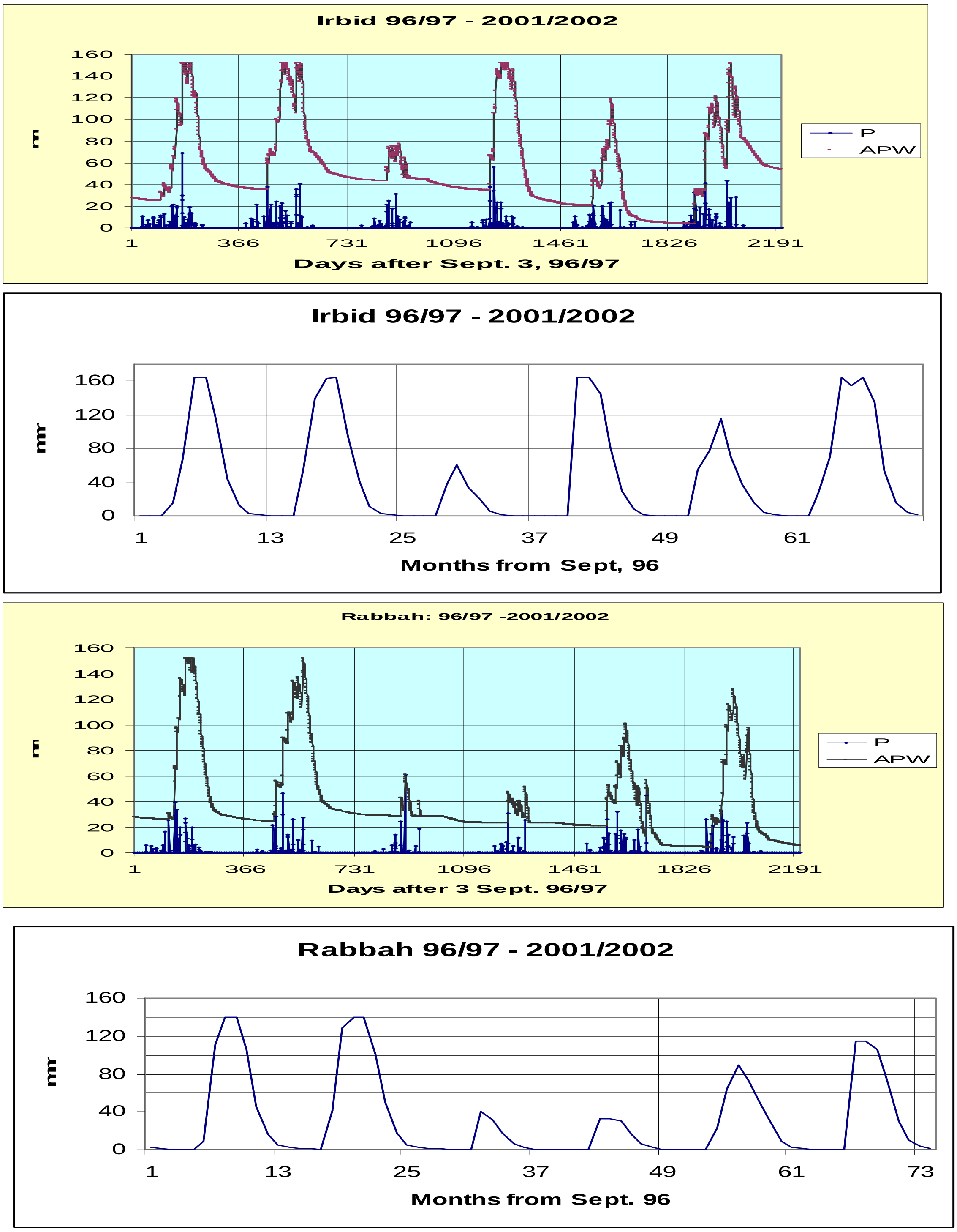


Figure 12.15: Comparison between soil moisture as calculated with the Palmer procedure and with a daily time step. Daily precipitation is included in the daily method.

We also compared Palmer with an SPI procedure to investigate the matching between the two and the possibility of using one in lieu of the other. Figure 12.16 displays the linkage between Palmer Drought severity Index and SPI method.

To give authenticity to modelling results, we carried out experimental investigations of soil moisture in a field crop during the growing season 2010-2011. Soil moisture was monitored using Decagon devices. Figure 12.17 shows a sample of model performance in predicting soil moisture at 15 cm beneath the surface.

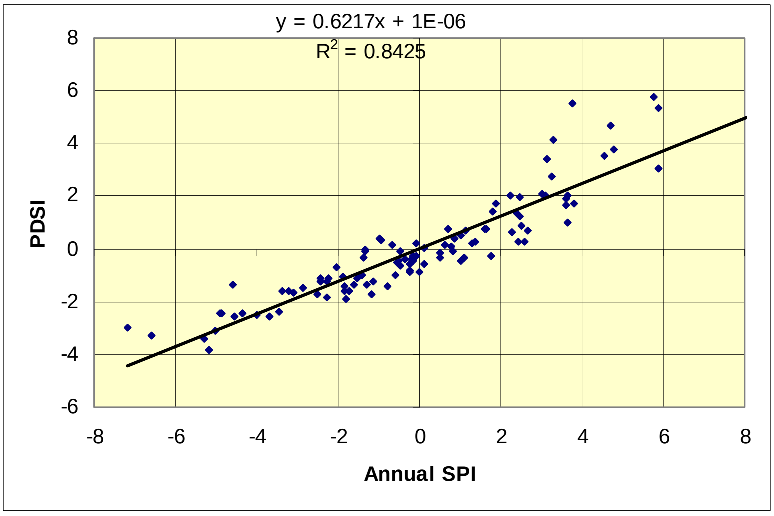


Figure 12.16: Comparison between SPI and Palmer drought index for three stations in Jordan.

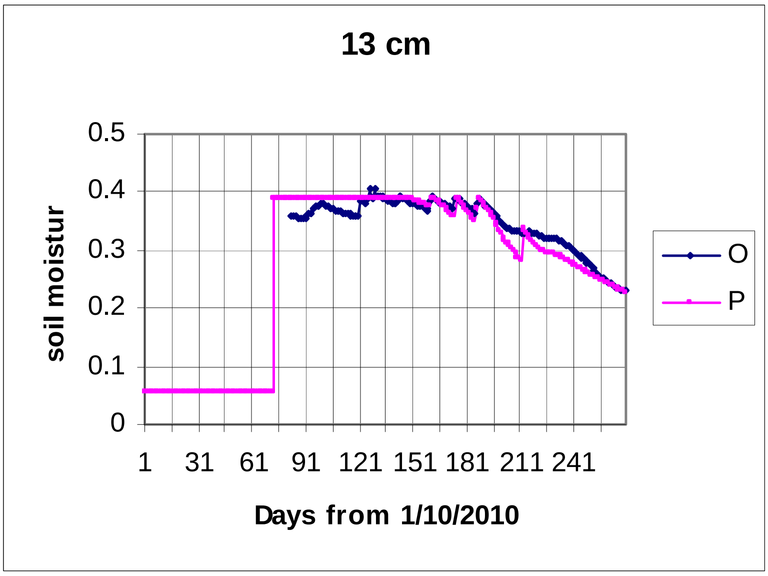


Figure 12.17: Predicted (pink) and measured (blue) soil moisture at 13 cm in a typical clay soil planted with wheat during the growing season 2010-2011 (October 1, 2010 to June 28, 2011).

12.2.3.2 Hydrological drought analysis – contribution of Hebrew University

Drought analysis was conducted in two different aspects: 1) definition of meteorological and hydrological droughts based on rain, stream flow and spring discharge data records, and, 2) synoptical classification of drought conditions.

Meteorological Droughts

After the examination of different methods, the Standardized Precipitation Index (SPI) has been chosen for identification of meteorological droughts. Based on the SPI and with consideration to the spatial aspect, the following definition for meteorological drought was developed: If two out of the three rain gauges (Avney Eitan, Har Knaan and Golan Exp. St.) have an SPI value below -1 (moderate drought), and provided that the third rain gauge has a negative SPI value as well, the year is defined as a meteorological drought year. With this method, the years identified as meteorological drought years were: 1988/1989, 1998/1999, 2000/2001 and 2007/2008 (the analysis period is 1987/1988-2007/2008). Figure 12.18a presents the three rain gauges index results, where the identified meteorological droughts are marked.

Hydrological droughts in streams

The hydrological drought identification is based on the Standardized Runoff Index (SRI), which calculation procedure is identical to SPI calculation, but implemented on the runoff data. In an equivalent form to the meteorological drought definition, a year is defined as a hydrological drought year when two out of the four streams (Meshushim, Yehudia, Daliot and Samek) have an SRI value smaller than -1, and provided that the two additional streams have a negative SRI value as well. The years identified as streams hydrological drought years are 1989/1990, 1990/1991, 1998/1999, 2000/2001 and 2007/2008. The indices calculations, both at the rain gauges and at the streams, were implemented by fitting gamma distributions. The Gamma distribution was chosen based on fitting examinations of four theoretical distributions – Gamma, Pearson type 3, Log normal and GEV. Figure 12.18b presents the four streams index results, where the identified hydrological droughts in streams are marked.

Hydrological drought in springs

The spring data series has a low time resolution, moreover, in part of the springs the data contains gaps. In order to enable the implementation of the index calculation procedure (implemented for rain gauges and streams) in springs, quality control procedures have been made. This includes tracking of change points and measurement procedure check. At the springs analysis a distinction between two spring types, the regional aquifer springs and the perched springs, has been made. In purpose to study about the hydrological response time in the different spring types, the correlation between annual precipitation depth and annual spring flow volume, while shifting the hydrological year 'time window' (at springs) has been examined.

Comparing meteorological droughts and streams hydrological droughts

The comparison of meteorological and streams hydrological droughts (Fig. 12.19) indicate that:

- In general there is a match between the meteorological and hydrological droughts; however, there are hydrological drought years not identified as meteorological drought years and vice versa
- In streams, it can be seen that in the lower indices range there is no meaningful difference in flow volumes. On the other hand, at rain gauges a noticeable increase of annual precipitation depth with index value increase can be seen in the lower range indices. Hence, meteorological drought years show sensitivity of rain amount to SPI value while hydrological drought years do not show such sensitivity to SRI value and are associated with narrow range of streamflow volumes

- The explanation for the similarity in streamflow volumes at the hydrological droughts is the “threshold behavior” of streamflow; under a certain amount of annual precipitations there is no significant contribution to base flow from flood water.

Synoptic classification of droughts over Israel

Daily rainfall data from 8 gauges in central and northern Israel were used for this research. Daily measurements were available for more than 3 stations between the years 1939 to 2008, while full data from all 8 stations were available between 1962 and 2003. A dry period was defined as at least 10 sequential days with less than 0.1 mm rain in all working stations. Periods in which less than 3 stations worked were not used. Dry periods were included in the current analysis if they started or ended in December, January or February. The synoptic data were taken from the NCEP/NCAR reanalysis as daily maps for the period of 1948-2010. Anomaly maps were produced for each period, in order to identify the synoptic pattern. 73 dry periods were found in this method, between the years 1940 to 2008. The longest dry period was 26 days, and the average was 1.3 days. The synoptic patterns were divided into 3 categories (Fig. 12.20); each period was assigned to one of the categories

- Siberian high: high pressure accumulates over Europe. These periods are characterized by cold temperatures and dryness in the East Mediterranean and high temperatures in Europe
- Sub-tropical high: high pressure in the east Mediterranean “pushes” the cyclones to the north, leaving the area dry
- A Trough in the Centre or West Mediterranean and a ridge in the East Mediterranean cause the eastern Mediterranean to be dry and the center or west to be wet

In the analysis the Empirical Orthogonal Function (EOF) method was applied. With the method the variance of a single variable is examined spatially, so that areas with high variability are marked. Every EOF’s are orthogonal, differs spatially. Linear combinations of the EOF’s can be used to extract “Rotated EOF”, these are very similar to the EOF’s, although not orthogonal. The advantage of the rotated EOF’s is the better explanation of inter seasonal variability. The number of EOFs were chosen so that they together account for 80% of the inter-seasonal variability of the geopotential height at 500 mb. The EOFs were produced using the Ingrid Data Analysis Language in Columbia University (Bar, PhD Thesis, 2010).

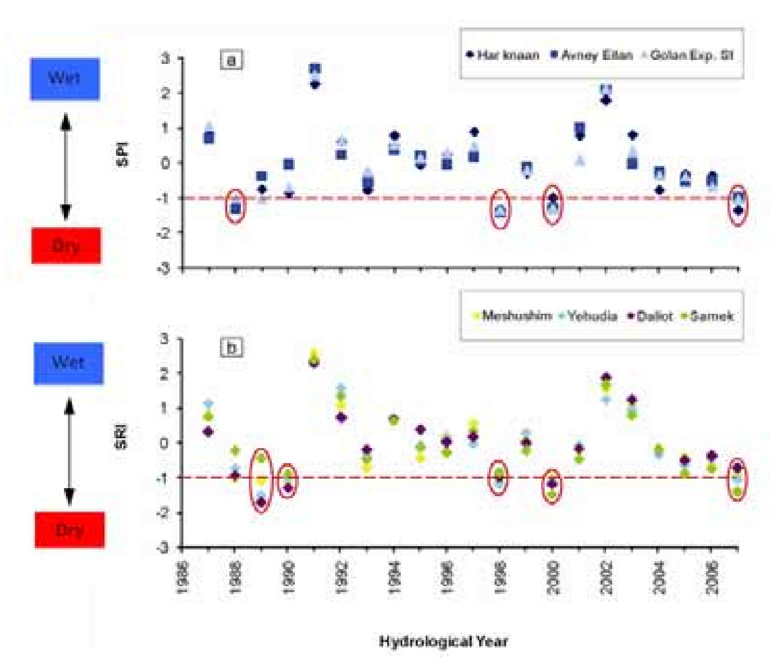


Figure 12.18: (a) SPI results for the 3 rain gauges; (b) SRI results for the 4 stream stations. The -1 drought threshold is indicated and drought years are marked by red circle.

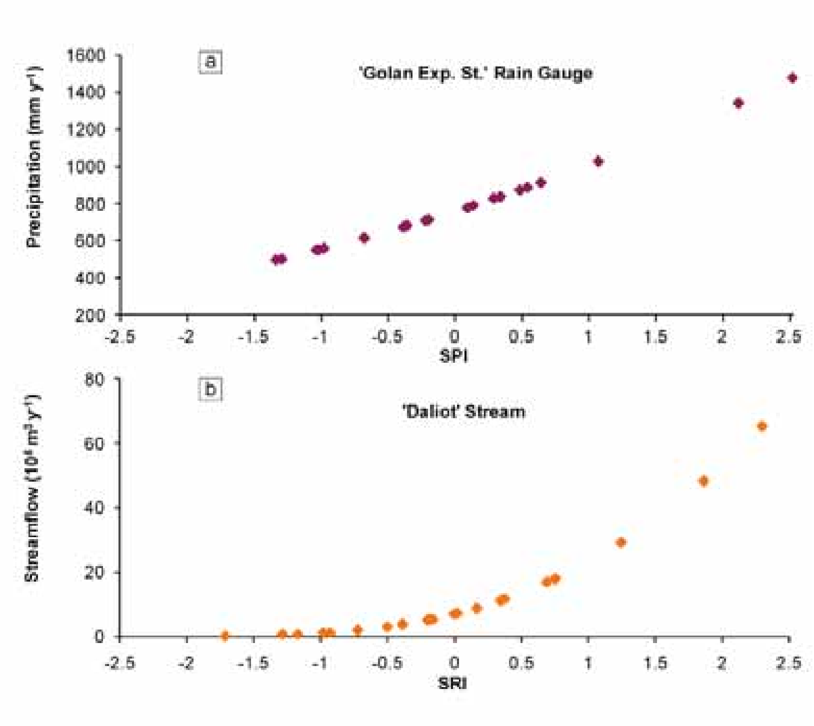


Figure 12.19: (a) Precipitation depth as a function of SPI for the Golan Exp. St. rain gauge; (b) Streamflow volume as a function of SRI for the Daliot stream station.

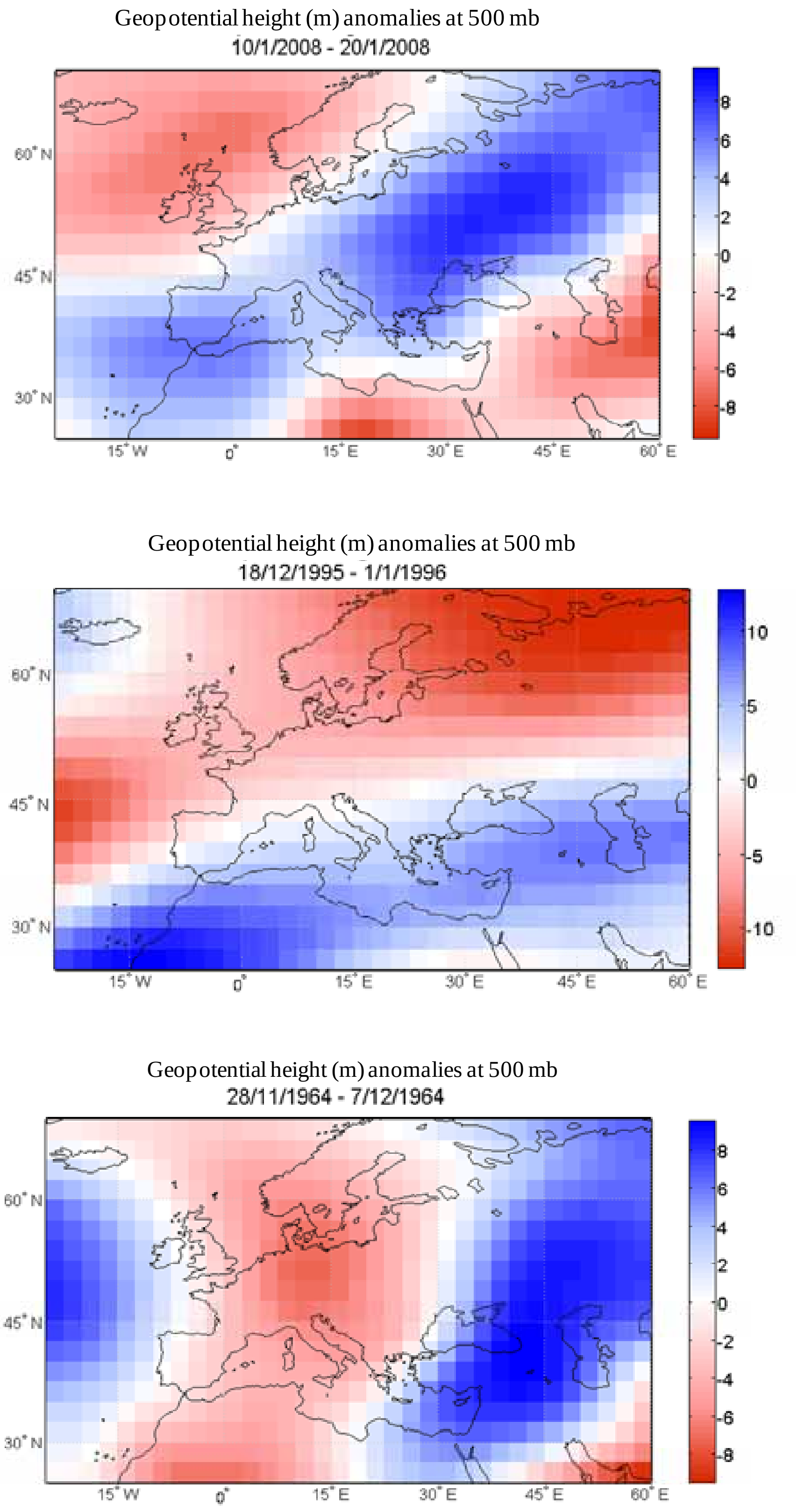


Figure 12.20: Examples of the three synoptic pattern categories: top: Siberian high, middle: sub-tropical high, bottom: a trough in the centre or west Mediterranean and a ridge in the east Mediterranean

12.2.3.3 Hydrological drought analysis – contribution of Heidelberg University

Drought characterization

The Standardized Precipitation Index (SPI) has been used to assess agricultural drought within the entire JRR. This has been done on a 1x1 km spatial scale as well as according to land-use. SPI is based on precipitation data and calculates the index dependent on the deviation from the long term mean precipitation. The index suitability for the region was shown by an existing correlation with the Normalized Differenced Vegetation Index (NDVI) derived from remote sensing. With additional correlation analysis also the time lag of which vegetation responds to the index could be determined.

SPI was applied on monthly precipitation and it was calculated for three climate scenarios based on the IPCC emission scenario A1B delivered from Tel Aviv University and IMK-IFU.: ECHAM5 RegCM3, ECHAM5 MM5 v3.7 and HadCM3 MM5 v3.7. The current conditions (1961-1990) were compared to future ones (2031-2060) by deriving the statistics like; drought- frequency (number of droughts per decade), -duration (months) and -intensity (moderate, severe and extreme). The statistics were calculated for three precipitation regions, referring to arid, semi-arid and sub-humid conditions. Although the natural precipitation in the arid zone is not enough to sustain rain-fed agriculture, the statistics are still valuable for other than the agricultural sector.

The average length of current droughts (1961-1990) was 8 months and 23 days, 8 months and 29 days as well as 9 months and 12 days in the sub-humid, semi-arid and arid zone, respectively (Fig. 12.21a). The future droughts (2031-2060) are projected to be prolonged with about 1.5 months. The longest increase is expected to take place in the arid region.

The frequency of moderate droughts is predicted to slightly decrease, whereas the number of moderate and extreme droughts is expected to increase over the whole region (Fig. 12.21b). The frequency of extreme droughts is expected to be doubled in the future.

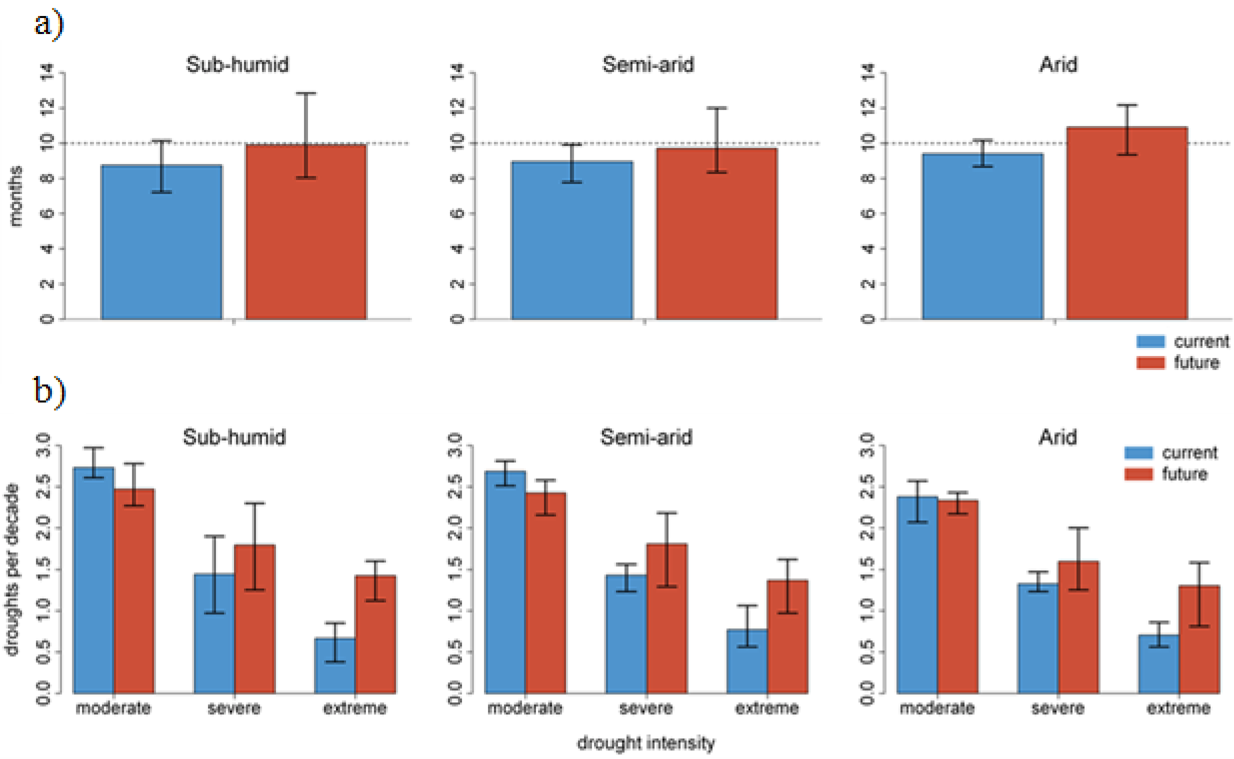


Figure 12.21: The length (a) and frequency (b) of current and future droughts. The bars show the average value derived from three climate projections and the error bars refer to the most and least severe projection.

Simulating large scale irrigation water demand during drought

The Irrigation Water Demand (IWD) is simulated by TRAIN. The IWD during the longest current and future drought (20 and 25 months, respectively) was chosen as an indicator of the drought vulnerability of the region. The mean annual IWD during the entire reference period 1961-1990 was 80 mm. Over the whole study region this corresponds to a water amount of 1810 million m^3. The annual mean IWD during the drought conditions were simulated to be 122 mm (2770 million m^3) and 174 mm (3950 million m^3) for the longest current and future drought, respectively (Fig. 12.22). The results show that the region is expected to become more vulnerable to droughts.

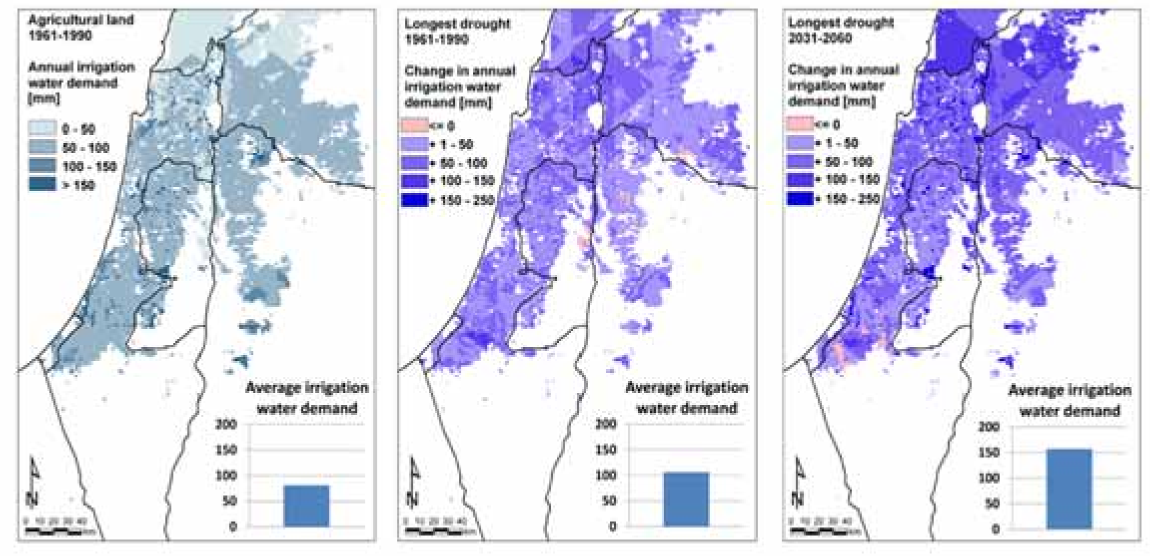


Figure 12.22: Simulated mean annual irrigation water demand for the years 1961-1990 (left) as well as during the longest current (middle) and longest future drought (right).

12.2.3.4 Regional drought analysis – contribution of Freiburg University

As shown above, drought seasons are most critical for water management in the region. The seasonal map of generated overland flow shows a spatial variable drought impact (Fig. 12.23).

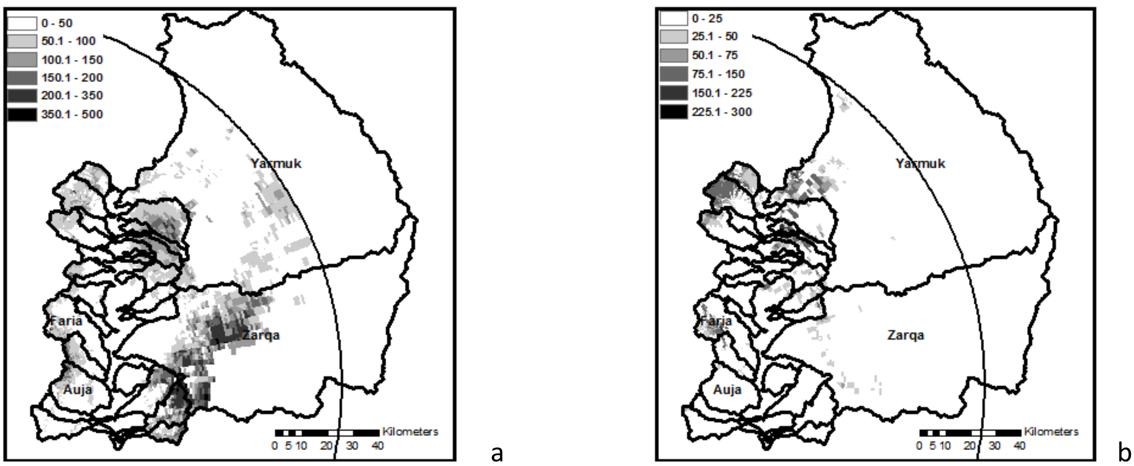


Figure 12.23: Overland Flow generated in the LJRB for a) the average and b) drought season. Areas outside a 150 km range around the location of the rainfall radar (Tel Aviv airport) are neglected due to uncertainties in rainfall measurements.

Seasonal wadi runoff values - these include channel transmission losses - illustrate the variance between the average and the drought season (Fig. 12.24) and the fact that the historical drought season has a different impact on the runoff of the different sub-basins of the LJRB.

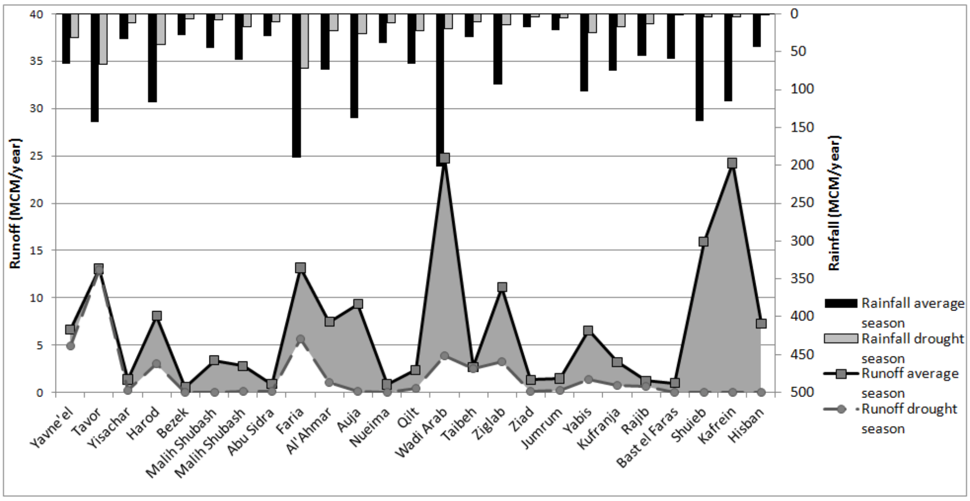


Figure 12.24: Basin-wide rainfall and simulated wadi runoff in the average and drought season for the 25 sub-basins

For all 4 SAS scenarios, changes in water balance were calculated, based on changed land-use maps (output from LandShift) for 2050 and the rainfall input from historical rainfall. The total water balance of the drought season did not show large changes also when the two most extreme SAS scenarios are simulated. However, the distribution of water between the elements of the water cycle changes, if different land use types are considered (Fig. 12.25).

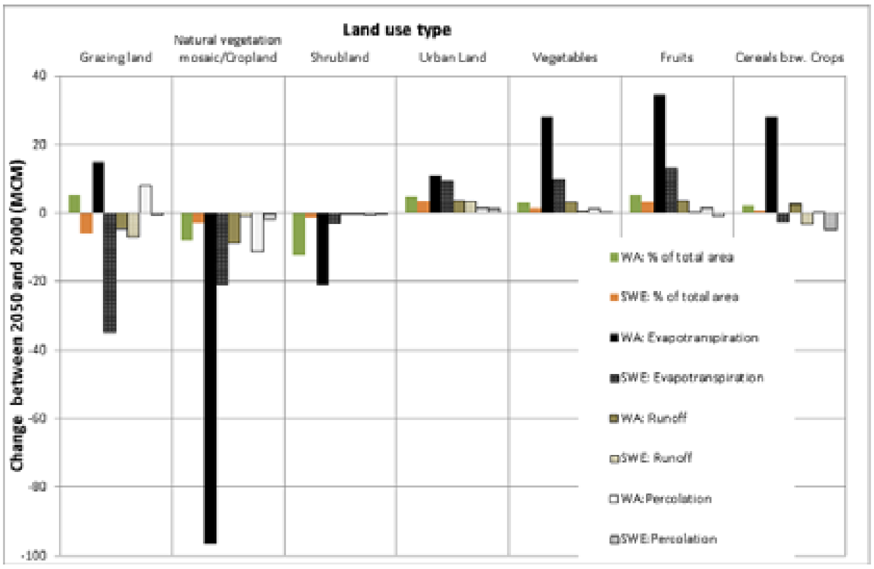


Figure 12.25: Water balance components (mm) for rainfall during the drought season (1998/99) simulated for different landuse types for two selected SAS scenarios (defined by LandShift): “Willingness and Ability (WA)” and “Suffering of the Weak and the Environment (SWE)”.

12.3 Discussion and conclusion of scientific highlights and outlook

A high variety of methods have been applied to address the impact of environmental change on the water resources in the JRR. Several models and methods have successfully been developed and set up for the regional conditions. Based on data from climate stations and remote sensors, model validations have been conducted both on the point- and the large scale, respectively.

With calibrated models, future conditions have been addressed by applying climate scenarios delivered by subproject 4.1 (Chapter 11). The results show a clear hydrological response to the changing climate; with decreasing rainfall and increasing temperatures, the water resources are declining. It is shown how the evapotranspiration is expected to increase (due to higher temperature) and that the water availability is expected to decrease with up to 30%. As a further effect of the changing climate, the irrigation water demand is expected to increase with up to 50 % (assumed that agriculture will be practised according to the same extension as today). Land-use changes are expected to further enhance a shift between the water balance components.

Strong focus has been on drought conditions. Both the Standardized Precipitation Index (SPI) and the Palmer Drought Index (PDI) have been applied. Their suitability has been approved, past drought years have been identified and the water balance components during the extreme weather event have been assessed. Furthermore, the synoptic systems associated with rainfall deficits in the region could be determined. Based on the climate scenarios, it has been shown that future droughts are expected to become both longer and more severe as a shift from moderate to severe and extreme droughts is expected to take place. The results are highly valuable for the water management in the region. It is also an essential base for a drought preparedness plan.

12.4 Applied value of results

Results regarding water balance components, irrigation water demand, synoptic system associated with droughts as well the duration- and frequency of droughts have been delivered. These are valuable for the current water management of the region. It is also essential to have a strategy to cope with future conditions, therefore several land-use and climate scenarios were applied. The results are valuable for sustainable water management of the region and relevant for several stakeholders and decision makers including; environmental institutions, the Ministry of Irrigation (Jordan), Ministry of Agriculture (Israel and Jordan) and the Ministry of Planning (Jordan). Practical usages of the results include to:

- estimate the amount of water that is available for human usages under normal- as well as abnormally wet- and dry conditions
- plan for the allocation of water for different sectors and regions
- identify regions with vulnerable rainfed and irrigated farmlands
- identify areas where the irrigation infrastructures have to be improved or the amount of irrigation has to be increased to sustain the production under a changing climate
- plan for double-cropping and the allocation of different crop types
- assess the impact of drought on water reservoirs and aquifers (water level & quality)
- use the results to furthermore assess the socio-economical impacts of drought

Furthermore, relevant results are delivered to WEAP which is used by the water authorities in the region. The results have been widely cited in the literature regarding climate change impacts on blue water availability, direct evaporation and green water fluxes in Jordan under current and future climatic conditions. The Hydrological Service of Israel begins to use the drought analysis in its yearly report. The tools could furthermore be used for an independent drought declaration by the governmental institutions.

12.5 References

Israeli Central Bureau of Statistics (CBS) 2012. CBS Statistical Abstract 2012. Available online at www.cbs.gov.il/engindex.htm. Last visited 29 October 2012.

Menzel L, Koch J, Onigkeit J & Schaldach R 2009. Modelling the effects of land-use and land-cover change on water availability in the Jordan River region. Adv. Geosci., 21, 73-80.

Lagouarde J P and Brunet Y 1993. A simple model for estimating the daily upward longwave surface radiation flux from NOAA-AVHRR data. International Journal of Remote Sensing, 907–926, 1993.

13 Rainwater harvesting, managed aquifer recharge, sustaining environmental baseflow

J. Lange, Freiburg University
L. Menzel, Heidelberg University
P. Berliner, J. Ben-Asher, Blaustein Inst. For Desert Research, Ben Gurion University of the Negev
Anan Jayyousi, Hafez Shaheen, Mohammad Almasri, Sameer Shadeed, An-Najah National University, Nablus
I. M. Oroud, Mu'tah University

13.1 Aim

Rainwater Harvesting (RWH) and Managed Aquifer Recharge (MAR) are promising new water sources for the LJRB and are regionally evaluated in this work package.

The aims are to:

- Derive rural RWH potentials on a small (slope) scale and thereafter to extrapolate the potentials to the entire LJRB. The approaches apply remote sensing data, GIS techniques as well as the TRAIN-ZIN model to produce RWH suitability maps.
- Address the potential of urban RWH by field measurements of rainfall upon rooftops and by handing out and evaluating questionnaires in an urban study area.
- Quantify the potentials of MAR - the controlled percolation of stream flow – in the LJRB by combining data on surface lithology, topography, urban areas and availability of water resources in GIS.
- Address the importance of Sustaining Environmental Baseflow (SEB) of the Lower Jordan River for the continuous flows from karstic springs under current and future climates.

13.2 Description of research

13.2.1 Material and methods

This sub project applies several methods and approaches to address rainwater harvesting, managed aquifer recharge and the sustaining of an environmental baseflow. Data have been collected in the field, hydrological models have been developed and applied and questionnaires have been handed out, collected and evaluated. To address future conditions, climate projections delivered from other sub-project have furthermore been applied. The approaches are described in detail in the results.

13.2.2 Results: Rainwater Harvesting (RWH)

13.2.2.1 Rainwater Harvesting (RWH) at the hillslope scale - contribution of Ben Gurion University

The basic objective of this sub-project was to develop a tool for designing a runoff harvesting system at the hillslope scale. The designed system is based on the characteristics of the three major components soil, rainfall and radiation (Figure 13.1). Both rainfall amounts and intensities affect runoff and infiltration volume. However, the properties of the soil are the major factors that determine infiltration rate and soil water storage capacity. Among these factors are, soil porosity, depth and hydraulic conductivity. Radiation is a major factor affecting the rate of evapotranspiration, and thus, the storage of water within the soil. When designing a runoff harvesting system, one should keep this in mind, especially if the system should support in situ agriculture. During GLOWA phase 3 the following tasks were accomplished:

- Characterization of rain storms under several statistical probabilities based on the existing rainfall database.
- Development of a runoff model based on Green & Ampt infiltration assumption at hill slope scale.
- Larger scale calculation of the spatial distribution of accumulated radiation during winter season.
- Small-scale radiation calculations (trench scale)

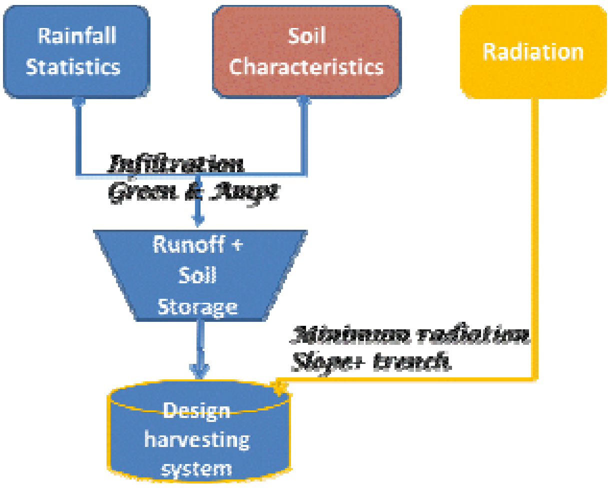


Figure 13.1: Schematic description of the research concept

Designing a rainwater harvesting system

Based on the results of the runoff simulation and the knowledge gained by the distribution of the accumulated solar radiation, the planning of the harvesting system may be done. First, since south facing slopes are exposed to higher radiation, measures to reduced evaporation may rely on designing trenched with higher ratio of height/width. However, one must also take into consideration the soil depth as a limiting factor to the trench's depth. In Figure 13.2 the main consideration are demonstrated in the runoff harvesting designed system. The calculations were done for the Sandy Loam (SL) and Clay Loam (CL) type of soils; for 200m' slope length; for a 10% probability synthetic rain storm. The soil depth along the slope was estimated as 30-80 cm (top to bottom) and the surface storage was evaluated according to the characteristics of the slope cover (from Shadeed, 2008). The following guide lines were taken:

1. For each slope-segment runoff was calculated, and according to the soil-depth and the initial soil moisture at that point it was decided if to harvest or not (if runoff was smaller than soil storage- Yes otherwise No).

2. According to the answer of previous step and soil depth, the trench dimensions were designed. For North and South facing slopes we have used the trench height/width ration of 0.5 and 1 respectively.

The designed system has the following characteristics:

- For CL soil the density of trenches along the slope is higher than foe SL soil due to higher runoff volume.
- The trenches' density on south slopes is higher but their dimensions are smaller, because of the limiting factor soil depth and trench height/ width ratio.
- As we go down the slope the trenches' dimensions are bigger and the distance between them is bigger. This is due to the increased water storage of the deeper soil.

The designed runoff harvesting configuration shown in Figure 13.2, is only an example, demonstrating the tool which we have developed. Also, no consideration was taken regarding the water demand of the plants. Under a real case this issue poses a heavy requirement that must be met.

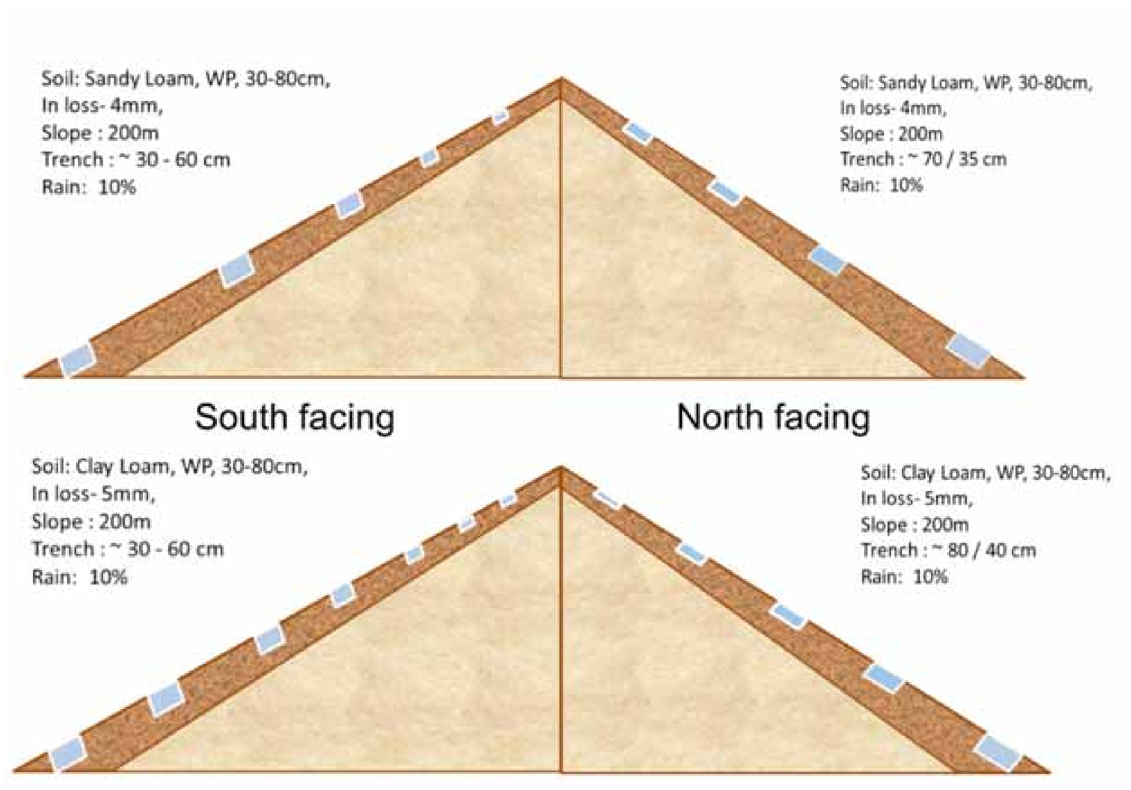


Figure 13.2: Slope harvesting system configuration for 10% rainstorm.

Scientific highlights and outlook: rural rainwater harvesting at the hillslope scale

1. At slope scale, runoff coefficient changes considerably with soil characteristics, rainfall intensity and temporal distribution. The results of the soil-infiltration model show that as expected, runoff coefficient is higher for clay soils than for sandy soils. This trend becomes more pronounced as the initial soil moisture increases. The initial soil moisture and the location of the rain-peak (along the storm), affect more dramatically runoff generation, at higher probability rainstorms. This means that that under lower rainfall intensities runoff may not develop at all if the rain-peak appears at the begging of the storm or if the soil is dry.

2. Incoming solar radiation during the winter season changes dramatically with slopes' orientation. The accumulated solar radiation during the wet season (Dec-Feb) is considerably higher on the south facing

slopes than the north facing slopes. This fact correlates with the higher vegetation cover on the northern slopes which are exposed to less solar radiation.

3. Trench configuration may serve as an efficient harvesting configuration due to the reduced incoming solar flux within the trench in respect to the outside. According to the calculations, even for shallow trenches, with height half the width, the radiation is reduced by 30% inside the trench.

4. The optimal configuration of a runoff harvesting system should be designed according to slope orientation, soil characteristics, rainfall distribution and plants water demand.

For clay soils the density of trenches along the slope should be higher than for sandy soils due to higher runoff volume. The distance between trenches on south slopes should be smaller and so are their dimensions, because of the limiting factor of soil depth and trench height/ width ratio. As we go down the slope the trenches' dimensions may become bigger and so is the distance between them. This is due to the increased water storage of the deeper soil.

13.2.2.2 Regional rainwater harvesting potential in Jordan - contribution of Mu'tah University

Experiments were carried out in Jordan to determine volumes of rainwater that could be harvested under different climatic and topographic conditions. An area of 2000 km2 situated in the Karak plateau was selected for this purpose (Fig. 13.3). This plateau is characterized by Mediterranean type climate with the Koeppen classification of Csa and the other portion is of the climate type Bwk. The plateau was divided into 2000 grids, 1x1 km2 in size. Precipitation and soil moisture were measured at several stations in the plateau, and soil maps and land cover were used to characterize the hydraulic properties of soils in terms of their field capacity, wilting point, porosity, and saturation threshold when runoff occurs. Daily climatic data of each grid were interpolated from neighbouring stations where such data were measured. The model was run for six years, and generated runoff was compared to measured data obtained from the Mujib dam. Predicted and measured data were found to agree well.

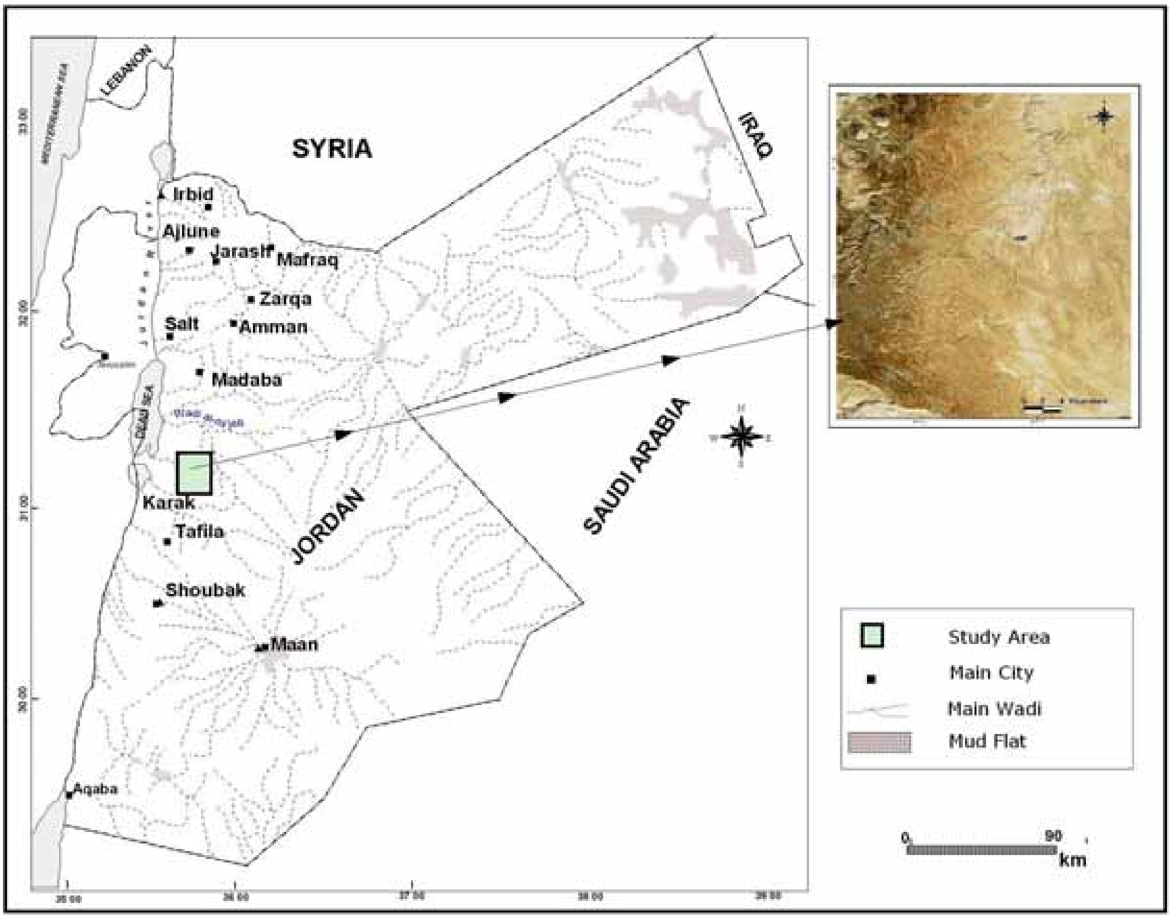


Figure 13.3: Location of the study area and spatial extent.

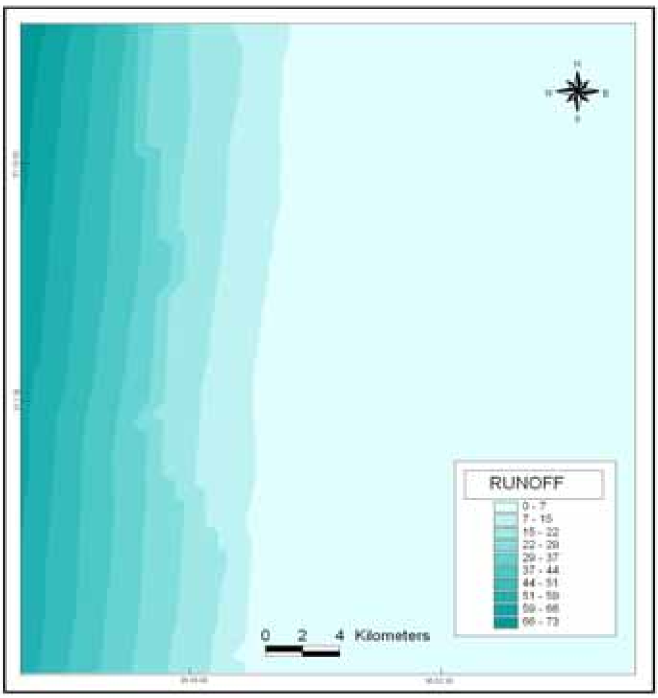


Figure 13.4: Runoff [mm] in the study area for a typical "normal" year.

Figure 13.4 shows the spatial distribution of runoff within the plateau. Desert areas lose more than 95% of their rain via direct evaporation. Without collecting this scarce water resource in such areas, vegetation growth and water runoff/recharge is extremely limited or even non-existent. The best option for such areas would be through concentration of rainwater into narrow land strips. This increases effective precipitation, thereby enhancing both green and blue water fluxes.

In areas receiving more precipitation, runoff and deep recharge could be as high as 10-15% of annual precipitation. Figure 13.4 also shows the spatial distribution of blue water production under a "normal" year (P = 330 mm). A sharp drop in runoff and recharge occurs along the climate gradient. These results suggest that desert areas, although they have some surface runoff, provide very little contribution to deep recharge, making them insignificant in replenishing underground aquifers, unless water harvesting is implemented.

Additionally, small scale water harvesting schemes were designed and tested within the study area. Collected water was used for small-scale agricultural plots to produce fruits and vegetables. The average water harvested by an urban structure in the Karak Plateau is close to 0.2 m given an average annual rainfall of 300 mm (efficiency close to 65%).

13.2.2.3 Regional RWH mapping - contribution of An-Najah University

To arrive at a RWH suitability map for the entire West Bank the best available datasets at national level of soil, land cover, DEM, and rainfall were compiled in a GIS-based database. All layers were converted into grid themes of a 25 m × 25 m cell size. Shadeed and Masri (2010) had developed a map of CN coefficients for the entire West Bank. From these data the spatial distribution of annual runoff was obtained using the SCS-CN method. Different suitability values (weights) were assigned to the land cover, soil texture, slope, and runoff layers. The weight of each layer reflected its importance on RWH potential. Depending on the assigned input layer weights, an RWH model was developed from a weighted overlay process (WOP) of the soil texture, land cover, slope, and runoff with different weights for all the layers. WOP allows the combination of data from several input grids by converting their cell values to a common scale, assigning a weight to each grid, and then aggregating the weighted cell values together. WOP, also known as the multi-criteria evaluation, is a weighted linear method commonly used in GIS-based decision.

Each layer is multiplied by its weight and the results are summed according to the following equation:

$$A_j = \sum_{i=1}^{n} W_i . S_{ij}$$

where: Aj is the final cell suitability score index, Sij is the suitability of the ith cell with respect to the jth layer, and weight Wi is a normalized weight so that ∑Wi = 1.

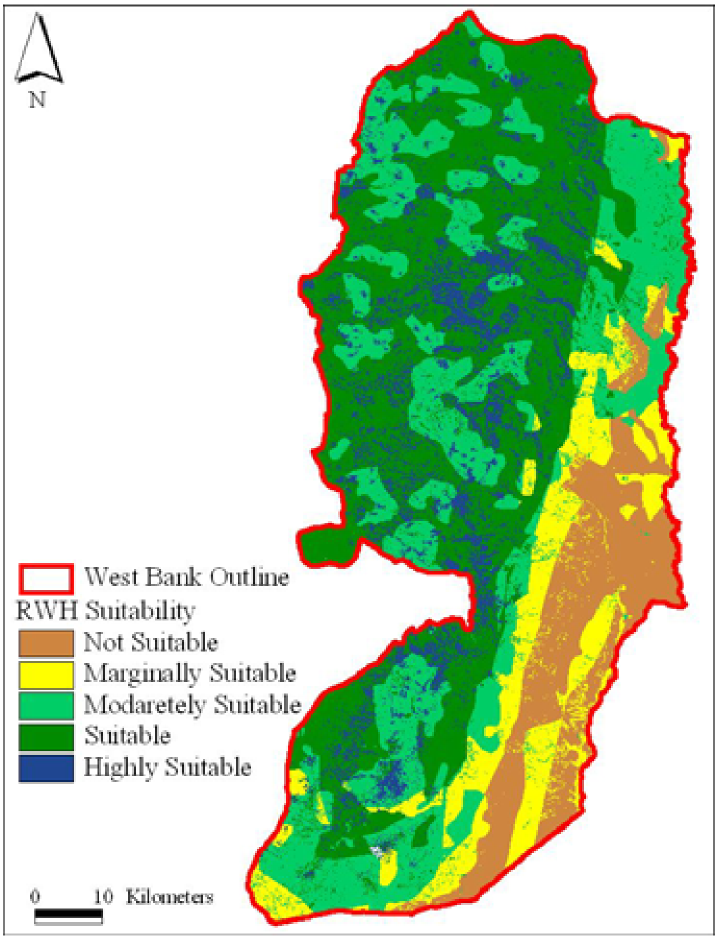


Figure 13.5: RWH Suitability Map for the West Bank.

Based on WOP a RWH suitability map was generated (Figure 13.5). It indicates that the most suitable areas for RWH are mainly located in the western part of the West Bank. The eastern part was found to be the least suitable. This can mainly be attributed to the rainfall distribution in the West Bank which increases towards the north-west and decreases towards the south-east.

In the Faria catchment a runoff generation map had been developed during the second phase of GLOWA JR, where areas of high potential for runoff generation were delineated. For these areas it is proposed to construct underground reservoirs (cisterns) to capture runoff for future uses. Such cisterns are proposed to contribute to isolated rain-fed agricultural farms.

Topographically, these farms are elevated and suffer from a shortage of water availability due to the difficulty to pump water from distant agricultural wells. Cisterns in these areas may increase water availability thus improving productivity in agriculture. In central and lower parts of the catchment where Bedouins are living and mainly depend on livestock, hillslope rainwater harvesting systems may supply water for families and livestock. Depending on the developed runoff generation map and a detailed air photo, an inventory of the best locations to generate runoff (rocky slopes, gentle slopes with a crusted surface and even complete headwater areas) was done. As a result, 19 locations for cisterns were proposed (Figure 13.6).

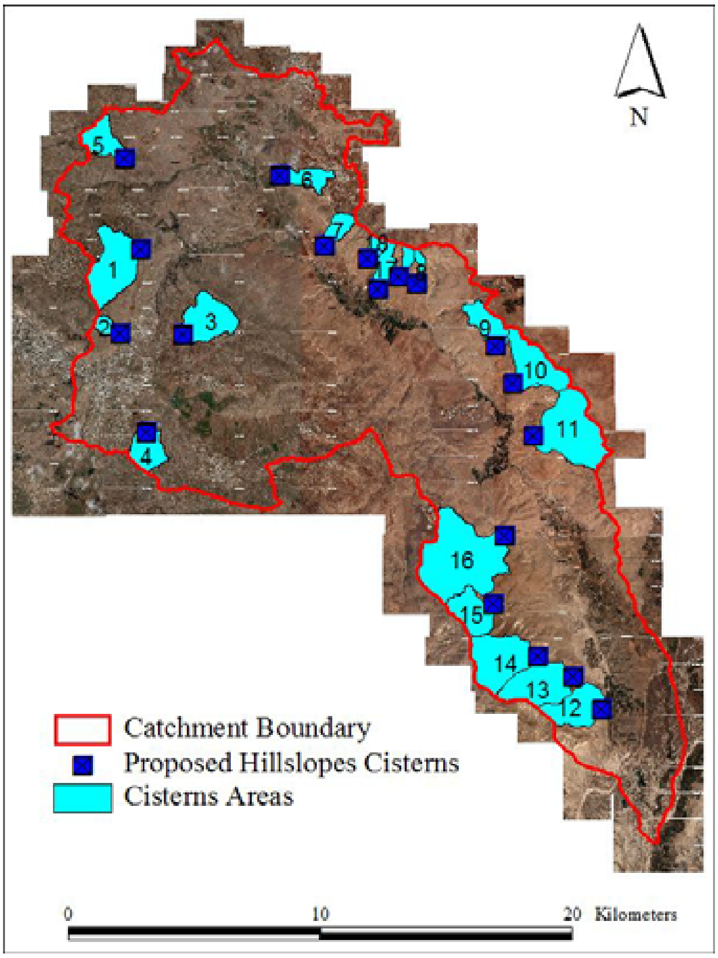


Figure 13.6: Proposed locations for the rural RWH cisterns (Google earth is the source of background image)

For the purpose of this study, two rainfall events are used as input for TRAIN-ZIN. These events were; 4-6/2/2005 (event 1) and 8-9/2/2006 (event 2). Although the catchment areas of the proposed cisterns accounts only for 15% of the entire Faria catchment, they generated 30% (event 1) and 62% (event 2) of the total catchment runoff. During event 1 rainfall had relatively moderate intensities but a higher volume than during event 2. Model simulations showed saturation excess runoff (SOF) as the dominating runoff generation process. Following higher rainfall intensities Hortonian Overland flow (HOF) was the dominating runoff generation process during event 2 On the 19 different rural rainwater harvesting sites the collected amount of runoff was highly variable, which reflects, on the one hand, differences in rainfall characteristics from event to event and, on the other hand, differences in the location of cisterns in the landscape.

13.2.2.4 Potential and limits of urban RWH - contribution of Freiburg University

We used a simple, one-parameter model to calculate the amount of harvested rooftop rainwater inside the city of Ramallah, Palestinian Authority (Fig. 13.7). In a one minute time step, the roof depression storage DS [mm] was filled with rainfall R [mm min-1] and emptied by potential evaporation PE [mm min-1]. Only when DS was reached, the exceeding water was treated as roof runoff RR [mm min-1]. Daily CLASS-A-PAN measurements of four meteorological stations were averaged and divided by day length [min] for instantaneous potential evaporation. Evaporation was hypothesized to start at sunrise and terminate at sunset. Daily sun data was obtained from the Astronomical Applications Department of the U.S. Naval Observatory (USNO). Finally, RR values were accumulated to seasonal amounts and divided by seasonal rainfall to arrive at seasonal roof runoff coefficients (RC, %). During three winter seasons (1999/2000, 2000/2001 and 2001/2002) rainfall had been measured at nine different locations inside Ramallah by rooftop tipping bucket raingauges. The raw 0.1 mm tips of ULTIMETER TB Rain Gauges equipped with Hobo event data loggers were accumulated to 1 min time intervals. Due to instrument failures and limited accessibility following riots inside the town, not a single station measured continuously. Incomplete records were not excluded from the analysis but rather treated in a similar way as independent data from low rainfall seasons.

When the seasonal RC-values of all rainfall stations were plotted against recorded rainfall, an increase of RC with annual rainfall depth was noticed (Fig.13.8). For low annual rainfall values, a large scatter was observed with single RC values plotting outside the 95% confidence band of the regression. This was mainly an effect of the short recording periods. When a single high intensity rainfall event occurred during the period of record, RC values were relatively high, even at little total rainfall. Above 300 mm of annual rainfall, RC values were more alike, because they contained a relatively similar rainfall intensity spectrum. The 95% prediction band was used to estimate RC uncertainty.

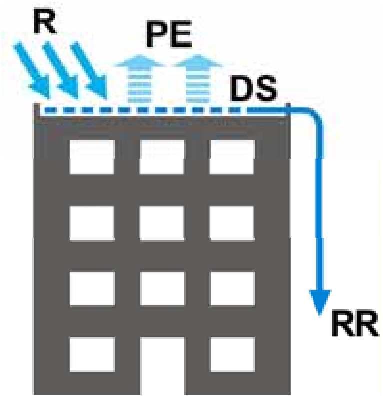


Figure 13.7: Conceptual sketch of the rooftop harvesting model; R: rainfall, PE: potential evaporation, DS: depression storage, RR: roof runoff.

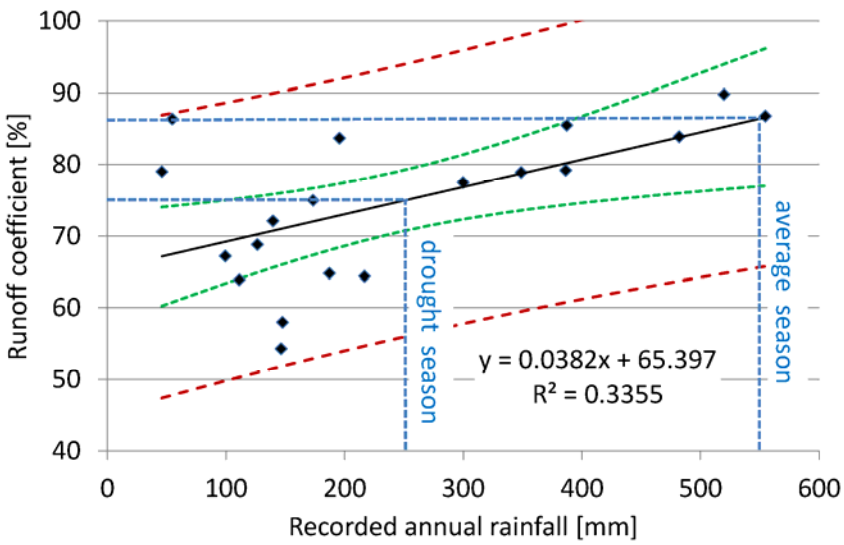


Figure 13.8: Annual RC values calculated for all stations plotted against annual rainfall; DS is set to 2 mm; dashed lines show 95% confidence band (green) and 95% prediction band (red).

For Ramallah this data suggested a RC of 75% (56 - 94%) for a drought season (250 mm rainfall) resulting in 190 mm (140 - 240 mm) of rooftop runoff. For an average season (550 mm) a reasonable RC estimate was about 87% (66 - 100%) which resulted in approximately 480 mm (370 - 550 mm) of rooftop water.

In a second step, all roofs inside the city were digitized from a 1: 2000 orthophoto of the year 1997. By GIS analysis the total roof area was calculated and individual roofs were assigned to the respondents of urban questionnaires. A large number of questionnaires had been distributed in a 1.3 km2 district close to the city centre in the summer months of the year 2000. If reported, cistern capacities [m3] were compared to connected rooftop catchment areas [m2]. To simulate continuous cistern use, a constant value of daily water consumption was subtracted from the accumulated rooftop runoff obtained by the model. For this purpose, literature values of average per capita water consumption were multiplied by the number of persons living in the individual households. The rainfall station with the largest rainfall volume (554 mm) was used as model input since it represented long term average rainfall. This model exercise also considered overflow when the simulated roof runoff exceeded cistern capacity. At the end of the season, the total volume of consumed roof runoff [m3] was divided by cistern capacity [m3] to yield cistern efficiency [-].

At the time of the survey, 577 separate buildings existed in the selected district of Ramallah with a total roof area of about 154,000 m2. 36 were uninhabited (under construction, functional buildings, etc.) and excluded from the questionnaire survey. From 541 distributed copies of the questionnaire, 513 were re-collected yielding a response rate of 95%. 78% of the buildings had flat concrete roofs, 97% had access to the public water supply and 2% had private swimming pools. 83% were connected to the public sanitation network, the remaining buildings used cesspits for waste water disposal. Households were inhabited by 5.1 persons on average, which used 1.8 showers and 3.8 water taps. Two-thirds of the buildings had surrounding private land. According to their owners, this land had an average size of about 700 m2. From the collected questionnaires, a total area of 242,000 m2 private land was calculated for investigated city district. About 67% of this land was used as a cultivated garden and 60% was irrigated, which added up to an irrigated area of approximately 144,000 m2, 11% of the investigated area. Asked about the source for irrigation water, 56% of garden owners reported to use water from the public water supply, whereas 44% relied on cisterns. In total, 40% of the households had cisterns installed that were filled by roof runoff. 94% of these active cisterns supply enough water according to their owners. Rooftop runoff was used for different purposes and had good overall quality according to its users.

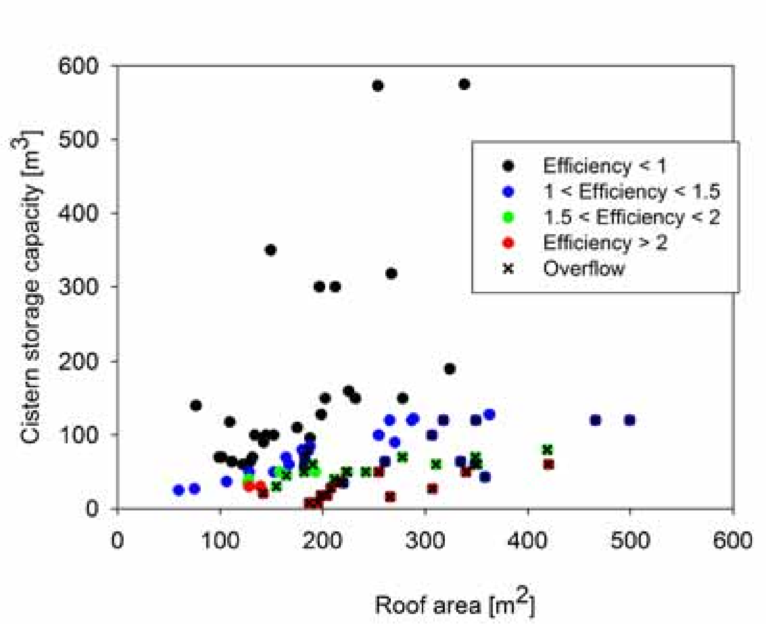


Figure 13.9: Storage capacity and connected rooftop area of 79 active cisterns in Ramallah.

Information about storage capacity was available for 79 active cisterns (Fig. 13.9). Six cisterns plotted far above the rest and had small efficiency. Assuming a per capita water consumption of 85 l/day, overflow occurred in 39 cisterns. Twelve of them had efficiencies larger than 2 indicating that they are filled more than two times during an average rainfall year. Finally, the expectancies of urban RWH during droughts and during average seasons (Fig. 13.8) were combined with questionnaire data and connected roof areas. The resulting volumes of rooftop water to be expected for Ramallah are summarized in Table 13.1.

Table 13.1: Potentials for rooftop water harvesting in Ramallah; calculations are based on an orthophoto of 1997 and a questionnaire survey of 2000; uncertainty intervals are estimated by the 95% prediction interval of the RC-rainfall regression (Figure 13.8).

	Number	Total rooftop area	Rooftop runoff expected for a drought season	Rooftop runoff collected during an average season
Rooftop runoff [mm]	-	-	190 (140-240)	480 (370–550)
Houses with active cisterns in the investigated city district	149	33 x 103 m2	6 (4-8) x 103 m3	16 (12-18) x 103 m3
Houses with installed cisterns in the investigated city district	223	53 x 103 m2	10 (7-13) x 103 m3	26 (19-30) x 103 m3
All houses in the investigated city district	558	154 x 103 m2	29 (21-37) x 103 m3	74 (56-85) x 103 m3
Houses in entire Ramallah*	2777	621 x 103 m2	118 (86-147) x 103 m3	298 (226-342) x 103 m3

***only those that were included in the available**

For the entire Lower Jordan River Basin, we created a contiguous GIS data layer of urban areas combining different data sources. For the Israeli part, a vector data set of 2002 delineated buildings as a distinct class. Urban areas of the PA were digitized from aerial photos with a spatial resolution of 1x1 m². In Jordan, urban areas were extracted as a distinct pixel value class (78 x 78 m²) from a 2002 land use map and converted to vector data. A C-Band volume scanning rainfall radar system located at Ben-Gurion international airport, close to Tel Aviv, provided regional data sets of 1.4°x 1 km (polar coordinates) rainfall during an average season (2002/2003) and during a drought (1998/1999). Five-minute radar data was obtained from E. Morin (Hebrew University of Jerusalem, Israel), after pre-correction by a multiple regression approach (Morin and Gabella 2007). This data was converted to a 1 x 1 km² grid, regionalized to the LJRB and calibrated by station data. The Jordanian parts of the LJRB outside a 150 km range around the location of the rainfall radar had to be excluded due to uncertainties in rainfall estimates. For both rainfall seasons, a GIS overlay of 1 x 1 km² annual rainfall volumes and the urban vector data set yielded the annual rainfall that fell on urban areas. This data set was multiplied by factor 0.2 due to the fact that approximately 20% of urban areas in the Middle East are covered by roof areas (Grodek et al., 2011). To obtain volumes of urban RWH, the data was multiplied by a variable roof runoff coefficient RC. RC was varied according to a linear regression found between annual rainfall amount and simulated RC of the rainfall stations in Ramallah. Thereby, we set the lower boundary for the RC values at 0.7 and the upper boundary at 0.9. Regional RWH potentials are summarized in Tab. 13.2. Results indicate considerable differences between the drought and the average season, especially for Jordan. Here, the drought season 1998/99 was characterized by low precipitation especially in the eastern parts.

Tab. 13.2: Potentials of urban RWH in different parts of the Lower Jordan River Basin for the average season 2002/2003 and the drought season 1998/1999.

Part of the LJRB	Total area [km²]	Urban area [km²]	RWH potential [10^6 m^3]	RWH potential [10^6 m^3]
			Drought (1998/1999)	Average Season (2002/2003)
PA	1523	39	1.34	4.29
Israel	979	22	0.83	2.27
Jordan*	6877	233	0.87	13.21
Total*	9379	294	3.04	19.77

*** only parts inside the 150 km range from the rainfall radar**

13.2.3 Results: Managed Aquifer Recharge (MAR) and sustaining environmental baseflow (SEB)

13.2.3.1 MAR potentials in the entire LJRB - contribution of Freiburg University

To prepare a suitability map for MAR, the input parameters surface lithology, topography, urban areas and availability of water resources were processed to thematic layers, which were then combined using a GIS-based overlay approach. The resulting map delineated areas of distinct MAR suitability classes (Fig. 13.10).

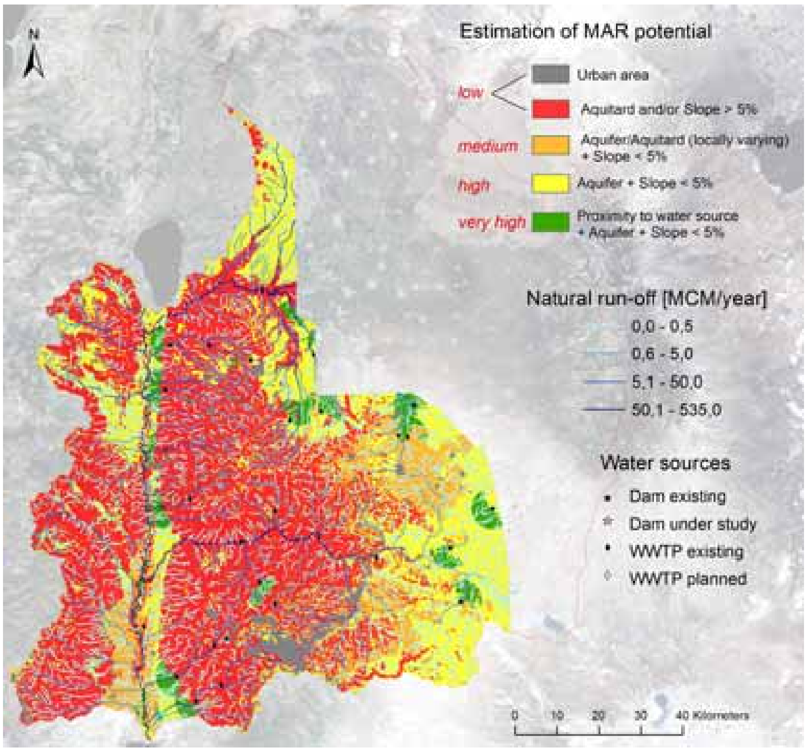


Figure 13.10: Suitability map for MAR in the LJRB.

Hydraulic properties of the surface lithology were derived from geological maps or were estimated based on information derived from literature. Hydrogeological units were classified into: aquifer, aquitard and aquifer/aquitard (locally varying). The latter class was referring to geological units with widely differing hydraulic characteristics due to post sedimentary processes (e.g. karstification). A high potential for MAR via surface infiltration was given to areas where an aquifer was combined with a slope < 5 %, a medium potential for the combination aquifer/aquitard (locally varying) and slope < 5 %. All areas classified as aquitard and/or a slope > 5 % were attributed with a low MAR potential. Urban areas and smaller settlements were considered as a restricting factor since it was assumed that surface infiltration required an appropriate amount of area. Therefore, urban areas were given a low MAR potential in the map. Water from dams and wastewater treatment plants were regarded as water sources which can principally be utilized for MAR. Therefore, a 5 km buffer around the location of both existing and planned dams and wastewater treatment plants was used, whereby only sites at a lower altitude than the respective water source were considered suitable. If those areas coincided with areas previously classified high (aquifer + slope < 5 %) the overlay assigned a very high potential for MAR. Wadi runoff as direct response to rainfall was simulated by TRAIN-ZIN and included along the channel network. This may serve as additional water source.

13.2.3.2 MAR - SEB potentials in Wadi Faria under climate change - contribution of Freiburg University in collaboration with the Institute for Meteorology and Climate Research (IMK-IFU), Karlsruhe Institute of Technology (KIT)

In 2011 the impact of climate change on Faria Spring, the largest karst spring in the West Bank, was evaluated. In order to account for uncertainty in climate change predictions, in downscaling them to the Faria catchment and in the choice of the right hydrological models, we considered a variety of climate model runs, downscaling methods and hydrological models. Five realizations of regional climate models were used from the GLOWA-climate projections (Table 13.3).

Table 13.3: Used climate change projections

Acronym	Driving GCM (realization)	RCM	SVAT	DX [km]	Institution Reference
V35E	EchAM5(1)	MM5 V3.5	OSU LSM	18.6	KIT/IMK-IFU
V35H	HADCM3(1)	MM5 V3.5	OSU LSM	18.6	(Smiatek et al., 2011)
V37E	EchAM5(1)	MM5 V3.7	Noah LSM	18.6	
V37H	HADCM3(1)	MM5 V3.7	Noah LSM	18.6	
RCM3	EchAM5(3)	RegCM3	BATS	25	TAU (Krichak et al., 2011)

The daily simulated precipitation was corrected by application of the quantile to quantile approach. The local station Taluza served as a historic reference. The hydrological models additionally required temperature as input to calculate potential evaporation. Since observed temperature at Nablus meteorological station was found to agree well with the temperature of the RCMs during the rainy season, no bias correction was performed. During the dry season, the RCMs tended to overestimate the observed temperature. However, since evaporation can only occur when there is water available as in the wet season, this error could be neglected.

The five realizations of the climate models provided gridded time series of precipitation and temperature (Table 13.3). To account for downscaling uncertainty, we averaged (1) the four grid points surrounding the estimated recharge area and (2) the two grid points at the Eastern side of the estimated recharge area, that were expected to differ most from the four point average because they received less precipitation due to the regional rainfall gradient. The five realizations of the climates scenarios and two averaging types yielded ten independent data sets that served as input to five different hydrological models (Fig. 13.11). Hence, in total we used an ensemble of 50 different model chains for our climatic change simulation exercise.

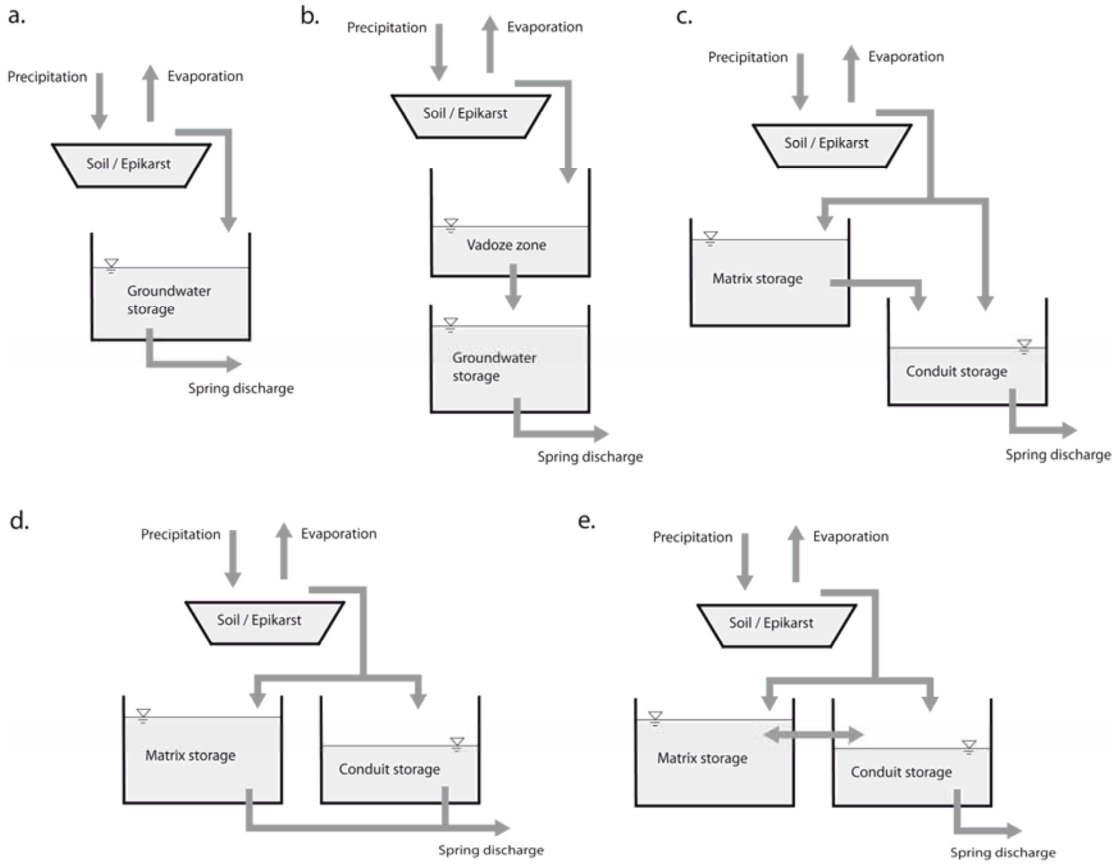


Figure 13.11: Set of applied model structures: (a) the simple model, (b) the serial model, (c) the combined model, (d) the parallel model, and (e) the exchange model.

Before the climate change projections could be studied, the five different hydrological models had to be calibrated and validated with the help of historic discharge observations. All models required almost the entire warming up period to approach the measurements but then showed equal performance (Fig. 13.12).

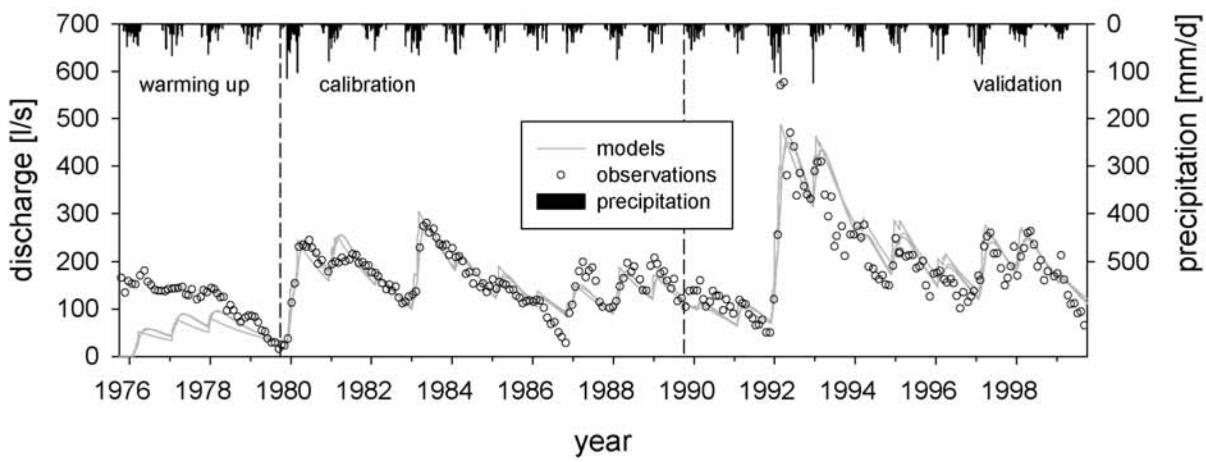


Figure 13.12: Calibration and validation of the five hydrological models to historic data.

After this successful model test, we compared three different periods of transient ensemble data: historic (1971-2001), near future (2021-2051) and far future (2068-2098). For this purpose the model outputs were averaged to 30-year means of monthly discharge and actual evaporation (Fig. 13.13).

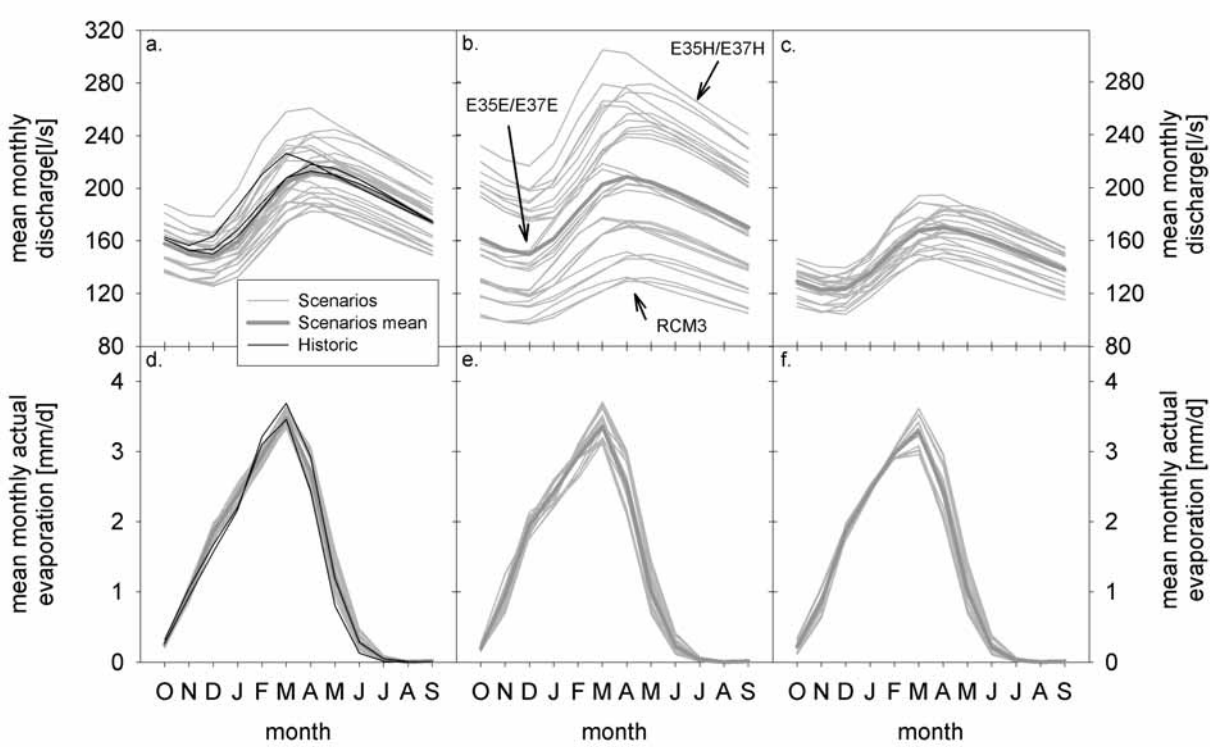


Figure 13.13: Results of the scenario ensemble exercise for mean monthly discharge and actual evaporation in the historic period (1971-2001; a, d), near future period (2021-2051; b, e), and far future period (2068-2098; c, f); note that there are no RCM3 scenarios for the far future period.

During the historic period we found a large spread and a high variability of the mean monthly discharges (Fig. 13.13a), which was even amplified in the near future period (Fig. 13.13b). In the latter period three groups could be identified: (a) The HadCM3 driven E35H and E37H revealed a general increase of water availability, (b) the E35E and E37E, with boundary forcings from ECHAM5 indicated not much change from the historic period, and (c) the RCM3 as well with ECHAM5 forcings showed a strong decrease of mean monthly discharges. In the far future period (Fig. 13.13c), no more grouping could be found and all predictions indicated a general decrease of water availability. Overall, no significant changes could be found for actual evaporation (Fig. 13.13d/e/f).

Driven by measured precipitation at Taluza station, we used the calibrated hydrological models to study recent changes in spring discharge due to the impact of groundwater abstractions (Fig. 13.14). From the end of 2005, the impact of increased pumping from the aquifer became evident, as observed discharges fell below model simulations. From October 2007 on, the spring completely dried out. Model simulations indicated that without pumping the spring discharge would have continued.

Our model exercise suggests that a reduction of spring discharge due to climate change is uncertain for the near future but will most probably occur in the far future. However, considering the recent data, it is quite obvious that human impact, i.e. increased pumping from the aquifer, poses a much higher threat to spring water resources than climate change. This has to be considered for water resources management and MAR, SEB considerations.

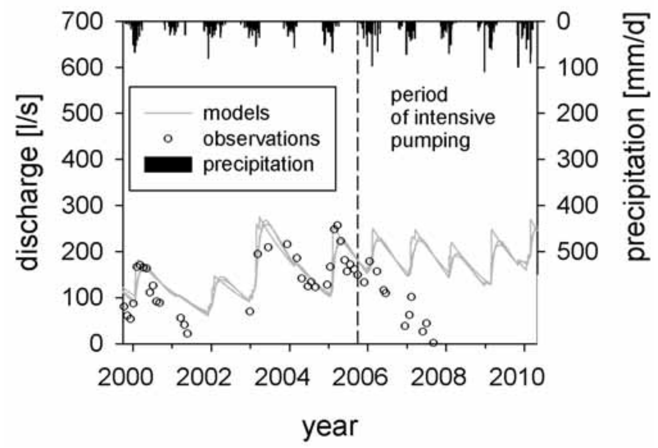


Figure 13.14: Predictions of the five hydrological models from 2000 to 2010 versus the observed declining spring discharge (due to pumping).

13.2.4 Discussion and conclusion of scientific highlights and outlook

The different maps of RWH suitability and potentials, both rural and urban, as well as the MAR suitability maps including suitable MAR locations give valuable information for decision makers to develop and implement a strategy that guides the sustainable wide scale adoption of the methods. The results have the potential to enhance the development of a comprehensive water resources management strategy to bridge the increasing supply-demand gap in the region. Furthermore, the scenario modeling of spring discharges are highly relevant for future water resources planning.

13.3 Applied value of results

All those engaged in the water sector and in neighbouring sectors (e.g. agriculture), especially farmers, may be interested in rural RWH, while water suppliers (mainly municipalities) may be interested to get informed about urban RWH. This is especially true for the city of Ramallah, the case study of our urban RWH evaluation. Calculated RWH-potentials will be used via WEAP in the water management system of Jordan Different maps of RWH suitability and potentials, both rural and urban.

Also the MAR suitability maps including suitable MAR locations should be of interest for the water management on the small scale. These maps are already presented in the atlas of GLOWA JR and/or in GLOWA JR briefings.

13.4 References

Grodek, T., Lange, J., Lekach, J., and Husary, S. 2011. Urban hydrology in mountainous middle eastern cities. Hydrol. Earth Syst. Sci., 15, 953-966.

Krichak S, Breitgand J, Samuels R & Alpert P 2011. A double-resolution transient RCM climate change simulation experiment for near-coastal eastern zone of the Eastern Mediterranean region. Theor. Appl. Climatol., 103, 167-195.

Morin, E. and Gabella, M. 2007: Radar-based quantitative precipitation estimation over mediterranean and dry climate regimes. J. Geophys. Res. Atmos., 112, D20108.

Smiatek G, Kunstmann H & Heckl A 2011. High-resolution climate change simulations for the Jordan River area. J. Geophys. Res, 116, D16111 doi:10.1029/2010JD015313.

Annex 1: Publications GLOWA Jordan River Phase I, II & III

Journal Articles

ABU SADAH, M. 2009. Application of WEAP-MODFLOW in the Western Aquifer Basin, Palestine. First Arab WEAP conference. Damascus, Syria.

ABU SHABAN, A., DOPPLER, W. & WOLFF, H.-P. 2005. Consumers' Attitude and Farmers' Situation with Regard to Agricultural Production with Treated Wastewater in the Northern Gaza Strip Deutscher Tropentag 2005, The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies. University of Hohenheim.

ABU SHABAN, A., DOPPLER, W. & WOLFF, H.-P. 2005. Trade-Offs of Using Treated Wastewater in Irrigated Agriculture - The Case of Gaza Strip. Deutscher Tropentag 2005, The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies. University of Hohenheim.

ABU SHABAN, A., DOPPLER, W. & WOLFF, H.-P. 2006. Determinants of Farmers' Acceptance of Treated Wastewater in Irrigated Agriculture in the Northern Gaza Strip. In: ASCH, F. & BECKER, M. (eds.) Tropentag 2006: Prosperity & Poverty in a globalized world: Challenges for Agricultural Research. University of Bonn.

AGAM, N., RAZ-YASEEF, N., ROTENBERG, E. & YAKIR, D. 2006. The relative contribution of the uppermost soil layer to the total soil heat flux at different timescales. 1st iLEAPS Science Conference. Boulder, Colorado.

ALCAMO, J. 2005. Scenarios for the Glowa-Jordan River Project: The Story and Simulation approach. Glowa-JR Planning Meeting. Cologne, Germany.

ALCAMO, J. 2007. GLOWA Jordan River. Phase III GLOWA Jordan River Project: The way forward with regional strategies and user support. GLOWA JR Status Conference. Herrenberg, Germany.

ALCAMO, J. 2008. The GLOWA Jordan River Project: Global change science for integrated water resources management. Global Catchment Initiative Expert Meeting. Global Water System Project. Bonn.

ALCAMO, J. 2008. The usefulness of scenario analysis in international environmental assessments. Fachgespräch: Szenarien – Rolle, Leistungsfähigkeit, Perspektiven. CESR, University of Kassel, Germany.

ALCAMO, J., KOCH, J., LÜBKERT, B. & ONIGKEIT, J. 2006. The Glowa-JR scenario exercise. Glowa-JR Advisory Committee Meeting. Reichenau, Germany.

ALCAMO, J., KOCH, J., LÜBKERT, B., ONIGKEIT, J. & SCHALDACH, R. 2007. Project 1 Integration: Regional scenario analysis and land cover modelling. GLOWA JR Status Conference. Herrenberg, Germany.

ALFARRA, A., KEMP-BENEDICT, E., HÖTZL, H., SADER, N., SONNEVELD, B., ALI, W. & WOLF, L. 2009. Simulation of Water Supply and Demand in the Jordan Valley Region using WEAP21: Initial Results. First Arab WEAP conference. Damascus, Syria.

ALMASRI, M. 2009. Application of WEAP-MODFLOW in the Eocene Aquifer Basin, Palestine. First Arab WEAP conference. Damascus, Syria.

ALPERT, P. 2005. Assessment of Global Warming Impacts on Water Availability in the Jordan River Basin (GLOWA-Jordan River)-Regional Climate Modeling and Dynamical Downscaling for Global Warming Scenario. NATO Advanced Research Workshop, Air, Water and Soil Quality Modelling for Risk and Impact Assessment. Tabakhmela (near Tbilisi), Georgia.

ALPERT, P. 2006. Climate change toward increased aridity. Advanced International Postgraduate Course on Integrated Approach and Sustainable Management of Adverse Climate Changes, Drought and Desertification. Tal Hotel, Tel Aviv, Israel.

ALPERT, P. 2006. The ECHAM4/OPYC3 and HadCM3 simulations of the E. Mediterranean climate vs NCEP/NCAP reanalysis over 1960–1990 based on the regional synoptic systems. The Annual Conference of the Israeli Meteorological Association. Bazel Hotel, Tel Aviv, Israel.

ALPERT, P. 2006. Review Lectures on GLOWA-JR: Hebrew University – 5 January 2006. Environmental Conference. Tel-Aviv University.

ALPERT, P. 2007. Dan David Prize Events, Symposium on Global Warming and Renewable Energy. Tel Aviv University, Tel Aviv, Israel.

ALPERT, P. 2007. Rising technologies - New horizons in the 21st century, Aircraft house. Herzelia, Israel.

ALPERT, P. 2007. WATEC Israel 2007, The 4th International Exhibition of Water Technology and Ecology. Ganei Hataaroha Exhibition Center, Tel Aviv Israel.

ALPERT, P. 2007. GLOWA Jordan River, 3rd Scenario Panel Meeting. Dead Sea Jordan.

ALPERT, P. 2007. Climate Change and Impact Research: The Mediterranean Environment. Kick-off Meeting. Bologna, Italy.

ALPERT, P. 2007. Climatic trends to extremes and regional modeling over the E. Mediterranean. RIHN-Research Project ICCAP. Kyoto Symposium, Japan.

ALPERT, P. 2007. Teleconnection and the horizontal scale, Connections between Mediterranean and global climate variability. ESF-MedCLIVAR 2nd workshop. La Londes les Maures, Toulon, France.

ALPERT, P., KISHCHA, P., KAUFMAN, Y. J., BARKAN, Y. & SCHWARZBARD, R. 2006. Global dimming or local dimming?: The large cities contribution. 2nd International Conference on Global Warming and the Next Ice Age and Aerosol Workshop on Climate Prediction Uncertainties. Santa Fe, NM, USA.

ALPERT, P., KITOH, A., YATAGAI, A., KRISCHAK, S., KUNIN, P. & JIN, F. 2008. First super-high-resolution modeling study that the ancient "Fertile Crescent" will disappear in this century and comparison to regional climate models. EGU General Assembly. Vienna, Austria.

ALPERT, P., KRICHAK, S. O. & DAYAN, M. 2004. Regional climate downscaling over the E. Mediterranean – Preliminary results. Proceedings of the International Workshop for the Research Project on the Impact of Climate Change on Agricultural Production System in Arid Areas (ICCAP). Cappadocia, Turkey.

ALPERT, P., KRICHAK, S. O., OSETINSKY, I., DAYAN, M., HAIM, D. & SHAFIR, H. 2006. Climatic trends to extremes and regional modeling over the Eastern Mediterranean. Proceedings of the International Conference on Climate Change and the Middle East, Past, Present and Future. Istanbul, Turkey.

ALPERT, P., KRICHAK, S. O., OSETINSKY, I., DAYAN, M., HAIM, D. & SHAFIR, H. 2006. Climatic trends to extremes and regional modeling over the Eastern Mediterranean. Proceeding of the International Conference on Climate Change and the Middle East, Past, Present and Future. Technical University, Istanbul, Turkey.

ALPERT, P., MESSER, H. & ZINEVICH, A. 2006. Environmental monitoring by cellular networks. 8th EGU Plinius Conference on Mediterranean Storms and Extreme Events in an Era of Climate Change. Dead-Sea, Israel.

ALPERT, P., OSETINSKY, I., ZIV, B. & SHAFIR, H. 2003. Objectively classified synoptic systems as a tool for climate change analysis: Application to the eastern Mediterranean. EGS-AGU-EUG Joint Assembly. Nice, France.

ALPERT, P. & RAYITSFELD, A. 2008. Rainfall analysis using cellular networking measurements. EGU General Assembly. Vienna, Austria.

ALPERT, P., RAYITSFELD, A., DAVID, N., GOLDSHTEIN, O., MESSER, H. & ZINEVICH, A. 2009. Recent findings with rainfall monitoring by cellular communication systems. Geosciences Union General Assembly. Vienna, Austria.

ALPERT, P., SHAFIR, H., KRICHAK, S. O., OSETINSKY, I., DAYAN, M. & HAIM, D. 2007. Climatic trends to extremes employing regional modeling and statistical interpretation over the Eastern Mediterranean. 9th EGU Plinius Conference Mediterranean Storms. Varenna Italy.

ALPERT, P. & SILVERMAN, D. 2003. Vulnerability of water resources in eastern Mediterranean ecosystems due to climate change – an integrated approach to sustainable management. AMS Conference. Long Beach, California, USA.

ALPERT, P., ZINEVICH, A., RAYITSFELD, A., DAVID, N. & MESSER, H. 2008. Recent advances in measuring rainfall by commercial microwave communication networks (solicited). EGU General Assembly. Vienna, Austria.

ARIZA, C. & TIELBÖRGER, K. 2007. Adaptation to biotic and abiotic conditions along an environmental gradient. StEve meeting. Tübingen.

ARIZA, C. & TIELBÖRGER, K. 2007. Do interactions among plants determine successful range shifts under climate change? International workshop colonization versus invasion: do the same traits matter? Towards a joint perspective in research on range expansion of native and biological invasion of non-indigenous plants. Ascona, Switzerland.

ARIZA, C. L. & TIELBÖRGER, K. 2005. Ecotypic variation in competitive abilities along a rainfall gradient in Israel. XVII International Botanical Congress. Vienna, Austria.

BADECK, F.-W. & TIELBÖRGER, K. 2005. Global Change Ecology (Symposium Summary).

BANGERTER, S., LIANCOURT, P. & PRASSE, R. 2007. Evaluation of restoration measures of degraded semi-arid rangelands under climate change in Jordan. 37th Annual Conference of the Ecological Society of Germany, Switzerland and Austria (GfÖ). Marburg, Germany.

BEN-ASHER, J. & AL., E. 2007. Two posters presented at the annual meeting of the Israeli Society of Geography.

BEN-ASHER, J. & AL., E. 2007. Presentation during the annual meeting of the American Society of Agronomy.

BEN-ASHER, J. & AL., E. 2007. Presentation during the annual workshop of the Japanese project ICCAP (Impact of Climate Change on Agricultural Production).

BEN-ASHER, J., EVRENDILEK, F., AYDIN, M., MENZEL, L. & ALPERT, P. 2004. Climate Change in the Eastern Mediterranean and Agriculture. Proc. Int. Workshop on the Impact of Climate Change on Agricultural Production Systems in Arid Areas (ICCAP). Cappadokya, Turkey.

BEN-ASHER, J., MUSSARI, A., KAFKAFI, U. & JESUS, J. 2003. New approach for large scale experimental research in agriculture and ecology. Proceding of the International Workshop for Research Project on the Impact of Global Climate Change on Agricultural Production Systems in Arid Areas (ICCAP) Kyodai Kaikan., Kyoto, Japan

BERLINER, P. R. 2007. Afforestation and sustainable forests as a means to combat desertification. . Role of water quantity and quality in dry land forest sustainability, IUFRO Conference. Jerusalem, Israel.

BONZI, C., HOFF, H., STORK, J., SUBAH, A., WOLF, L. & TIELBÖRGER, K. 2010. WEAP for IWRM in the Jordan River Region; Bridging between scientific complexity and application. Integrated Water Resources Management. Karlsruhe.

DANIELS, J. & ALPERT, P. 2005. Overview of the GLOWA Jordan River Project. Water is Life – 40 Years of Diplomatic Relations Germany-Israel Conference. International Convention Center Jerusalem, Israel.

DISEGNI, D. M., SHECHTER, M., & STERNBERG, M 2010. Estimating the Economic Value of Climate Change effect on ecosystem services via fluctuations in Genuine Saving Indicator of Sustainability. 12th Annual BIOECON Conference "From the Wealth of Nations to the Wealth of Nature: Rethinking Economic Growth". Venice, Italy.

EBERHARDT, A. & TIELBÖRGER, K. 2006. An experimental test of the sib-competition hypothesis along a climatic gradient. Annual meeting of the Plant Population Biology Group. Halle, Germany.

EVRENDILEK, F., BEN-ASHER, J., AYDIN, M. & ELIKD, I. 2004. Diurnal CO2 fluxes of different Seyhan Watershed Ecosystems. Proceeding of the International Workshop for the Research Project on the Impact of Climate Change on Agriculture Production System in Arid Areas (ICCAP) Cappadokya; Turkey.

FISCHER, C., GUNKEL, A., LANGE, J., MENZEL, L., GRODEK, T., LEKACH, J. & MORIN, E. 2007. Application of the TRAIN-ZIN model to Nahal Harod, Israel: runoff generation and impact of urbanization (posters). GLOWA Status Conference. Herrenberg.

GEISSLER, K., KÖCHY, M., JELTSCH, F. 2010. Response of dryland natural vegetation to simulated change of climate and land use. Latsis Symposia. Lausanne, Switzerland.

GEISSLER, K., KÖCHY, M., JELTSCH, F. 2010. Response of dryland natural vegetation to simulated change of climate and land use. GfÖ Conference. Gießen, Germany.

GOPHEN, M. 2007 (in press). Lake Management Perspectives in Arid, Semi-Arid, Sub-Tropical and Tropical Dry climate. Proceedings of the 12th International Lake Conference. Jaipur, India.

GUETA, Y., KROTMAN, Y. & GOREN, M. 2004. The rainbow trout as an intruder species in the Jordan Valley. 41st Conference of the Zoological Society of Israel. Haifa

GUNKEL, A., LANGE, J., MENZEL, L. & WIESENDANGER, C. 2007. Development of a new modelling tool as starting point for water management in the lower Jordan river catchment. Geophysical Research Abstracts.

HAERING, M., SALMAN, A., AL-KARABLIEH, E., GAESE, H. & AL-QUR'AN, S. 2009. Predicted unmet irrigation demands due to climate change in the lower Jordan river basin. First Arab WEAP conference. Damascus, Syria.

HAIM, D., SHECHTER, M. & BERLINER, P. 2006. Economic impacts of climate change on Israeli Agriculture (Poster). GLOWA meeting. Esslingen.

HAIM, D., SHECHTER, M. & P., B. 2006. Economic impacts of climate change on Israeli agriculture. Third World Congress of Environmental and Resource Economists. Kyoto, Japan.

HAIM, D., SHECHTER, M. & P., B. 2006. Economic impacts of climate change on Israeli agriculture. UN-CCD: International Conference on Deserts and Desertification: Challenges and Opportunities. Sede Boqer, Israel.

HAREL, D., STERNBERG, M., METZ, J. & TIELBÖRGER, K. 2007. Seed bank and annual plant communities responses to short-term climate change. Poster presentation. GLOWA Jordan River Status Conference. Herrenberg, Germany.

HARTMANN, A., LANGE, J. & RIMMER, A. 2009. Applied dual porosity concept for large karst basins in the east Mediterranean. European Geosciences Union General Assembly. Vienna, Austria

HARTMANN, A., RIMMER, A. & LANGE, J. 2008. HYMKE_DUAL: Modelling of the Mt. Hermon hydrological system based on karst specific processes. GLOWA JR Status Conference. Aqaba, Jordan.

HECKL, A. 2007. Auswirkung der Klimaänderung auf die Wasserverfügbarkeit im oberen Jordan Einzugsgebiet. Doktorandenseminar des IMK-IFU mit Universität Stuttgart und UniBW München. Schluchsee-Seebrugg.

HECKL, A. 2007. Klimaänderung im Nahen Osten und Auswirkung auf die Wasserverfügbarkeit im oberen Jordan Einzugsgebiet. Doktorandencolloquium am Institut für Geographie, Universität Augsburg.

HECKL, A. & KUNSTMANN, H. 2007. Climate Change in the Jordan River region. 3rd Scenario Panel Meeting of GLOWA Jordan River. Sweihmeh, Jordan.

HIJAWI, T. 2002. Economics analysis of water quality in farming system development, the case of Al Faria'a Basin- western of the Jordan Valley Deutscher Tropen Tag (DTT). Kasel, Germany.

HIJAWI, T. 2002. Economics and Management of water Reuse in Agriculture, the case of Al Faria'a basin-western of the Jordan valley. 5th IFSA European Symposium on Farming and Rural Systems

Research and Extension. Florence, Italy.

HIJAWI, T. 2002. Potential of GIS Analysis in Farming System Development: a case study of Al Faria'a Basin-west of the Jordan Valley. 5th IFSA European Symposium on Farming and Rural Systems Research and Extension. Florence, Italy.

HOFF, H., CLAUS, C. & TIELBOERGER, K. 2005. GLOWA Jordan River Project - Global Change Research for Integrated Water Resources Management. In: KHATIB, I., ASSAF, K., CLAEYS, D. & AL HAJ DAOUD, A. (eds.) Proceedings of the International Conference on Water Values and Rights. Ramallah, Palestinian Authority.

HOFF, H., TIELBÖRGER, K. & ALCAMO, J. 2005. Proceeding of the Integrated Science for Sustainable Water Management in the Jordan River Basin. In: TIELKES, E. & AL., E. (eds.) Tropentag 2005. Hohenheim, Germany.

HOLZAPFEL, C. & STERNBERG, M. 2004. To stay at home or to see the world? Climate versus biotic control of plant coexistence. 89 Ecological Society of America Annual Meeting. Oregon, USA.

HOLZAPFEL, C., TIELBOERGER, K., HOBBHAHN, N., PETRU, M. & STERNBERG, M. 2006. Sex and climate change: sex ratio responses to experimental rainfall scenarios in an Israeli shrub. ESA 91st annual meeting. Memphis, USA.

JAYYOUSI, A. F. & ALMASRI, M. N. 2010. The Use of Water Allocation Models in Managing Trans-boundary Water Resources: A Case from Palestine. International Conference "Transboundary Aquifers: Challenges and New Directions"(ISARM 2010). Paris, France.

JELTSCH, F., KÖRNER, K., SCHIFFERS, K., SCHURR, F. & KÖCHY, M. 2005. Plant population modelling –quo vadis? (Invited lecture). GFÖ Section Plant Population Biology. Potsdam, Germany.

JÜSCHKE, E. & MARSCHNER, B. 2003. Effects of treated wastewater irrigation on the amount and properties of dissolved organic matter in Israeli soils – first steps of the project. 9th Nordic IHSS Symposium. Sundsval, Sweden.

JÜSCHKE, E. & MARSCHNER, B. 2005. Veränderung der mikrobiellen Aktivität in Böden unter Abwasserberegnung. Poster contribution on the Annual meeting of the Deutsche Bodenkundliche Gesellschaft 2005. Marburg.

JÜSCHKE, E. & MARSCHNER, B. 2006. Effects of effluent irrigation on the carbon dynamics in soils of the Middle East. Oral paper presentation on EMWater Regional Conference "Efficient Management of Wastewater Treatment and Reuse in the Mediterranean Countries". Amman, MEDA Water, InWent.

JÜSCHKE, E. & MARSCHNER, B. 2006. Long-term influence of effluent irrigation on organic matter in Israeli soils. Poster presentation on IHSS 13th International Conference "Humic Substances – Linking Structure to Functions". Karlsruhe.

JÜSCHKE, E., MARSCHNER, B., TARCHITZKY, J. & CHEN, Y. 2004. Chemical and Biological aspects of effluent irrigation on organic soil components. XII International Meeting of IHSS Proceedings: Humic Substances and soil and water environment.

KADISHI, N., ZEITOUNI, N., SHAMIR, S. & SHECHTER, M. 2002. Climate Change and Israeli Agriculture: An Economic Perspective. 32nd Annual Meeting of the Israeli Society for Ecology & Environmental Quality Sciences (ISEEQS). Tel Aviv.

KAN, I., RAPAPORT-ROM, M., HAIM, D. & SHECHTER, M. 2006. Economic analysis of climate-change impacts on agricultural profitability and land use in Israel (Workshop). Workshop on: Economic implications of the Greenhouse Effect and Climate Change in Israel Aspects. Rehovot, Israel.

KAN, I., RAPAPORT-ROM, M., HAIM, D. & SHECHTER, M. 2006. Economic analysis of climate-change impacts on agricultural profitability and land use: The case of Israel. Third World Congress of Environmental and Resource Economists. Kyoto, Japan.

KAN, I., RAPAPORT-ROM, M., HAIM, D. & SHECHTER, M. 2006. Economic analysis of climate-change impacts on agricultural profitability and land use: The case of Israel. Deserts and Desertification: Challenges and Opportunities. Sede Boqer, Israel.

KAN, I., RAPAPORT-ROM, M. & SHECHTER, M. 2005. Climate Change Effects on Agricultural Land Use in Israel. 21th Annual Meeting of the Israeli Economic Association. Ma'aleh Hahamisha, Israel.

KAN, I., RAPAPORT-ROM, M. & SHECHTER, M. 2005. Climate Change Effects on the Vegetative Agriculture in Israel. 8th International Meeting of the Israel Society for Ecology & Environmental Quality Sciences. Rehovot, Israel.

KAN, I., RAPAPORT-ROM, M. & SHECHTER, M. 2007. Economic analysis of climate-change impacts on agricultural profitability and land use: The case of Israel. 15th EAERE Annual Conference. Thessaloniki, Greece.

KATRA, I. 2007. Topsoil moisture patterns on arid hillsides. DRI's Environmental Seminar Series. Desert Research Institute, Reno and Las Vegas, NV, United States.

KHATIB, I., GERSTENGARBE, F.-W. & HAJ-DAOUD, A. 2006. East Mediterranean Climate Change Trends in the last century. The 3rd International Conference on water resources in the Mediterranean Regions , "WATMED". Tripoli, Lebanon.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2005. Productivity and plant diversity along a climatic gradient: testing effects of precipitation scenarios. Israel Society for Ecology and Environmental Quality Sciences; International conference: Living with Global Change: Challenges in Environmental Sciences. Weizmann Institute of Science, Rehovot, Israel.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2005. Productivity and plant diversity along a climatic gradient: testing effects of precipitation scenarios. Israel Society for Ecology and Environmental Quality Sciences. International conference: Living with Global Change: Challenges in Environmental Sciences. Weizmann Institute of Science, Rehovot, Israel.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2005. Spatial and temporal variation in the productivity-diversity relationship in Mediterranean plant communities. XVII International Botanical Congress. Vienna, Austria.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2005. Spatial and temporal variation in the productivity-diversity relationship in Mediterranean plant communities. XVII International Botanical Congress. Vienna, Austria.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2007. Temporal patterns of germination in Mediterranean annual species. Seed Ecology II Conference. Perth, Australia.

KIGEL, J. & OFIR, M. 2004. Environmental control of summer dormancy in Mediterranean geophytes. 25th Reunion Argentina de Fisiologia Vegetal. La Pampa, Argentina.

KIGEL, J. & OFIR, M. 2007. Summer dormancy in Perennial grasses: a physiological continuum. Medecos XI. Perth, Australia.

KIGEL, J., OSEM, Y. & PEREVOLOTSKI, A. 2007. Is seed germination of annual species in the soil seed-bank a stable trait across years? Seed Ecology II Conference. Perth, Australia.

KOCH, J., MENZEL, L. & SCHALDACH, R. 2008. Coupled scenario studies for the Jordan River region. Interaktionen von Atmosphäre – Hydrosphäre – Biosphäre, Modell-Konzepte zur integrierten Betrachtung komplexer Systeme. 12. Workshop großskalige hydrologische Modellierung. Kiel, Germany.

KOCH, J. & SCHALDACH, R. 2006. Adapting a Land Use Change Model to the Jordan River Region. In: ÜNAL, Y., KAHYA, C. & DEMIRHAN BARI, D. (eds.) Proceedings of the First International Conference on "Climate Change and the Middle East: Past, Present and Future". Istanbul Technical University, Turkey.

KOCH, J. & SCHALDACH, R. 2006. Simulating Land Use Change Scenarios. GLOWA Jordan River Status

Conference. Esslingen, Germany.

KOCH, J. & SCHALDACH, R. 2007. P1a: Simulation of Land Use Change Scenarios. GLOWA Jordan River Status Conference. Herrenberg, Germany.

KOCH, J. & SCHALDACH, R. 2007. Poster presentation: "Scenario-based Land Use Simulations for the Jordan River Region". Second International Conference on “Earth System Modelling”. Hamburg, Germany.

KOCH, J. & SCHALDACH, R. 2008. Szenarienbasierte Modellierung der Auswirkungen verschiedener Beweidungsstrategien auf die Landnutzung in der Jordanregion. GfÖ Arbeitskreis Weideökologie Workshop „Beweidungsökologie und –Management in Trockengebieten“. UFZ Kubus Leipzig, Germany.

KOCH, J., SCHALDACH, R. & KÖLKING, C. 2009. Modelling the impact of rangeland management strategies on (semi-)natural vegetation in Jordan. In: ANDERSON, R. S., BRADDOCK, R. D. & NEUHAM, L. T. H. (eds.) 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation.

KOCH, J., WIMMER, F., SCHALDACH, R., ONIGKEIT, J. & FOLBERTH, C. 2012. Modelling the impact of climate change on irrigation area demand in the Jordan River. 6th International Congress on Environmental Modelling and Software (iEMSs). Leipzig, Germany.

KÖCHY, M. 2004. Was ist ein "gutes Jahr" für Annuelle in humiden bis ariden Gebieten. AK "Experimentelle Ökologie" der GFÖ. Potsdam, Germany.

KÖCHY, M. 2006. Opposite trends in life stages of annual plants caused by daily rainfall variability — interaction with climate change. In: ÜNAL, Y., KAHYA, C. & DEMIRHAN BARı, D. (eds.) Proceedings of the International Conference on Climate Change and the Middle East: Past, Present and Future. Turkish State Meteorological Service (DMI), Ankara, Turkey.

KÖCHY, M. 2006. Opposite trends in performance of annual plant communities caused by daily rainfall variability. Climate Change and the Middle East: Past, Present and Future. Istanbul Technical University, Turkey.

KÖCHY, M. 2007. Food resources for small livestock in semi-arid and Mediterranean landscapes under climate change. 91. Annual meeting of the Ecological Society of America. San José, U.S.A.

KÖCHY, M. 2007. Grazing capacity of Middle East landscapes under contrasting climate change scenarios. Verhandlungen der Gesellschaft für Ökologie.

KÖCHY, M. 2007. Processes of landscape change assessed by models. Zentrum für Agrarlandschaftsforschung. Müncheberg, Germany.

KÖCHY, M. 2007. Upscaling of vegetation dynamics in semi-arid landscapes under climate change. Annual meeting of the Canadian Society for Ecology and Evolution. Toronto, Canada.

KÖCHY, M. & F., J. 2006. Opposite trends in performance of annual plant communities caused by daily rainfall variability. Macroecological Tools for Global Change Research. Potsdam.

KÖCHY, M. & JELTSCH, F. 2002. Rainfall distribution and population dynamics of desert annuals. 87. Annual Meeting of the Ecological Society of America. Tucson, Arizona, USA.

KÖCHY, M. & JELTSCH, F. 2004. Effect of rainfall characteristics on performance of ten annual species. 89. Annual Meeting of the Ecological Society of America. Portland, Oregon, USA.

KÖCHY, M. & JELTSCH, F. 2004. Variation of shoot mass of annual plants with rain pattern. 34. Jahrestagung der Gesellschaft für Ökologie. Verhandlung der Gesellschaft für Ökologie 34. Gießen, Germany.

KÖCHY, M. & JELTSCH, F. 2005. Standing crop of an abundant grass species is not affected by rainfall intensity. 35. Annual Meeting of the Gesellschaft für Ökologie (GFÖ). Verahndlungen der Gesellschaft für Ökologie 36. Regensburg, Germany.

KÖCHY, M. & JELTSCH, F. 2005. Standing crop of an abundant grass species is not affected by rainfall intensity. 90. Annual Meeting of the Ecological Society of America and IX International Congress of Ecology. Montréal, Québec, Canada.

KÖCHY, M. & JELTSCH, F. 2006. Opposite trends of performance in the life cycle of annual plants caused by daily precipitation variability. Jahrestreffen der Gesellschaft für Ökologie. Bremen.

KÖCHY, M., JELTSCH, F. & MALKINSON, D. 2007. Landscape-scale models of semi-natural vegetation and run-off. GLOWA Jordan River status conference. Herrenberg (Germany).

KÖCHY, M., MALKINSON, D., MATHAJ, M., TIETJEN, B. & JELTSCH, F. 2006. Projections of climate change effects on semi-natural vegetation. GLOWA JR Status Conference. Esslingen.

KÖCHY, M. & TIELBÖRGER, K. 2003. Rainfall distribution and persistence of populations of semi-desert annuals. 88. Annual Meeting of the Ecological Society of America. Savannah, Georgia, USA.

KÖCHY, M. & TIELBÖRGER, K. 2003. Rainfall distribution and persistence of populations of semi-desert annuals. Annual Meeting of the Gesellschaft für Ökologie (GFÖ). Halle, Germany

KÖCHY, M., TIELBÖRGER, K. & STERNBERG, M. 2002. Rainfall distribution and population dynamics of desert annuals. 32. Annual Meeting of the Gesellschaft für Ökologie (GFÖ). Cottbus, Germany.

KRICHAK, S., ALPERT, P., BASSAT, K. & KUNIN, P. 2007. Assessing mechanisms of future climate trends over the E. Mediterranean region based on results of multiple RCM simulations, Connections between Mediterranean and global climate variability. ESF-MedCLIVAR 2nd workshop. La Londes les Maures, Toulon, France.

KRICHAK, S. O. & ALPERT, P. 2003. Climate variations over Europe and the eastern Mediterranean precipitation. International Conference on Earth System Modeling. Hamburg, Germany.

KRICHAK, S. O. & ALPERT, P. 2003. An observational and modeling evidence of the lee-cyclogenetic effect of Cyprus island in the Israeli climate. Session CL3, EGS - AGU – EUG Joint Assembly. Nice, France.

KRICHAK, S. O. & ALPERT, P. 2003. Role of the Eurasian Decadal Trends in the Eastern Mediterranean Climate. Wengen Conference. Wengen, Switzerland.

KRICHAK, S. O. & ALPERT, P. 2004. Eastern Mediterranean precipitation – climate modeling and analysis evaluations. European Geosciences Union General Assembly. Nice, France.

KRICHAK, S. O. & ALPERT, P. 2007. Upper-troposphere effects of hurricane Olga (2001) in the development of conditions for torrential rains over the southeastern Mediterranean. European Geosciences Union General Assembly.

KRICHAK, S. O. & ALPERT, P. 2010. Projection of climate change during first half of twenty-first century over the Easter Mediterranean region according to results of a transient RCM experiment with 25 km resolution. Geophysical Research Abstracts. EGU2010.

KRICHAK, S. O., ALPERT, P., BASSAT, K. & DAYAN, M. 2006. An RCM Evaluation of Climate Change Trends and Uncertainties over the Eastern Mediterranean Region for GLOWA Jordan River Project. 8th EGU Plinius Conference on Mediterranean Storms and Extreme Events in an Era of Climate Change Dead Sea, Israel.

KRICHAK, S. O., ALPERT, P., BASSAT, K. & KUNIN, P. 2007. Assessment of expected climate change over the eastern Mediterranean region in three simulation experiments with RegCM model. European Geosciences Union General Assembly. Vienna Austria: EGU PLINIUS 8. Geophysical Research Abstracts

KRICHAK, S. O., ALPERT, P. & DAYAN, M. 2003. A numerical study of the 3–5 December, 2001 flood in Israel. Session NH2, EGS - AGU - EUG Joint Assembly. Nice, France.

KRICHAK, S. O., ALPERT, P. & DAYAN, M. 2005. Israel Adaptation of the MM5 and RegCM3 for regional climate modeling over the eastern Mediterranean region. European Geosciences Union General Assembly. Vienna, Austria.

KRICHAK, S. O., ALPERT, P. & DAYAN, M. 2005. Simulation of the surface climatology over the Eastern

Mediterranean region using the RegCM3 model. European Geosciences Union General Assembly. Vienna, Austria.

KRICHAK, S. O., ALPERT, P. & DAYAN, M. 2006. A dynamic perspective of a link between of hurricane Olga (2001) and extreme synoptic event with torrential rains in Israel. 8th EGU Plinius Conference on Mediterranean Storms and Extreme Events in an Era of Climate Change. Dead Sea, Israel

KRICHAK, S. O., ALPERT, P., KISHKA, P. & GRELL, G. A. 2002. Impact of MM5 model resolution and domain-size in regional climate simulations over E. Mediterranean. Conference on Detection and Modeling of Regional Climate Change. Trieste, Italy.

KRICHAK, S. O., ALPERT, P. & KUNIN, P. 2009. Projections of eastern Mediterranean climate change simulated in a transient RCM experiment with RegCM3. In: ROCKEL, B., BARRING, L. & RECKERMANN, M. (eds.) 2nd International Lund RCM Workshop. 21st century challenges in regional scale climate modeling. Intern. BALTEX Secretariat.

KRICHAK, S. O., BREITGAND, J. S. & ALPERT, P. 2009. Frequency of extreme precipitation climate events over the Mediterranean region according to NNRP data for 1961-2000. In: COTE, J. (ed.) Research Activities in Atmospheric and Oceanic Modelling. WMO/TD.

KRICHAK, S. O., BREITGAND, J. S. & ALPERT, P. 2009. Trends in frequency of extreme precipitation climate events in the Mediterranean region according to NNRP data for 1961-2000. In: COTE, J. (ed.) Research Activities in Atmospheric and Oceanic Modelling. WMO/TD.

KRICHAK, S. O., KISHCHA, P. & ALPERT, P. 2001. Decadal trends of NAO and EA/WR, SLP anomaly patterns and the Mediterranean precipitation. Open Climate Conference Holland.

KROTMAN, Y. & GOREN, M. 2004. Biodiversity and community structure of the Jordan River system fishes and their relationship to habitat structure and anthropogenic impact. 41st Conference of the Zoological Society of Israel. Haifa.

KUNSTMANN, H. 2006. Was leisten meteorologische Modelle in der Hydrologie? SYNAP Symposium. Technische Universität Dresden.

KUNSTMANN, H., HECKL, A., SUPPAN, P., ALPERT, P., KRICHAK, S., KUNIN, B., BASSAT, K. & KHATIB, I. 2006. Regional Climate Simulations for the Near East and the Jordan River Region. GLOWA Jordan River Status conference. Herrenberg.

KUNSTMANN, H., SUPPAN, P., HECKL, A., KRICHAK, S. & PINHAS, A. 2006. Impact of Climate Change on Water Availability in the Near East. GLOWA-Jordan Statuskonferenz. Esslingen.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2005. Combined High Resolution Climate and Distributed Hydrological Simulations for the Eastern Mediterranean / Near East and the Upper Jordan Catchment. Proceedings of the Conference on International Agricultural Research for Development Stuttgart-Hohenheim.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2005. Coupled High Resolution Climate - Hydrology Simulations for the Upper Jordan Catchment. In: TIELKES, E. & AL., E. (eds.) Proceedings of Tropentag 2005. Hohenheim, Germany.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2006. Regional Climate Change Simulations for the Near East. Geophysics Seminary. Tel Aviv University, Tel Aviv, Israel.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2007. Quantification and Reduction of Predictive Uncertainty for Sustainable Water Resources Management. Proceedings of Symposium HS2004 at IUGG2007. Perugia: IAHS Publ. 313.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2007. Regional climate change in the Middle East and impact on hydrology in the Upper Jordan catchment. IAHS publication 313, Quantification and reduction of predictive uncertainty for sustainable water resources management. Perugia.

LAMPEI, C. & TIELBÖRGER, K. 2006. Estimating extinction probabilities of annual plant species under climate change: an experimental approach. Annual meeting of the GFÖ. Bremen, Germany.

LAMPEI, C. & TIELBÖRGER, K. 2007. Adaptation of annual plants: what can we learn from climatic gradients? EES summer school of the Ludwig Maximilliam University. Frauenchiemsee, Germany.

LAMPEI, C., TIELBÖRGER, K., PETRU, M., ARIZA, C. & METZ, J. 2006. Evolution versus dispersal: how will annual plant communities respond to a climate change? . StEve-meeting. University of Tübingen, Germany.

LANGE, J., ARBEL, Y., GREENBAUM, N. & GRODEK, T. 2009. Process studies of water percolation in a Mediterranean karst area. Geophysical Research Abstracts.

LANGE, J., GUNKEL, A., SCHÜTZ, T., WIESENDANGER, C., FISCHER, C., SHADEED, S., ALMASRI, M., JAYYOUSI, A., SHAHEEN, H., GRODEK, T. & MORIN, E. 2008. Hydrological Impact Modelling: Applying TRAIN-ZIN in the Lower Jordan River Catchment. MedClivar/GLOWA-workshop. Reading, UK.

LANGE, J., GUNKEL, A., SHADEED, S., FISCHER, C., KRIER, R., MORIN, E., GRODEK, T. & MENZEL, L. 2008. New insights into the variability of water resources in the Jordan River Catchment. Geophysical Research Abstracts.

LANGE, J., GUNKEL, A., SHADEED, S., MORIN, E., GRODEK, T. & MENZEL, L. 2008. New insights into the variability of water resources in the Jordan River Catchment. Fourth environmental symposium of german-arab forum for environmental studies. Marocco.

LANGE, J., KOHN, I. & GUNKEL, A. 2009. Hydrologischer Wandel in Karstgebieten des östlichen Mittelmeerraums: vom Prozessverständnis zu belastbaren Prognosen. Forum für Hydrologie und Wasserbewirtschaftung. in print.

LANGE, J. & MENZEL, L. 2005. Water resources under global change: Process based hydrological modelling for the lower catchment of the Jordan River. presentation of GLOWA-Jordan work at the Deutscher Tropentag 2005. Stuttgart-Hohenheim.

LANGE, J. & MENZEL, L. 2007. Assessing water availability for the lower Jordan River under global change (presentation). GLOWA Jordan River Status Conference. Herrenberg.

LANGE, J., SCHÜTZ, T., GUNKEL, A., GRODEK, T., STEINMANN, A. & MENZEL, L. 2007. Representing dryland runoff generation processes in hydrological models: experiences from a small mediterranean catchment Geophysical Research Abstracts. .

LIANCOURT, P. 2006. Facilitation and ecological speciation: Disruptive or cohesive force" ESF LESC Exploratory workshop". Positive interactions, biodiversity and invisibility in a changing world. Arcachon, France.

LIANCOURT, P., BANGERTER, S., ORAN, S., PRASSE, R. & TIELBOERGER , K. 2007. Impact on grazing cessation on the biomass in Jordan (Poster). GLOWA Jordan River Status Conference. Herrenberg, Germany.

LIANCOURT, P. & TIELBÖRGER, K. 2007. Plant strategies and local adaptation: the role of competition and the length of the vegetation season along an aridity gradient. 37th Annual Conference of the Ecological Society of Germany, Switzerland and Austria (GfÖ). Marburg, Germany (Oral presentation).

MALKINSON, D. & JELTSCH, F. 2005. The use of spatially explicit models to evaluate the importance of facilitation and competition among shrubs along a climatic gradient. IGA meetings. Haifa, Israel.

MARSCHNER, B., HAMER, U., JUESCHKE, E., CHEN, Y. & TARCHITZKY, J. 2005. Is substrate availability a major limiting factor for the degradation of soil organic matter? . Poster presented at the 22. IMOG-conference Sevilla, Spain.

MARSCHNER, B., JUESCHKE, E., TARCHITZKY, J. & CHEN, Y. 2005. Changes of organic matter in soils irrigated with reclaimed wastewater. International Conference of the Israeli Society for Ecology and Environmental Quality Science. Rehovot, Israel.

MATHAJ, M., JELTSCH, F. & KÖCHY, M. 2006. Consequences of climate change for stocking rates of sheep and goats in the Mediterranean. Jahrestreffen der Gesellschaft für Ökologie. Bremen.

MENZEL, L. 2006. Assessment of blue and green water. First Scenario Panel Meeting of the GLOWA-Jordan Project. Waldeck.

MENZEL, L. 2006. Erfassung und Modellierung der Wasserhaushaltskomponenten auf unterschiedlichen räumlichen Skalen. Kolloquium an der Fakultät für Forst- und Umweltwissenschaften der Universität Freiburg. Universität Freiburg.

MENZEL, L. 2006. Modelling of the water balance components on different spatial scales (in German). Colloquium at the Faculty of Forest and Environmental Sciences. University of Freiburg.

MENZEL, L. 2007. Changing water availability in the Upper and Lower Jordan River Region. GLOWA Jordan River 2nd Scenario Panel Meeting. Hofgeismar.

MENZEL, L. 2007. Integrated river basin management: new challenges in hydrology (in German). Colloquium at the Faculty of Civil Engineering and Geodesy. Technical University Munich.

MENZEL, L. 2007. Model based simulation of the water balance of forests on different spatial scales. In: FEGER, K.-H., YANHUI, W., BERNHOFER, C. & SEEGERT, J. (eds.) The role of forests and forest management in the water cycle. Progress in Hydro Sciences and Engineering. TU Dresden: Dresden Water Center, Dresden.

MENZEL, L. 2007. Simulation studies of human impact on the hydrological cycle. Colloquium at the Centre for Agricultural Landscape Research (ZALF). Müncheberg.

MENZEL, L. 2008. Climate change: hydrological effects in the semi-arid and arid parts of the Jordan region. MedClivar / GLOWA workshop. University of Reading, UK.

MENZEL, L. 2008. Environmental change and water scarcity in the Jordan Region: An interdisciplinary model exercise (in German). Colloquium at the Faculty of Chemistry and Geosciences. University of Heidelberg.

MENZEL, L. 2008. Water resources in the semi-arid Jordan basin: What will bring the future? (in German). 16. HGN Hydrogeological colloquium “Climate change and its impact on the groundwater“. Halle/Saale.

MENZEL, L., ALKHOURY, W. & WEIß, M. 2006. Green water fluxes, irrigation water demand and environmental change in the Lower Jordan Basin. GLOWA Jordan River Status Conference. Esslingen.

MENZEL, L., ALKHOURY, W. & WEIß, M. 2006. Green water fluxes, irrigation water demand and environmental change in the Lower Jordan Basin. GLOWA Jordan River Status Conference. Esslingen, Germany.

MENZEL, L., FLÖRKE, M., MATOVELLE, A. & ALCAMO, J. 2007. Impact of socio-economic development and climate change on water resources and water stress. First International Conference on Adaptive and Integrative Water Management (CAIWA 2007). Basel.
MENZEL, L., FLÖRKE, M., MATOVELLE, A. & ALCAMO, J. 2007. Impact of socio-economic development and climate change on water resources and water stress. First International Conference on Adaptive and Integrative Water Management (CAIWA 2007). Basel.
MENZEL, L. & LANGE, J. 2006. Assessing water availability for the Lower Jordan River under global change. GLOWA Jordan River Status Conference. Esslingen.

MENZEL, L. & LANGE, J. 2008. Global change and water resources in the Lower Jordan River. GLOWA Jordan River Status Conference. Aqaba, Jordan.

MENZEL, L., LANGE, J., GUNKEL, A., ALKOURY, W. & WEIß, M. 2007. Impact of climate and land management on the water balance in the semi-arid catchment of the Jordan river (in German). Hydrology Day 2007. University of Rostock.

MENZEL, L., SCHLAFFER, S., HECKL, A. & KUNSTMANN, H. 2007. Changing water availability and irrigation water requirements in the Jordan River Region. GLOWA Jordan River 3rd Scenario Panel Meeting. Dead Sea (Jordan).

MENZEL, L., TEICHERT, E. & WEISS, M. 2007. Climate change impact on the water resources of the semi-arid Jordan region. In: HEINONEN, M. (ed.) Proceedings of the 3rd International Conference on Climate and Water. Helsinki.

MENZEL, L. & WEIß, M. 2007. Regional water balance components under climate and land cover change in the Jordan Region. GLOWA Jordan River Status Conference. Herrenberg.

METZ, J. 2007. Mediterranean and Semi-Arid Plant Communities under Climate Change. Oral presentation. StEvE-Meeting. Tübingen, Germany.

METZ, J., STERNBERG, M., KIGEL, J. & TIELBÖRGER, K. 2007. Impact of climate change on annual plant communities in the eastern Mediterranean. Oral presentation. Caress – Conference. Weizman Institute of Science, Rehovot, Israel.

METZ, J. & TIELBÖRGER, K. 2006. Impact of climate change on annual plant communities in the eastern Mediterranean. Annual Meeting of the German Ecological Society (GfÖ) Bremen.

METZ, J. & TIELBÖRGER, K. 2007. Plant – plant interactions along temporal stress gradients. Oral presentation. Annual Meeting of the German Ecological Society (GfÖ). Marburg, Germany.

MORIN, E., ARBEL, S., ARAZI, A., GETKER, M., HARATS, N., YACOBY, Y., GRODEK, T. & DAYAN, U. 2006. Studying the extremes: Hydrometeorological investigation of a flood-causing rainstorm over Israel. 8th Plinius Conference on Mediterranean Storms and extreme events in an era of climate change. European Geosciences Union, Israel.

NADAV, I., A. GILBOA, J. TARCHITZKY, & Y. CHEN 2010. Enhanced Infiltration Regime for Treated Wastewater Purification in Soil Aquifer Treatment (SAT) (oral presentation). XV Meeting of the International Humic Substances Society. Puerto de la Cruz, Tenerife, Canary Islands, Spain.

NAVON, Y. & STERNBERG, M. 2005. Plant litter decomposition under climate change: an experimental approach along an aridity gradient. 35th Annual Conference Ecological Society of Germany, Austria & Switzerland. Regensburg, Germany.

ONIGKEIT, J., ALCAMO, J. & ALPERT, P. 2009. Workshop Documentation. GLOWA Jordan River 4th Scenario Panel Meeting. Tel Aviv, Israel: Center for Environmental Systems Research (CESR), University of Kassel, Germany.

ONIGKEIT, J., ALCAMO, J. & JAYYOUSI, A. 2009. Workshop Documentation. GLOWA Jordan River 4th Scenario Panel Meeting. Ramallah, Palestinian Authority: Center for Environmental Systems Research (CESR), University of Kassel, Germany.

ONIGKEIT, J., ALCAMO, J. & LÜBKERT, B. 2009. The Procedure for Developing the GLOWA JR Scenarios for Regional Development under Global Change. Report Center for Enviromental Systems Research, University of Kassel, Germany.

ONIGKEIT, J., ALCAMO, J. & LUEBKERT, B. 2006. The Glowa JR Scenario Exercise. GLOWA Jordan River Status Conference. Esslingen, Germany.

ONIGKEIT, J., ALCAMO, J. & LUEBKERT, B. 2007. Applying fuzzy-set analysis to generate quantitative model input from qualitative scenario information. GLOWA Jordan River Status Conference. Herrenberg, Germany.

ONIGKEIT, J., ALCAMO, J. & LUEBKERT, B. 2007. Scenarios as an Integration Tool in the Glowa JR Project. 2nd Scientific Coordination Meeting of the SMART-Project. Amman.

ONIGKEIT, J., ALCAMO, J. & SALMAN, A. 2009. Workshop Documentation. GLOWA Jordan River 4th Scenario Panel Meeting. Amman, Jordan: Center for Environmental Systems Research (CESR), University of Kassel, Germany.

OROUD, I. M. 2006. Land Use Changes in the Jordan Valley and the Impact of Climate Change on Irrigation

Water Requirements. Climate Change and the Middle East: Past, Present and Future. Technical University, Istanbul , Turkey.

OROUD, I. M. 2007. Two posters presented during the GLOWA Jordan River Status Conference. Herrenberg.

OROUD, I. M. 2007. Presentation during the 4th Jordanian Conference on the Environment.

OSETINSKY, I. & ALPERT, P. 2004. Evaluation of GCM/RCM by the classified synoptic systems' approach. Paper presented in the 84th Annual AMS Meeting. Seattle, WA, USA.

OSETINSKY, I. & ALPERT, P. 2009. South Hemispheric Teleconnection to Eastern Mediterranean synoptic systems. European Geosciences Union General Assembly. Vienna, Austria.

PETRŮ, M. & TIELBÖRGER, K. 2004. Germination behavior of annual plants in variable rainfall conditions: adaptive of passive responses? . International Conference on Seed Ecology. Rhodes, Greece.

PETRŮ, M. & TIELBÖRGER, K. 2004. Responses of annual plants to variable rainfall patterns: an empirical test of three models. Annual Meeting GFÖ Section Plant Population Biology. Regensburg, Germany.

PETRŮ, M., TIELBÖRGER, K. & STERNBERG, M. 2004. Responses of annual plants to variable rainfall patterns: an empirical test of three models. MEDECOS X, Conference on Mediterranean Types Ecosystems. Rhodes, Greece.

PRANGE, S. G., K., JELTSCH, F. 2010. Feedbacks between vegetation and hydrology with a special view on extreme events in Israel. GfÖ Conference. Gießen, Germany.

PRASSE, R. 2005. Beispiele ökologischer Forschung im Nahen Osten. Festvortrag zur Verabschiedung der Diplomanden des Fachbereichs Umweltforschung der Universität Lüneburg. Universität Lüneburg.

PRASSE, R. 2005. Climate change and local cucumbers - Examples of applied ecological research in Israel and the Palestinian Autonomy. Guest lecture at the Ecology Seminar of Fullerton States University. California.

PRASSE, R. 2005. Grenzüberschreitungen - Beispiele ökologischer Forschung im Nahen Osten. Festive Colloquium for the 75th birthday of Prof. Dr. Reinhard Bornkamm. Technische Universität Berlin.

PRASSE, R. 2006. Examples of ecological research in the Middle East. Fairchild Tropical Botanical Garden, Coral Gables, Florida.

PRASSE, R. 2006. Local drought resistant crop-varieties and intercropping - combining water use efficiency and nature conservation. Triangle Research Center, Kufar Kara, Israel.

PRASSE, R., MASSALHA, J. & BERLINER, P. 2006. Water productivity in agricultural/farming systems. GLOWA meeting. Esslingen.

REGNER, H. J., SALMAN, A. Z., WOLFF, H.-P. & KARABLIEH, E. 2006. Approaches and Impacts of Participatory Irrigation Management (PIM) in Complex, Centralized Irrigation Systems - Experiences and Results from the Jordan Valley. In: ASCH, F. & BECKER, M. (eds.) Tropentag 2006: Prosperity & Poverty in a globalized world: Challenges for Agricultural Research. University of Bonn.

RIMMER, A. 2006. Modelling recession curve of karstic springs – parallel or serial reservoirs? European Geosciences Union General Assembly. Vienna.

RIMMER, A. 2006. System approach hydrology for the UCJR and Lake Kinneret. 5th Rosenberg International Forum on Water Policy. Banff, Canada.

RIMMER, A. 2006. System approach models combining long-term ecological changes, in coherent with field observation data: Lake Kinneret (Israel) and Lake Biwa (Japan). International Workshop for Lake Observation Systems. Otsu, Shiga, Japan.

RIMMER, A. 2007. Hydrological Model for Karst Environment (HYMKE)-Application to the Hermon Mountain (North of Israel). EGU General Assembly. Vienna, Austria.

RIMMER, A. 2009. System hydrology models for managing the salinity of Lake Kinneret, Israel. Proceedings of the IHP Symposium. Capri: IAHS Publ. 327.

RIMMER, A., BOGER, M., AOTA, Y. & KUMAGAI, M. 2004. Modelling long-term salinization process in fresh water lakes. European Geosciences Union 1st General Assembly. Nice, France.

RIMMER, A., BOGER, M., AOTA, Y. & KUMAGAI, M. 2007. System dynamics simulation tool to evaluate and predict lake salinization process. The IAHS meeting within the IUGG meeting. Perugia, Italy.

RIMMER, A. & LECHINSKI, Y. 2007. Decision Support System to predict long term salinity trends in Lake Kinneret. The IAHS meeting within the IUGG meeting. Perugia, Italy.

RIMMER, A. & SALINGAR, Y. 2006. Modelling precipitation-streamflow processes in large karst basin. European Geosciences Union General Assembly. Vienna.

RIMMER, A. & SALINGAR, Y. in press. Modelling precipitation-streamflow processes in Karst basin: The Jordan River sources. Water Engineering, fluids and irrigation.

SARAH, P. 2002. Spatial distribution of enzyme activity in the soil in different climatic zones. Isr. Geogr. Assoc. Annual Meeting. Be'er Sheva.

SCHACHT, K. 2010. GIS-based soil suitability risk assessment for wastewater reuse in the Middle East (Poster). Autumn School of the Marsilius College, University of Heidelberg: "Bridging the water gap – interdisciplinary perspectives". International Science Forum (IWH) at Heidelberg, Germany.

SCHACHT, K. 2010. Land evaluation for irrigation with treated wastewater (oral presentation). IWRM - Integrated Water Resources Management Karlsruhe, Germany.

SCHACHT, K., GÖNSTER, S., JÜSCHKE, E. & MARSCHNER, B. 2009. GIS-gestützte Risikobewertung der Bodeneignung für die Bewässerung mit Abwässern in Israel und dem Westjordanland. Böden - eine endliche Ressource. Bonn, Germany.

SCHACHT, K. & MARSCHNER, B. 2011. Benetzungshemmung nach Abwasserbewässerung in Israel - Bestimmung des Repellency Index mittels Mini-Disk-Infiltrometer. Jahrestagung der Deutschen Bodenkundlichen Gesellschaft. Berlin and Postdam.

SCHIFFERS, K. & TIELBÖRGER, K. 2003. Variation of interaction intensity among life history stages – an experimental approach with annual plants along a climatic gradient in Israel. Annual Meeting GFÖ Section Plant Population Biology. Copenhagen, Denmark.

SCHIFFERS, K. & TIELBÖRGER, K. 2004. Many small or few big neighbors? Spatial distribution of plant biomass affects interaction intensity. Annual Meeting GFÖ Section Plant Population Biology. Potsdam, Germany.

SCHLAFFER, S. & MENZEL, L. 2008. Interpolation of observed meteorological data on a high density grid in the Jordan River Region. GLOWA Jordan River Status Conference. Aqaba, Jordan.

SEILER, K.-P. 2004. The role of transient flow in regional flow pattern for water use. 33rd IAH Congress On Groundwater Flow Understanding from Local to Regional Scales. Zacatecas, Mexico.

SEITELBACH, S., REICHMANN, O., BRAND, S., HAIM, A., LITAOR, M. I. & SHENKER, M. 2002. Processes governing P release from rewetted soils of the Hula Valley. Lecture paper presented in the 32nd Annual Meeting of the Israel Society for Ecology and Environmental Quality Sciences (ISEEQS) Tel-Aviv, Israel.

SHADEED, S. & ALMASRI, M. 2007. Statistical Analysis of Long-Term Rainfall Data for a Mediterranean Semi-Arid Region: A Case Study from Palestine. Sustainable Development and Management of Water in Palestine, International Conference on Palestine Water. Amman, Jordan.

SHADEED, S. & J., L. 2009. Best Surface Water Management Options for Faria Catchment: Present Knowledge and Up to Date Modeling Capabilities. 2nd international conference, Water: Values and Rights. Ramallah, Palestine: Palestine Academy for Science and Technology.

SHADEED, S., JAYYOUSI, A., SHAHEEN, H., ALMASRI, M., LANGE, J., GUNKEL, A. & MENZEL, L. 2007. Project 5: Hydrological modelling in Faria catchment (posters). GLOWA Status Conference. Herrenberg.

SHADEED, S., JAYYOUSI, A. & SHAHEEN, H. Q. 2005. Probability Distribution of Faria-Catchment Rainfall.

Proceedings of the International Conference "Water: Values and Rights", Palestine Academy for Science and Technology (PALAST) and Palestinian Water Authority (PWA). Ramallah, Palestine.

SHADEED, S. & LANGE, J. 2009. Effects of Land Use and Climate Changes on Storm Runoff Generation in Arid and Semi-Arid Catchments: Up to Date Modeling Capabilities. 2nd international conference, Water: Values and Rights. Ramallah, Palestine: Palestine Academy for Science and Technology.

SHADEED, S., LANGE, J. & GUNKEL, A. 2008. Up To Date Hydrological Modeling in Arid and Semi-Arid Catchment, the Case of Faria Catchment, West Bank, Palestine. Geophysical Research Abstracts.

SHADEED, S. & SHAHEEN, H. 2007. GIS Based SCS-CN method for the Faria Catchment.Sustainable Development and Management of Water in Palestine. International Conference on Palestine Water. Amman, Jordan.

SHADEED, S., SHAHEEN, H. & JAYYOUSI, A. 2007. Management Options of Wadi Faria Baseflow. Proceedings of the 11th International Water Technology Conference (IWTC). Sharm Al-Sheikh, Egypt.

SHAHEEN, H. Q., JAYYOUSI, A., SHADEED, S. & JARRAR, A. 2005. Hydrograph Estimation in Semiarid Regions Using GIS supported GIUH Model. Proceedings of the 9th International Water Technology Conference IWTC Sharm Al-Sheikh, Egypt.

SHAMIR, S. & SHECHTER, M. 2003. Climate Change and Israeli Agriculture: An Economic Perspective. Agriculture, Climate Change and Economic Consequences: from Description to Mitigation. The Annual Meeting of European Phonological Network Meeting. Copenhagen.

SHECHTER, M. 2006. Economic assesment of climate-change impacts (Workshop). Workshop on the Economic implications of the Greenhouse Effect and Climate Change in Israel Aspects. Rehovot, Israel.

SHECHTER, M. & KAN, I. 2005. Economic Assessments of Climate Change Impact on Agriculture in a Semi-Arid Region. ICCAP Workshop. Kyoto, Japan.

SHECHTER, M., KAN, I. & FLEISCHER, A. 2006. The Economic Aspects of the Greenhouse Effect and Climate Change in Israel. Workshop on the Economic implications of the Greenhouse Effect and Climate Change in Israel Aspects. Rehovot, Israel.

SHECHTER, M. & KAN, I. A., O. 2004. Climate-Change Effects on Open-Space Land Use in Israel. Land Use and Land Cover Change (LUCC) Workshop: Integrated Assessment of the Land System: The Future of Land Use.

SHORE, L. S. 2004. Hormonal parameters of ecohydrology. Proc 4th Int'l Conf. Pharmaceutical and Endocrine Disrupting Chemical in Water. Minneapolis, MN, USA.

SHORE, L. S. & SHEMESH, M. 2002. Naturally Produced Steroid Hormones and their Release into the Environment. International SCOPE/IUPAC Symposium on Endocrine Active Substances. Kimron Veterinary Institute, Yokahama, Japan.

SHORE, L. S., SHEMESH, M., KRONFELD-SCHOR, N., BAREL-COHEN, K. & LITAOR, M. I. 2003. Measurement of natural and synthetic hormones in a watershed. Bestimmung natuerlicher und synthetischer Hormone zur Überwachung organischer Verunreinigungen in einem Wassereinzugsgebiet. Proceedings of the Workshop on Diffuse Input of Chemicals into Soil & Groundwater-Assessment & Management. Technische University Dresden, Dresden, Germany.

SHTIRBERG, I., T. DAYAN, M. STERNBERG, AND V. CHIKATUNOV. 2007. Biodiversity changes in two big beetle families: Carabidae and Tenebrionidae along a rainfall gradient in Israel. XIII European Carabidologist's Meeting. Blagoevgrad, Bulgaria.

SMIATEK, G., KUNSTMANN, H. & HECKL, A. 2011. High resolution climate change simulations for Eastern Mediterranean and Jordan River Region. Geophysical Research Abstracts. EGU2010-11251, EGU General Assembly 2010.

SOGAVKER, U. 2007. Ant-species richness along a productivity gradient: the importance of climate. Evolutionary and ecological consequences of global change workshop, Munich Graduate Program for Evolution, Ecology and Systematics (EES). Frauenchiemsee, Germany.

SOGAVKER, U. 2007. Food resources, foraging behavior and body-size variations in ant species along a productivity gradient. Plant Ecology Lab. Tübingen University, Germany.

SOGAVKER, U. 2007. Granivorous ant assemblages along a productivity gradient: variations in foraging behavior and effects on seed resources and vegetation structure. Plant Sciences Lab. Faculty of Agriculture, The Hebrew University, Israel.

STEINITZ, H., DAYAN, T. & YOM-TOV, Y. 2006. Predicting distributions of Israeli mammals under different climate change scenarios at the species and assemblage levels. Proceedings of the 43rd meeting of the Israeli Zoological Society.

STEINITZ, H., DAYAN, T. & YOM-TOV, Y. 2007. Predicting distributions of Israeli mammals under different climate change scenarios at the species and assemblage levels. Sixth Annual Conference on Active Research by Environmental Science Students.

STEINITZ, H., DAYAN, T. & YOM-TOV, Y. 2008. Projected Shifts In The Distribution Of Israeli Mammals In Different Climate Change Scenarios. Proceedings of the 45th meeting of the of the Israeli Zoological Society

STEINITZ, H., DAYAN, T., YOM-TOV, Y. & FERRIER, S. 2006. Snow Is White But Not All White Is Snow – The Logic Error Of Modeling The Effects Of Global Warming. Proceedings of the1st international workshop of modelling approaches in biodiversity research. Sede-Boqer.

STEINITZ, H., DAYAN, T. & YOM-TOV., Y. 2007. The Effects of Climate Change on the Distribution of Terrestrial Mammals in Israel.

STEINITZ, H. D., T.; YOM-TOV, Y.; ALPERT, P. 2006. Using Natural History Collections To Model Effects Of Climate Change On Mammal Distributions In Israel. Proceedings Of Global Environmental Change: Regional Challenges ESSP Open Science conference. Beijing, China.

STERNBERG, M. 2005. Is home the best place to decompose? Israel Society for Ecology and Environmental Quality Sciences. International conference: Living with Global Change: Challenges in Environmental Sciences. Weizmann Institute of Science, Rehovot, Israel.

STERNBERG, M., HOLZAPFEL, C., PARAG, H., KONSENS, I. & HAREL, D. 2006. Soil seed banks and climate change: an experimental approach along a climatic gradient in Israel. ESA 91st annual meeting. Memphis, USA.

STERNBERG, M., HOLZAPFEL, C., PARAG, H. A., TIELBÖRGER, K. & KIGEL, J. 2002. Climate control of annual-plant shrub coexistence. Annual Meeting of the Ecological Society of America. Tucson, USA.

STERNBERG, M., HOLZAPFEL, C., PARAG, H. A., TIELBÖRGER, K. & KIGEL, J. 2003. Climate control of annual-plant shrub coexistence. Oral contribution at the 32nd Annual Meeting of Israel Society of Ecology and Environmental Quality Science. Tel Aviv, Israel.

STERNBERG, M., HOLZAPFEL, C., TIELBÖRGER, K. & KIGEL, J. 2003. From Mediterranean to desert ecosystems: An integrated approach in climate change research. Invited talk, Conference of Frontiers of Sciences and Technology; US National Academy of Sciences. Istanbul, Turkey.

STERNBERG, M., TIELBÖRGER, K. & KIGEL, J. 2002. From Mediterranean to desert ecosystems: a new experimental approach for studying the effects of global climate change on plant community. 9th European Ecological Congress. Lund, Sweden.

STERNBERG, M., TIELBÖRGER, K. & KIGEL, J. 2003. From Mediterranean to desert ecosystems: a new experimental approach for studying the effects of global climate change on plant community. 32nd Annual Meeting of Israel Society of Ecology and Environmental Quality Science. Tel Aviv, Israel.

STERNBERG, M., TIELBÖRGER, K., KIGEL, J., JELTSCH, F. & KÖCHY, M. 2007. Vulnerability of eastern

Mediterranean ecosystems to climate change: lessons from an integrative study along an aridity gradient. EFIMED Annual Meeting. Palencia, Spain (invited keynote speaker).

STERNBERG, M., TIELBÖRGER, K., KIGEL, J., SARAH, P., LAVEE, H., JELTSCH, F. & KOECHY, M. 2005. From Mediterranean to desert ecosystems: an integrative approach for climate change research. Oral presentation at the 17th International Botanical Congress. Vienna, Austria.

SUPPAN, P., HECKL, A., KUNSTMANN, H., ALPERT, P. & KRICHAK, S. 2007. Climate Change in the Jordan River region. 2nd Scenario Panel Meeting of GLOWA Jordan River Hofgeismar.

SUPPAN, P., KUNSTMANN, H., ALPERT, P., KRICHAK, S. & KHATIB, I. 2006. Regional climate scenarios and modelling. 1st Scenario Panel Meeting of GLOWA Jordan River Waldeck, Deutschland.

SUPPAN, P., KUNSTMANN, H. & HECKL, A. 2006. Impact of Climate Change on Water Availability in the Near East. 3rd German-Arab Society Meeting Frankfurt a. M., Deutschland.

SUPPAN, P., KUNSTMANN, H., HECKL, A. & RIMMER, A. 2006. Coupled High Resolution Climate and Distributed Hydrological Simulations for the Eastern Mediterranean/Near East and the Upper Jordan Catchment. European Geosciences Union General Assembly. Vienna.

TIELBÖRGER, K. 2001. Einfluß von klimatischem Wandel auf verschiedene Ökotypen einjähriger Pflanzen entlang eines Klimagradienten: Ein Test von drei theoretischen Modellen. Annual Meeting GFÖ Section Desert Ecology. Leipzig, Germany.

TIELBÖRGER, K. 2007. Pride or prejudice- how interactions among plant determine the evolution of life histories. Invited keynote lecture. OPTIMA meeting. Pisa.

TIELBÖRGER, K. & ALPERT, P. 2005. GLOWA-Jordan River: Integrative science for managing the water crisis. Water Is Life – 40 Years of Diplomatic Relations Germany-Israel. Jerusalem, Israel.

TIELBÖRGER, K., KIGEL, J. & FLEISCHER, A. 2007. The response of Eastern Mediterranean ecosystems to climate change: lessons learned from the GLOWA Jordan River project. Invited talk. 30 years of binational collaboration Hohenheim-Rehovot. University of Hohenheim.

TIELBÖRGER, K. & PETRŮ, M. 2005. Maternal effects on seed germination of annual plants in variable environments. Annual Meeting GFÖ Section Plant Population Biology. Potsdam, Germany.

TIELBÖRGER, K. & STERNBERG, M. 2005. Green water and natural ecosystems under global change. Proceedings of theTropical Day 2005. Stuttgart-Hohenheim.

TIELBÖRGER, K., STERNBERG, M., BANGERTER, S., JELTSCH, F., KÖCHY, M., KIGEL, J., LAMPEI, C., LIANCOURT, P., MALKINSON, D., METZ, J., ORAN, S. & PRASSE, R. 2007. Fast response to land use change and slow response to climate change in eastern Mediterranean plant communities. GLOWA Jordan River Status conference. Herrenberg, Germany.

TIELBÖRGER, K., STERNBERG, M., KÖCHY, M., PETRŮ, M., ARIZA, C., KIGEL, J. J., F., PARIENTE, S., LAVEE, H. & FLEISCHER, A. 2005. Vulnerability of Eastern Mediterranean ecosystems to climate change: lessons from an integrative study along a steep climatic gradient. Annual Meeting GFÖ. Regensburg, Germany.

TIELBÖRGER, K., STERNBERG, M., ORAN, S. & AL., E. 2006. Developing management strategies of Mediterranean plant communities to global change- an integrated approach. GLOWA Jordan River Status conference. Esslingen, Germany.

TIELBÖRGER, K. & VALLERIANI, A. 2004. Can seeds predict their future? Maternal effects on annual plant germination enable escape from over-crowding. Annual Meeting GFÖ Section Plant Population Biology. Regensburg, Germany.

TIETJEN, B. 2007. Modelling sustainable management of semi-arid and arid grazing systems under climate change. Yearly campus of Heinrich-Böll-Foundation "The future of labour". Bad Bevensen, Germany.

TIETJEN, B., JELTSCH, F. & ZEHE, E. 2006. Semi-arid grazing systems under climate change – present model shortcomings and ways to handle them. Jahrestreffen der Gesellschaft für Ökologie. Bremen.

TÖRNROS, T. 2010. Precipitation trends and suitable drought index in the arid/semi-arid southeastern Mediterranean region. Proc. of the Sixth World FRIEND Conference. Global Change: Facing Risks and Threats to Water Resources. IAHS Publ. Fez, Morocco

TWITE, R. 2010. The Management of Water in the Jordan Basin, Adaptation to Climate Change. The Third International Conference on Drylands, Deserts and Desertification: The Route to Restoration. Sede Boqer Campus, Israel.

TZVIKEL, S. & SARAH, P. 2002. Seasonal variability of soil soluble salts along a climatological gradient. Isr. Geogr. Assoc. Annual Meeting. Be'er Sheva, Israel.

TZVIKEL, S., SARAH, P. & LAVEE, H. 2003. Spatio-temporal changes in Arylsulfatase activity in soils along climatic gradient in Israel. Isr. Geogr. Assoc. Annual Meeting. Ramat Gan, Israel.

WEIß, M. 2006. Model-based scenarios of Mediterranean Droughts. 8th EGU Plinius Conference on "Mediterranean Storms and Extreme Events in an Era of Climate Change". Dead Sea, Israel.

WEIß, M., KOCH, J., SCHALDACH, R., ONIGKEIT, J. & MENZEL, L. 2006. Vulnerability and Management of Water Resources in Eastern Mediterranean Ecosystems. Global Environmental Change: Regional Challenges. An ESSP Global Environmental Change Open Science Conference. Beijing, China.

WEIß, M. & MENZEL, L. 2007. First steps towards an improvement of the modelling of evapotranspiration in semi-arid areas with global models (in German). Workshop „Fortschritt und Visionen in der großskaligen hydrologischen Modellierung". Frankfurt/M.

WEIß, M. & MENZEL, L. 2008. Potential and actual evapotranspiration in the Jordan River Region. GLOWA Jordan River Status Conference. Aqaba, Jordan.

WOLFF, H.-P. 2005. GLOWA Jordan River - Challenges and Approaches in Building the Bridge on Water-Related Research between Socio-Economists and Natural Scientists in a Multi-National Environment. Deutscher Tropentag 2005, The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies. University of Hohenheim.

WOLFF, H.-P. 2007. Transboundary water governance in the socio-economic watershed of the Jordan Valley - a way from conjoint research to dissemination among national decision makers (poster presentation). Inauguration ceremony of the North-South-Centre. Swiss Federal Institute (ETH) Zurich.

WOLFF, H.-P., DOPPLER, W. & NABULSI, A. 2005. Shifting the Focus of Research on Water Resources Management from Natural to Socio-Economic Watersheds - The Conceptual Framework of a Research Network on Water Questions in the Jordan Valley. Deutscher Tropentag 2005, The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies. University of Hohenheim.

WOLFF, H.-P., DOPPLER, W. & SALMAN, A. Z. 2006. Widening the scope of IWRM from natural to socio-economic watersheds - the conceptual framework of a research network in the Jordan Valley. World Water Week in Stockholm, Beyond the River - Sharing Benefits and Responsibilities. Stockholm International Water Institute.

WOLFF, H.-P. & HIJAWI, T. 2006. Socio-economics of the preservation of Palestinian agro-biodiversity (Guest lecture). PARC, training center Jenin, PA.

WOLFF, H.-P., SHECHTER, M., FLEISCHER, A., SALMAN, A. Z., HIJAWI, T. & KAN, I. 2007. Evaluation of socio-economic consequences from changing water availability in the Jordan Valley- an example of shared cross-border water resources. World Water Week in Stockholm, Beyond the River - Sharing Benefits and Responsibilities. Stockholm International Water Institute.

WOLFF, H.-P., SHECHTER, M., FLEISCHER, A., SALMAN, A. Z., HIJAWI, T. & KAN, I. 2007. Forecasting social and economic impacts from Climate Change on farming systems in riparian countries of the Jordan River – a combined model-based approach. In: TIELKES, E. (ed.) Tropentag 2007: Utilisation of diversity in land use systems: Sustainable and organic approaches to meet human needs. Universities of Kassel and Goettingen.

WOLFF, H.-P., SHECHTER, M., SALMAN, A., HIJAWI, T., FLEISCHER, A., KARABLIEH, E., KAN, I. & BECKER, N. 2007. Preliminary Estimations on Development in Rural Areas under different Scenario Assumptions and Climate Change. Stakeholder conferences of GLOWA Jordan River 2007. Dead Sea.

WOLFF, H.-P., SHECHTER, M., SALMAN, A., HIJAWI, T., FLEISCHER, A., KARABLIEH, E., KAN, I. & BECKER, N. 2007. Socio-economic consequences of changes in frame conditions for the agricultural sector. Stakeholder conferences of GLOWA Jordan River 2007. Kassel.

YAKIR, D. & AL, E. 2006. Lessons from the edge of forestation (Symposium talk). ILEAPS science conference Boulder CO.

Books and book chapters

ALCAMO, J. 2008. The SAS Approach: Combining qualitative and quantitative knowledge in environmental scenarios. In: ALCAMO, J. (ed.) Environmental Futures: The Practice of Environmental Scenario Analysis. Amsterdam: Elsevier.

ALPERT, P. 2004. The water crisis in the Eastern Mediterranean - and relation to global warming? . In: ZEREINI, F. & JAESCHKE, W. (eds.) Water in the Middle East and in North Africa - Ressources, Protection and Management. Berlin: Springer Verlag.

ALPERT, P., BALDI, M., ILANI, R., KRICHAK, S. O., PRICE, C., RODÓ, X., SAARONI, H., ZIV, B., KISHCHA, P., BARKAN, J., MARIOTTI, A. & XOPLAKI, E. 2006. Relations between climate variability in the Mediterranean region and the tropics: ENSO, South Asian and African Monsoons, Hurricanes and Saharan dust. In: LIONELLO, P., MALANOTTE-RIZZOLI, P. & BOSCOLO, R. (eds.) Mediterranean climate variability. Amsterdam: Elsevier.

ALPERT, P. & SHAFIR, H. 2006. Global climate change affects desert climate. In: Safriel U (lead author) Chapter 3: Deserts and the Planet - Linkages between Deserts and Non-Deserts / The Physical Tele-Connections - Climate, Dust and Rivers / Desert and Global Climate. In: EZCURRA, E. (ed.) Global Deserts Outlook. Earthprint.

ALPERT, P. & SHOLOKHMAN, T. (eds.) 2011. Factor separation in the atmosphere, applications and future prospects, Cambridge: Cambridge University Press.

CHEN, Y., DOSORETZ, C., KATZ, I., MARSCHNER, B., JÜSCHKE, E. & TARCHITZKY, J. 2010. Organic matter in wastewater and treated wastewater irrigated soils: properties and effects. In: G.J. LEVY, P. F. A. A. B.-T. (ed.) Treated Wastewater in Agriculture: Use and Impact on the Soil Environment and Crops. Oxford, U.K: Blackwell Publishing Ltd.

FLEISCHER, A., KURUKULASURIYA, P. & MENDELSOHN, R. 2011. Reducing the impact of global climate change on agriculture – the use of endogenous irrigation and protected agriculture technology. In: DINAR, A. & MENDELSOHN, R. (eds.) Handbook on Climate Change and Agriculture. Edward Elgar Publishing.

GARRIDO, A. & DINAR, A. (eds.) 2009. Managing water resources in a time of global change Oxon: Routledge.

GOPHEN, M. 2004. Hydrology and management of Lake Kinneret aimed at water quality protection. In: ZEREINI, F. & JAESCHKE, W. (eds.) Water in the Middle East and in North Africa: Resource, protection and management. Heidelberg: Springer.

GOPHEN, M. 2004. Water utilization in semi-arid zone, the Hula Valley (Israel): Pollutant removal, agriculture and ecotourism management. In: ZEREINI, F. & JAESCHKE, W. (eds.) Water in the Middle East and in North Africa: Resources, protection, and management. Heidelberg: Springer.

GOPHEN, M. 2008. Climatological and anthropogenic influence on biodiversity in Lake Kinneret (Israel). In: JONES, J. (ed.) International Association of Theoretical and Applied Limnology, Vol 30, Pt 3, Proceedings. E Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

GOPHEN, M. 2008. Long term (1970 – 2001) eco–hydrological processes in Lake Kinneret and its watershed. In: ZEREINI, F. & HÖTZL, H. (eds.) Climatic changes and water resources in the Middle East and North Africa. Berlin Heidelberg: Springer

HOFF, H. 2009. Challenges in upland watershed management: the green-blue water approach. In: GARRIDO, A. & DINAR, A. (eds.) Managing water resources in a time of global change: mountains, valleys and flood plains. Oxford: Routledge Chapman & Hall.

HOFF, H., KÜCHMEISTER, H. & TIELBÖRGER, K. 2006. The GLOWA Jordan River Project - Integrated Research for Sustainable Water Management. In: BECK, M. B. & SPEERS, A. (eds.) 2nd IWA Leading-Edge on Sustainability in Water-Limited Environments. IWA Publishing.

KOCH, J., WIMMER, F., ONIGKEIT, J. & SCHALDACH, R. 2012. An integrated land-use system model for the Jordan River region. In: APPIAH-OPOKU, S. (ed.) Environmental Land Use Planning. Rijeka: InTech Open Science.

KRICHAK, S. O., ALPERT, P. & KUNIN, P. 2009. Projections of climate change over non-boreal East Europe during first half of the twenty-first century according to results of a transient RCM experiment. In: GROISMAN, P. Y. & IVANOV, S. (eds.) Regional aspects of climate-terrestial-hydrologic interactions in non-boreal Eastern Europe. Springer Science + Business Media B.V.

KUNSTMANN, H. 2007. Regionale Auswirkung der Klimaänderung auf die Wasserverfügbarkeit in klimasensitiven Gebieten. In: ENDLICHER, E. & GERSTENGARBE, F.-W. (eds.) Der Klimawandel – Einblicke, Rückblicke, Ausblicke. Potsdam.

LAHAV, O., KOCHVA, M. & TARCHITZKY, J. 2010. Potential drawbacks associated with agricultural irrigation with treated wastewaters from desalinated water origin and possible remedies Water Science & Technology. IWA Publishing 2010 .

LOZÁN, J., GRAßL, H., HUPFER, P., MENZEL, L. & SCHÖNWIESE, C.-D. (eds.) 2007. Global change: Enough water for all? , Hamburg: Wissenschaftliche Auswertungen und GEO-Verlag.

MCNEILL, L., ALMASRI, M. & MIZYED, N. 2010. A Sustainable Approach For Reusing Treated Wastewater In Agricultural Irrigation In The West Bank -Palestine. Desalination. Edinburgh,Scotland,UK.

MENZEL, L. 2010. Wasser als limitierender Entwicklungsfaktor. In: STRIGEL, G., EBNER VON ESCHENBACH, A.-D. & BARJENBRUCH, U. (eds.) Wasser - Grundlage des Lebens: Hydrologie für eine Welt im Wandel. Stuttgart: Schweizerbart.

MENZEL, L. 2011. Globaler Wandel, extreme hydrologische Ereignisse und Strategien zum Umgang mit Hochwasser und Dürre. In: LOZÁN, J., GRAßL, H., HUPFER, P., KARBE, L. & SCHÖNWIESE, C.-D. (eds.) Warnsignal Klima - Genug Wasser für alle? 3 ed.: Climate Service Center Germany.

MENZEL, L. & TÖRNROS, T. 2012. The water resources of the Eastern Mediterranean: Present and future conditions. In: RAUSCH, R., SCHÜTH, C. & HIMMELSBACH, T. (eds.) Hydrogeology of arid environments (Proceedings). Stuttgart: Borntraeger Science Publishers.

NABULSI, A. H. 2007. Socio-economic impacts of water availability and prices on farming systems – The case of the Eastern Jordan Valley. In: DOPPLER, W. & BAUER, S. (eds.) Farming & rural systems economics. Weikersheim: Margraf.

OROUD, I. M. 2012. Climate change impacts on green water fluxes in the Eastern Mediterranean. In: LEAL FILHO, W. (ed.) Climate change and the sustainable use of water resources. Berlin, Heidelberg: Springer.

OROUD, I. M. 2012. Relative impacts of climate change on water resources in Jordan. In: FERNANDO, H. J. S., KLAIĆ, Z. & MCCULLEY, J. L. (eds.) National security and human health implications of climate change. Springer Science+Business Media B.V.

SALMAN, A., KARABLIEH, E., WOLFF, H.-P., FISHER, F. M. & HADDADIN, M. J. 2006. The economics of water in Jordan. In: HADDADIN, M. J. (ed.) Water Resources in Jordan. Washington D.C.: Resources for the

Future (RFF).

SCHACHT, K., GÖNSTER, S., JÜSCHKE, E. & MARSCHNER, B. 2010. Land evaluation for irrigation with treated wastewater. In: STEUSLOFF, H. (ed.) Integrated Water Resources Management. Karlsruhe: KIT.

SHECHTER, M. 2003. Water in an era of peace: water need not create an economic 'short-circuit'. In: YANIV, N. & MARKS, E. (eds.) Beyond Peace: The Urgent Tasks of Israeli Society. Tel-Aviv: Tel-Aviv University.

SHECHTER, M. & GIUPPONI, C. (eds.) 2003. Climate change in the Mediterranean: Socio-economic perspectives of impacts, vulnerability and adaptation, Cheltenham, UK: Edward Elgar Publishing.

SHECHTER, M. & YEHOSHUA, N. 2002. Exploratory economic assessments of climate change impacts in Israel: agriculture. In: BENISTON, M. (ed.) Climate change: Implications for the hydrological cycle and for water management. Springer.

SHOLOKHMAN, T. & ALPERT, P. 2007. Factor separation in atmospheric modelling-a review. In: EBEL, A. & DAVITASHVILI, T. (eds.) Air, water and soil quality modelling for risk and impact assessment. Springer Netherlands.

STERNBERG, M., HOLZAPFEL, C., TIELBÖRGER, K., SARAH, P., KIGEL, J., LAVEE, H., FLEISCHER, A., JELTSCH, F. & KÖCHY, M. 2011. The use and misuse of climatic gradients for evaluating climate impact on dryland ecosystems - an example for the solution of conceptual problems. Combining 'space for time' with experiments and modeling: a novel gradient approach to integrated climate change research. In: BLANCO, J. & KHERADMAND, H. (eds.) Climate Change - Geophysical Foundations and Ecological Effects. InTech.

SUPPAN, P., KUNSTMANN, H., HECKL, A. & RIMMER, A. 2008. Impact of climate change on water availability in the Near East. In: ZEREINI, F. & HÖTZL, H. (eds.) Climatic changes and water resources in the Middle East and in North Africa. Berlin Heidelberg: Springer.

TRIGO, R., XOPLAKI, E., ZORITA, E., LUTERBACHER, J., KRICHAK, S. O., ALPERT, P., JACOBEIT, J., SÁENZ, J., FERNÁNDEZ, J., GONZÁLEZ-ROUCO, F., GARCIA-HERRERA, R., RODO, X., BRUNETTI, M., NANNI, T., MAUGERI, M., TÜRKEŞ, M., GIMENO, L., RIBERA, P., BRUNET, M., TRIGO, I. F., CREPON, M. & MARIOTTI, A. 2006. Relations between variability in the Mediterranean region and mid-latitude variability. In: LIONELLO, P., MALANOTTE-RIZZOLI, P. & BOSCOLO, R. (eds.) Mediterranean Climate Variability. Amsterdam: Elsevier.

YAKIR, D. 2003. The stable isotopic composition of atmospheric CO2. In: KEELING, R. F. (ed.) The atmosphere. Elsevier.

YEHOSHUA, N. & SHECHTER, M. 2003. Climate change and agriculture: an Israeli perspective. In: GIUPPONI, C. & SHECHTER, M. (eds.) Climate change in the Mediterranean: socio-economic perspectives of impacts, vulnerability and adaptation. Edward Elgar Publishing Ltd.

Conference abstracts and proceedings

ABU SADAH, M. 2009. Application of WEAP-MODFLOW in the Western Aquifer Basin, Palestine. First Arab WEAP conference. Damascus, Syria.

ABU SHABAN, A., DOPPLER, W. & WOLFF, H.-P. 2005. Consumers' Attitude and Farmers' Situation with Regard to Agricultural Production with Treated Wastewater in the Northern Gaza Strip Deutscher Tropentag 2005, The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies. University of Hohenheim.

ABU SHABAN, A., DOPPLER, W. & WOLFF, H.-P. 2005. Trade-Offs of Using Treated Wastewater in Irrigated Agriculture - The Case of Gaza Strip. Deutscher Tropentag 2005, The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies. University of Hohenheim.

ABU SHABAN, A., DOPPLER, W. & WOLFF, H.-P. 2006. Determinants of Farmers' Acceptance of Treated

Wastewater in Irrigated Agriculture in the Northern Gaza Strip. In: ASCH, F. & BECKER, M. (eds.) Tropentag 2006: Prosperity & Poverty in a globalized world: Challenges for Agricultural Research. University of Bonn.

AGAM, N., RAZ-YASEEF, N., ROTENBERG, E. & YAKIR, D. 2006. The relative contribution of the uppermost soil layer to the total soil heat flux at different timescales. 1st iLEAPS Science Conference. Boulder, Colorado.

ALCAMO, J. 2005. Scenarios for the Glowa-Jordan River Project: The Story and Simulation approach. Glowa-JR Planning Meeting. Cologne, Germany.

ALCAMO, J. 2007. GLOWA Jordan River. Phase III GLOWA Jordan River Project: The way forward with regional strategies and user support. GLOWA JR Status Conference. Herrenberg, Germany.

ALCAMO, J. 2008. The GLOWA Jordan River Project: Global change science for integrated water resources management. Global Catchment Initiative Expert Meeting. Global Water System Project. Bonn.

ALCAMO, J. 2008. The usefulness of scenario analysis in international environmental assessments. Fachgespräch: Szenarien – Rolle, Leistungsfähigkeit, Perspektiven. CESR, University of Kassel, Germany.

ALCAMO, J., KOCH, J., LÜBKERT, B. & ONIGKEIT, J. 2006. The Glowa-JR scenario exercise. Glowa-JR Advisory Committee Meeting. Reichenau, Germany.

ALCAMO, J., KOCH, J., LÜBKERT, B., ONIGKEIT, J. & SCHALDACH, R. 2007. Project 1 Integration: Regional scenario analysis and land cover modelling. GLOWA JR Status Conference. Herrenberg, Germany.

ALFARRA, A., KEMP-BENEDICT, E., HÖTZL, H., SADER, N., SONNEVELD, B., ALI, W. & WOLF, L. 2009. Simulation of Water Supply and Demand in the Jordan Valley Region using WEAP21: Initial Results. First Arab WEAP conference. Damascus, Syria.

ALMASRI, M. 2009. Application of WEAP-MODFLOW in the Eocene Aquifer Basin, Palestine. First Arab WEAP conference. Damascus, Syria.

ALPERT, P. 2005. Assessment of Global Warming Impacts on Water Availability in the Jordan River Basin (GLOWA-Jordan River)-Regional Climate Modeling and Dynamical Downscaling for Global Warming Scenario. NATO Advanced Research Workshop, Air, Water and Soil Quality Modelling for Risk and Impact Assessment. Tabakhmela (near Tbilisi), Georgia.

ALPERT, P. 2006. Climate change toward increased aridity. Advanced International Postgraduate Course on Integrated Approach and Sustainable Management of Adverse Climate Changes, Drought and Desertification. Tal Hotel, Tel Aviv, Israel.

ALPERT, P. 2006. The ECHAM4/OPYC3 and HadCM3 simulations of the E. Mediterranean climate vs NCEP/NCAP reanalysis over 1960–1990 based on the regional synoptic systems. The Annual Conference of the Israeli Meteorological Association. Bazel Hotel, Tel Aviv, Israel.

ALPERT, P. 2006. Review Lectures on GLOWA-JR: Hebrew University – 5 January 2006. Environmental Conference. Tel-Aviv University.

ALPERT, P. 2007. Dan David Prize Events, Symposium on Global Warming and Renewable Energy. Tel Aviv University, Tel Aviv, Israel.

ALPERT, P. 2007. Rising technologies - New horizons in the 21st century, Aircraft house. Herzelia, Israel.

ALPERT, P. 2007. WATEC Israel 2007, The 4th International Exhibition of Water Technology and Ecology. Ganei Hataaroha Exhibition Center, Tel Aviv Israel.

ALPERT, P. 2007. GLOWA Jordan River, 3rd Scenario Panel Meeting. Dead Sea Jordan.

ALPERT, P. 2007. Climate Change and Impact Research: The Mediterranean Environment. Kick-off Meeting. Bologna, Italy.

ALPERT, P. 2007. Climatic trends to extremes and regional modeling over the E. Mediterranean. RIHN-Research Project ICCAP. Kyoto Symposium, Japan.

ALPERT, P. 2007. Teleconnection and the horizontal scale, Connections between Mediterranean and global climate variability. ESF-MedCLIVAR 2nd workshop. La Londes les Maures, Toulon, France.

ALPERT, P., KISHCHA, P., KAUFMAN, Y. J., BARKAN, Y. & SCHWARZBARD, R. 2006. Global dimming or local dimming?: The large cities contribution. 2nd International Conference on Global Warming and the Next Ice Age and Aerosol Workshop on Climate Prediction Uncertainties. Santa Fe, NM, USA.

ALPERT, P., KITOH, A., YATAGAI, A., KRISCHAK, S., KUNIN, P. & JIN, F. 2008. First super-high-resolution modeling study that the ancient "Fertile Crescent" will disappear in this century and comparison to regional climate models. EGU General Assembly. Vienna, Austria.

ALPERT, P., KRICHAK, S. O. & DAYAN, M. 2004. Regional climate downscaling over the E. Mediterranean – Preliminary results. Proceedings of the International Workshop for the Research Project on the Impact of Climate Change on Agricultural Production System in Arid Areas (ICCAP). Cappadocia, Turkey.

ALPERT, P., KRICHAK, S. O., OSETINSKY, I., DAYAN, M., HAIM, D. & SHAFIR, H. 2006. Climatic trends to extremes and regional modeling over the Eastern Mediterranean. Proceedings of the International Conference on Climate Change and the Middle East, Past, Present and Future. Istanbul, Turkey.

ALPERT, P., KRICHAK, S. O., OSETINSKY, I., DAYAN, M., HAIM, D. & SHAFIR, H. 2006. Climatic trends to extremes and regional modeling over the Eastern Mediterranean. Proceeding of the International Conference on Climate Change and the Middle East, Past, Present and Future. Technical University, Istanbul, Turkey.

ALPERT, P., MESSER, H. & ZINEVICH, A. 2006. Environmental monitoring by cellular networks. 8th EGU Plinius Conference on Mediterranean Storms and Extreme Events in an Era of Climate Change. Dead-Sea, Israel.

ALPERT, P., OSETINSKY, I., ZIV, B. & SHAFIR, H. 2003. Objectively classified synoptic systems as a tool for climate change analysis: Application to the eastern Mediterranean. EGS-AGU-EUG Joint Assembly. Nice, France.

ALPERT, P. & RAYITSFELD, A. 2008. Rainfall analysis using cellular networking measurements. EGU General Assembly. Vienna, Austria.

ALPERT, P., RAYITSFELD, A., DAVID, N., GOLDSHTEIN, O., MESSER, H. & ZINEVICH, A. 2009. Recent findings with rainfall monitoring by cellular communication systems. Geosciences Union General Assembly. Vienna, Austria.

ALPERT, P., SHAFIR, H., KRICHAK, S. O., OSETINSKY, I., DAYAN, M. & HAIM, D. 2007. Climatic trends to extremes employing regional modeling and statistical interpretation over the Eastern Mediterranean. 9th EGU Plinius Conference Mediterranean Storms. Varenna Italy.

ALPERT, P. & SILVERMAN, D. 2003. Vulnerability of water resources in eastern Mediterranean ecosystems due to climate change – an integrated approach to sustainable management. AMS Conference. Long Beach, California, USA.

ALPERT, P., ZINEVICH, A., RAYITSFELD, A., DAVID, N. & MESSER, H. 2008. Recent advances in measuring rainfall by commercial microwave communication networks (solicited). EGU General Assembly. Vienna, Austria.

ARIZA, C. & TIELBÖRGER, K. 2007. Adaptation to biotic and abiotic conditions along an environmental gradient. StEve meeting. Tübingen.

ARIZA, C. & TIELBÖRGER, K. 2007. Do interactions among plants determine successful range shifts under climate change? International workshop colonization versus invasion: do the same traits matter? Towards a joint perspective in research on range expansion of native and biological invasion of non-indigenous plants. Ascona, Switzerland.

ARIZA, C. L. & TIELBÖRGER, K. 2005. Ecotypic variation in competitive abilities along a rainfall gradient in

Israel. XVII International Botanical Congress. Vienna, Austria.

BADECK, F.-W. & TIELBÖRGER, K. 2005. Global Change Ecology (Symposium Summary).

BANGERTER, S., LIANCOURT, P. & PRASSE, R. 2007. Evaluation of restoration measures of degraded semi-arid rangelands under climate change in Jordan. 37th Annual Conference of the Ecological Society of Germany, Switzerland and Austria (GfÖ). Marburg, Germany.

BEN-ASHER, J. & AL., E. 2007. Two posters presented at the annual meeting of the Israeli Society of Geography.

BEN-ASHER, J. & AL., E. 2007. Presentation during the annual meeting of the American Society of Agronomy.

BEN-ASHER, J. & AL., E. 2007. Presentation during the annual workshop of the Japanese project ICCAP (Impact of Climate Change on Agricultural Production).

BEN-ASHER, J., EVRENDILEK, F., AYDIN, M., MENZEL, L. & ALPERT, P. 2004. Climate Change in the Eastern Mediterranean and Agriculture. Proc. Int. Workshop on the Impact of Climate Change on Agricultural Production Systems in Arid Areas (ICCAP). Cappadokya, Turkey.

BEN-ASHER, J., MUSSARI, A., KAFKAFI, U. & JESUS, J. 2003. New approach for large scale experimental research in agriculture and ecology. Proceding of the International Workshop for Research Project on the Impact of Global Climate Change on Agricultural Production Systems in Arid Areas (ICCAP) Kyodai Kaikan., Kyoto, Japan

BERLINER, P. R. 2007. Afforestation and sustainable forests as a means to combat desertification. . Role of water quantity and quality in dry land forest sustainability, IUFRO Conference. Jerusalem, Israel.

BONZI, C., HOFF, H., STORK, J., SUBAH, A., WOLF, L. & TIELBÖRGER, K. 2010. WEAP for IWRM in the Jordan River Region; Bridging between scientific complexity and application. Integrated Water Resources Management. Karlsruhe.

DANIELS, J. & ALPERT, P. 2005. Overview of the GLOWA Jordan River Project. Water is Life – 40 Years of Diplomatic Relations Germany-Israel Conference. International Convention Center Jerusalem, Israel.

DISEGNI, D. M., SHECHTER, M., & STERNBERG, M 2010. Estimating the Economic Value of Climate Change effect on ecosystem services via fluctuations in Genuine Saving Indicator of Sustainability. 12th Annual BIOECON Conference "From the Wealth of Nations to the Wealth of Nature: Rethinking Economic Growth". Venice, Italy.

EBERHARDT, A. & TIELBÖRGER, K. 2006. An experimental test of the sib-competition hypothesis along a climatic gradient. Annual meeting of the Plant Population Biology Group. Halle, Germany.

EVRENDILEK, F., BEN-ASHER, J., AYDIN, M. & ELIKD, I. 2004. Diurnal CO2 fluxes of different Seyhan Watershed Ecosystems. Proceeding of the International Workshop for the Research Project on the Impact of Climate Change on Agriculture Production System in Arid Areas (ICCAP) Cappadokya; Turkey.

FISCHER, C., GUNKEL, A., LANGE, J., MENZEL, L., GRODEK, T., LEKACH, J. & MORIN, E. 2007. Application of the TRAIN-ZIN model to Nahal Harod, Israel: runoff generation and impact of urbanization (posters). GLOWA Status Conference. Herrenberg.

GEISSLER, K., KÖCHY, M., JELTSCH, F. 2010. Response of dryland natural vegetation to simulated change of climate and land use. Latsis Symposia. Lausanne, Switzerland.

GEISSLER, K., KÖCHY, M., JELTSCH, F. 2010. Response of dryland natural vegetation to simulated change of climate and land use. GfÖ Conference. Gießen, Germany.

GOPHEN, M. 2007 (in press). Lake Management Perspectives in Arid, Semi-Arid, Sub-Tropical and Tropical Dry climate. Proceedings of the 12th International Lake Conference. Jaipur, India.

GUETA, Y., KROTMAN, Y. & GOREN, M. 2004. The rainbow trout as an intruder species in the Jordan Valley. 41st Conference of the Zoological Society of Israel. Haifa

GUNKEL, A., LANGE, J., MENZEL, L. & WIESENDANGER, C. 2007. Development of a new modelling tool as starting point for water management in the lower Jordan river catchment. Geophysical Research Abstracts

HAERING, M., SALMAN, A., AL-KARABLIEH, E., GAESE, H. & AL-QUR'AN, S. 2009. Predicted unmet irrigation demands due to climate change in the lower Jordan river basin. First Arab WEAP conference. Damascus, Syria.

HAIM, D., SHECHTER, M. & BERLINER, P. 2006. Economic impacts of climate change on Israeli Agriculture (Poster). GLOWA meeting. Esslingen.

HAIM, D., SHECHTER, M. & P., B. 2006. Economic impacts of climate change on Israeli agriculture. Third World Congress of Environmental and Resource Economists. Kyoto, Japan.

HAIM, D., SHECHTER, M. & P., B. 2006. Economic impacts of climate change on Israeli agriculture. UN-CCD: International Conference on Deserts and Desertification: Challenges and Opportunities. Sede Boqer, Israel.

HAREL, D., STERNBERG, M., METZ, J. & TIELBÖRGER, K. 2007. Seed bank and annual plant communities responses to short-term climate change. Poster presentation. GLOWA Jordan River Status Conference. Herrenberg, Germany.

HARTMANN, A., LANGE, J. & RIMMER, A. 2009. Applied dual porosity concept for large karst basins in the east Mediterranean. European Geosciences Union General Assembly. Vienna, Austria

HARTMANN, A., RIMMER, A. & LANGE, J. 2008. HYMKE_DUAL: Modelling of the Mt. Hermon hydrological system based on karst specific processes. GLOWA JR Status Conference. Aqaba, Jordan.

HECKL, A. 2007. Auswirkung der Klimaänderung auf die Wasserverfügbarkeit im oberen Jordan Einzugsgebiet. Doktorandenseminar des IMK-IFU mit Universität Stuttgart und UniBW München. Schluchsee-Seebrugg.

HECKL, A. 2007. Klimaänderung im Nahen Osten und Auswirkung auf die Wasserverfügbarkeit im oberen Jordan Einzugsgebiet. Doktorandencolloquium am Institut für Geographie, Universität Augsburg.

HECKL, A. & KUNSTMANN, H. 2007. Climate Change in the Jordan River region. 3rd Scenario Panel Meeting of GLOWA Jordan River. Sweihmeh, Jordan.

HIJAWI, T. 2002. Economics analysis of water quality in farming system development, the case of Al Faria'a Basin- western of the Jordan Valley Deutscher Tropen Tag (DTT). Kasel, Germany.

HIJAWI, T. 2002. Economics and Management of water Reuse in Agriculture, the case of Al Faria'a basin-western of the Jordan valley. 5th IFSA European Symposium on Farming and Rural Systems Research and Extension. Florence, Italy.

HIJAWI, T. 2002. Potential of GIS Analysis in Farming System Development: a case study of Al Faria'a Basin-west of the Jordan Valley. 5th IFSA European Symposium on Farming and Rural Systems Research and Extension. Florence, Italy.

HOFF, H., CLAUS, C. & TIELBOERGER, K. 2005. GLOWA Jordan River Project - Global Change Research for Integrated Water Resources Management. In: KHATIB, I., ASSAF, K., CLAEYS, D. & AL HAJ DAOUD, A. (eds.) Proceedings of the International Conference on Water Values and Rights. Ramallah, Palestinian Authority.

HOFF, H., TIELBÖRGER, K. & ALCAMO, J. 2005. Proceeding of the Integrated Science for Sustainable Water Management in the Jordan River Basin. In: TIELKES, E. & AL., E. (eds.) Tropentag 2005. Hohenheim, Germany.

HOLZAPFEL, C. & STERNBERG, M. 2004. To stay at home or to see the world? Climate versus biotic control of plant coexistence. 89 Ecological Society of America Annual Meeting. Oregon, USA.

HOLZAPFEL, C., TIELBOERGER, K., HOBBHAHN, N., PETRU, M. & STERNBERG, M. 2006. Sex and climate change: sex ratio responses to experimental rainfall scenarios in an Israeli shrub. ESA 91st annual meeting. Memphis, USA.

JAYYOUSI, A. F. & ALMASRI, M. N. 2010. The Use of Water Allocation Models in Managing Trans-boundary Water Resources: A Case from Palestine. International Conference "Transboundary Aquifers: Challenges and New Directions"(ISARM 2010). Paris, France.

JELTSCH, F., KÖRNER, K., SCHIFFERS, K., SCHURR, F. & KÖCHY, M. 2005. Plant population modelling –quo vadis? (Invited lecture). GFÖ Section Plant Population Biology. Potsdam, Germany.

JÜSCHKE, E. & MARSCHNER, B. 2003. Effects of treated wastewater irrigation on the amount and properties of dissolved organic matter in Israeli soils – first steps of the project. 9th Nordic IHSS Symposium. Sundsval, Sweden.

JÜSCHKE, E. & MARSCHNER, B. 2005. Veränderung der mikrobiellen Aktivität in Böden unter Abwasserberegnung. Poster contribution on the Annual meeting of the Deutsche Bodenkundliche Gesellschaft 2005. Marburg.

JÜSCHKE, E. & MARSCHNER, B. 2006. Effects of effluent irrigation on the carbon dynamics in soils of the Middle East. Oral paper presentation on EMWater Regional Conference "Efficient Management of Wastewater Treatment and Reuse in the Mediterranean Countries". Amman, MEDA Water, InWent.

JÜSCHKE, E. & MARSCHNER, B. 2006. Long-term influence of effluent irrigation on organic matter in Israeli soils. Poster presentation on IHSS 13th International Conference "Humic Substances – Linking Structure to Functions". Karlsruhe.

JÜSCHKE, E., MARSCHNER, B., TARCHITZKY, J. & CHEN, Y. 2004. Chemical and Biological aspects of effluent irrigation on organic soil components. XII International Meeting of IHSS Proceedings: Humic Substances and soil and water environment.

KADISHI, N., ZEITOUNI, N., SHAMIR, S. & SHECHTER, M. 2002. Climate Change and Israeli Agriculture: An Economic Perspective. 32nd Annual Meeting of the Israeli Society for Ecology & Environmental Quality Sciences (ISEEQS). Tel Aviv.

KAN, I., RAPAPORT-ROM, M., HAIM, D. & SHECHTER, M. 2006. Economic analysis of climate-change impacts on agricultural profitability and land use in Israel (Workshop). Workshop on: Economic implications of the Greenhouse Effect and Climate Change in Israel Aspects. Rehovot, Israel.

KAN, I., RAPAPORT-ROM, M., HAIM, D. & SHECHTER, M. 2006. Economic analysis of climate-change impacts on agricultural profitability and land use: The case of Israel. Third World Congress of Environmental and Resource Economists. Kyoto, Japan.

KAN, I., RAPAPORT-ROM, M., HAIM, D. & SHECHTER, M. 2006. Economic analysis of climate-change impacts on agricultural profitability and land use: The case of Israel. Deserts and Desertification: Challenges and Opportunities. Sede Boqer, Israel.

KAN, I., RAPAPORT-ROM, M. & SHECHTER, M. 2005. Climate Change Effects on Agricultural Land Use in Israel. 21th Annual Meeting of the Israeli Economic Association. Ma'aleh Hahamisha, Israel.

KAN, I., RAPAPORT-ROM, M. & SHECHTER, M. 2005. Climate Change Effects on the Vegetative Agriculture in Israel. 8th International Meeting of the Israel Society for Ecology & Environmental Quality Sciences. Rehovot, Israel.

KAN, I., RAPAPORT-ROM, M. & SHECHTER, M. 2007. Economic analysis of climate-change impacts on agricultural profitability and land use: The case of Israel. 15th EAERE Annual Conference. Thessaloniki, Greece.

KATRA, I. 2007. Topsoil moisture patterns on arid hillsides. DRI's Environmental Seminar Series. Desert Research Institute, Reno and Las Vegas, NV, United States.

KHATIB, I., GERSTENGARBE, F.-W. & HAJ-DAOUD, A. 2006. East Mediterranean Climate Change Trends in the last century. The 3rd International Conference on water resources in the Mediterranean Regions , "WATMED". Tripoli, Lebanon.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2005. Productivity and plant diversity along a climatic gradient: testing effects of precipitation scenarios. Israel Society for Ecology and Environmental Quality Sciences; International conference: Living with Global Change: Challenges in Environmental Sciences. Weizmann Institute of Science, Rehovot, Israel.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2005. Productivity and plant diversity along a climatic gradient: testing effects of precipitation scenarios. Israel Society for Ecology and Environmental Quality Sciences. International conference: Living with Global Change: Challenges in Environmental Sciences. Weizmann Institute of Science, Rehovot, Israel.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2005. Spatial and temporal variation in the productivity-diversity relationship in Mediterranean plant communities. XVII International Botanical Congress. Vienna, Austria.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2005. Spatial and temporal variation in the productivity-diversity relationship in Mediterranean plant communities. XVII International Botanical Congress. Vienna, Austria.

KIGEL, J., KONSENS, I. & STERNBERG, M. 2007. Temporal patterns of germination in Mediterranean annual species. Seed Ecology II Conference. Perth, Australia.

KIGEL, J. & OFIR, M. 2004. Environmental control of summer dormancy in Mediterranean geophytes. 25th Reunion Argentina de Fisiologia Vegetal. La Pampa, Argentina.

KIGEL, J. & OFIR, M. 2007. Summer dormancy in Perennial grasses: a physiological continuum. Medecos XI. Perth, Australia.

KIGEL, J., OSEM, Y. & PEREVOLOTSKI, A. 2007. Is seed germination of annual species in the soil seed-bank a stable trait across years? Seed Ecology II Conference. Perth, Australia.

KOCH, J., MENZEL, L. & SCHALDACH, R. 2008. Coupled scenario studies for the Jordan River region. Interaktionen von Atmosphäre – Hydrosphäre – Biosphäre, Modell-Konzepte zur integrierten Betrachtung komplexer Systeme. 12. Workshop großskalige hydrologische Modellierung. Kiel, Germany.

KOCH, J. & SCHALDACH, R. 2006. Adapting a Land Use Change Model to the Jordan River Region. In: ÜNAL, Y., KAHYA, C. & DEMIRHAN BARI, D. (eds.) Proceedings of the First International Conference on "Climate Change and the Middle East: Past, Present and Future". Istanbul Technical University, Turkey.

KOCH, J. & SCHALDACH, R. 2006. Simulating Land Use Change Scenarios. GLOWA Jordan River Status Conference. Esslingen, Germany.

KOCH, J. & SCHALDACH, R. 2007. P1a: Simulation of Land Use Change Scenarios. GLOWA Jordan River Status Conference. Herrenberg, Germany.

KOCH, J. & SCHALDACH, R. 2007. Poster presentation: "Scenario-based Land Use Simulations for the Jordan River Region". Second International Conference on "Earth System Modelling". Hamburg, Germany.

KOCH, J. & SCHALDACH, R. 2008. Szenarienbasierte Modellierung der Auswirkungen verschiedener Beweidungsstrategien auf die Landnutzung in der Jordanregion. GfÖ Arbeitskreis Weideökologie Workshop „Beweidungsökologie und –Management in Trockengebieten“. UFZ Kubus Leipzig, Germany.

KOCH, J., SCHALDACH, R. & KÖLKING, C. 2009. Modelling the impact of rangeland management strategies on (semi-)natural vegetation in Jordan. In: ANDERSON, R. S., BRADDOCK, R. D. & NEUHAM, L. T. H. (eds.) 18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation.

KOCH, J., WIMMER, F., SCHALDACH, R., ONIGKEIT, J. & FOLBERTH, C. 2012. Modelling the impact of climate change on irrigation area demand in the Jordan River. 6th International Congress on Environmental Modelling and Software (iEMSs). Leipzig, Germany.

KÖCHY, M. 2004. Was ist ein "gutes Jahr" für Annuelle in humiden bis ariden Gebieten. AK "Experimentelle Ökologie" der GFÖ. Potsdam, Germany.

KÖCHY, M. 2006. Opposite trends in life stages of annual plants caused by daily rainfall variability — interaction with climate change. In: ÜNAL, Y., KAHYA, C. & DEMIRHAN BARı, D. (eds.) Proceedings of the International Conference on Climate Change and the Middle East: Past, Present and Future. Turkish State Meteorological Service (DMI), Ankara, Turkey.

KÖCHY, M. 2006. Opposite trends in performance of annual plant communities caused by daily rainfall variability. Climate Change and the Middle East: Past, Present and Future. Istanbul Technical University, Turkey.

KÖCHY, M. 2007. Food resources for small livestock in semi-arid and Mediterranean landscapes under climate change. 91. Annual meeting of the Ecological Society of America. San José, U.S.A.

KÖCHY, M. 2007. Grazing capacity of Middle East landscapes under contrasting climate change scenarios. Verhandlungen der Gesellschaft für Ökologie.

KÖCHY, M. 2007. Processes of landscape change assessed by models. Zentrum für Agrarlandschaftsforschung. Müncheberg, Germany.

KÖCHY, M. 2007. Upscaling of vegetation dynamics in semi-arid landscapes under climate change. Annual meeting of the Canadian Society for Ecology and Evolution. Toronto, Canada.

KÖCHY, M. & F., J. 2006. Opposite trends in performance of annual plant communities caused by daily rainfall variability. Macroecological Tools for Global Change Research. Potsdam.

KÖCHY, M. & JELTSCH, F. 2002. Rainfall distribution and population dynamics of desert annuals. 87. Annual Meeting of the Ecological Society of America. Tucson, Arizona, USA.

KÖCHY, M. & JELTSCH, F. 2004. Effect of rainfall characteristics on performance of ten annual species. 89. Annual Meeting of the Ecological Society of America. Portland, Oregon, USA.

KÖCHY, M. & JELTSCH, F. 2004. Variation of shoot mass of annual plants with rain pattern. 34. Jahrestagung der Gesellschaft für Ökologie. Verhandlung der Gesellschaft für Ökologie 34. Gießen, Germany.

KÖCHY, M. & JELTSCH, F. 2005. Standing crop of an abundant grass species is not affected by rainfall intensity. 35. Annual Meeting of the Gesellschaft für Ökologie (GFÖ). Verahndlungen der Gesellschaft für Ökologie 36. Regensburg, Germany.

KÖCHY, M. & JELTSCH, F. 2005. Standing crop of an abundant grass species is not affected by rainfall intensity. 90. Annual Meeting of the Ecological Society of America and IX International Congress of Ecology. Montréal, Québec, Canada.

KÖCHY, M. & JELTSCH, F. 2006. Opposite trends of performance in the life cycle of annual plants caused by daily precipitation variability. Jahrestreffen der Gesellschaft für Ökologie. Bremen.

KÖCHY, M., JELTSCH, F. & MALKINSON, D. 2007. Landscape-scale models of semi-natural vegetation and run-off. GLOWA Jordan River status conference. Herrenberg (Germany).

KÖCHY, M., MALKINSON, D., MATHAJ, M., TIETJEN, B. & JELTSCH, F. 2006. Projections of climate change effects on semi-natural vegetation. GLOWA JR Status Conference. Esslingen.

KÖCHY, M. & TIELBÖRGER, K. 2003. Rainfall distribution and persistence of populations of semi-desert annuals. 88. Annual Meeting of the Ecological Society of America. Savannah, Georgia, USA.

KÖCHY, M. & TIELBÖRGER, K. 2003. Rainfall distribution and persistence of populations of semi-desert annuals. Annual Meeting of the Gesellschaft für Ökologie (GFÖ). Halle, Germany

KÖCHY, M., TIELBÖRGER, K. & STERNBERG, M. 2002. Rainfall distribution and population dynamics of desert annuals. 32. Annual Meeting of the Gesellschaft für Ökologie (GFÖ). Cottbus, Germany.

KRICHAK, S., ALPERT, P., BASSAT, K. & KUNIN, P. 2007. Assessing mechanisms of future climate trends over the E. Mediterranean region based on results of multiple RCM simulations, Connections between Mediterranean and global climate variability. ESF-MedCLIVAR 2nd workshop. La Londes les Maures, Toulon, France.

KRICHAK, S. O. & ALPERT, P. 2003. Climate variations over Europe and the eastern Mediterranean precipitation. International Conference on Earth System Modeling. Hamburg, Germany.

KRICHAK, S. O. & ALPERT, P. 2003. An observational and modeling evidence of the lee-cyclogenetic effect of Cyprus island in the Israeli climate. Session CL3, EGS - AGU – EUG Joint Assembly. Nice, France.

KRICHAK, S. O. & ALPERT, P. 2003. Role of the Eurasian Decadal Trends in the Eastern Mediterranean Climate. Wengen Conference. Wengen, Switzerland.

KRICHAK, S. O. & ALPERT, P. 2004. Eastern Mediterranean precipitation – climate modeling and analysis evaluations. European Geosciences Union General Assembly. Nice, France.

KRICHAK, S. O. & ALPERT, P. 2007. Upper-troposphere effects of hurricane Olga (2001) in the development of conditions for torrential rains over the southeastern Mediterranean. European Geosciences Union General Assembly.

KRICHAK, S. O. & ALPERT, P. 2010. Projection of climate change during first half of twenty-first century over the Easter Mediterranean region according to results of a transient RCM experiment with 25 km resolution. Geophysical Research Abstracts. EGU2010.

KRICHAK, S. O., ALPERT, P., BASSAT, K. & DAYAN, M. 2006. An RCM Evaluation of Climate Change Trends and Uncertainties over the Eastern Mediterranean Region for GLOWA Jordan River Project. 8th EGU Plinius Conference on Mediterranean Storms and Extreme Events in an Era of Climate Change Dead Sea, Israel.

KRICHAK, S. O., ALPERT, P., BASSAT, K. & KUNIN, P. 2007. Assessment of expected climate change over the eastern Mediterranean region in three simulation experiments with RegCM model. European Geosciences Union General Assembly. Vienna Austria: EGU PLINIUS 8. Geophysical Research Abstracts

KRICHAK, S. O., ALPERT, P. & DAYAN, M. 2003. A numerical study of the 3–5 December, 2001 flood in Israel. Session NH2, EGS - AGU - EUG Joint Assembly. Nice, France.

KRICHAK, S. O., ALPERT, P. & DAYAN, M. 2005. Israel Adaptation of the MM5 and RegCM3 for regional climate modeling over the eastern Mediterranean region. European Geosciences Union General Assembly. Vienna, Austria.

KRICHAK, S. O., ALPERT, P. & DAYAN, M. 2005. Simulation of the surface climatology over the Eastern Mediterranean region using the RegCM3 model. European Geosciences Union General Assembly. Vienna, Austria.

KRICHAK, S. O., ALPERT, P. & DAYAN, M. 2006. A dynamic perspective of a link between of hurricane Olga (2001) and extreme synoptic event with torrential rains in Israel. 8th EGU Plinius Conference on Mediterranean Storms and Extreme Events in an Era of Climate Change. Dead Sea, Israel

KRICHAK, S. O., ALPERT, P., KISHKA, P. & GRELL, G. A. 2002. Impact of MM5 model resolution and domain-size in regional climate simulations over E. Mediterranean. Conference on Detection and Modeling of Regional Climate Change. Trieste, Italy.

KRICHAK, S. O., ALPERT, P. & KUNIN, P. 2009. Projections of eastern Mediterranean climate change simulated in a transient RCM experiment with RegCM3. In: ROCKEL, B., BARRING, L. & RECKERMANN, M. (eds.) 2nd International Lund RCM Workshop. 21st century challenges in regional scale climate modeling. Intern. BALTEX Secretariat.

KRICHAK, S. O., BREITGAND, J. S. & ALPERT, P. 2009. Frequency of extreme precipitation climate events over the Mediterranean region according to NNRP data for 1961-2000. In: COTE, J. (ed.) Research

Activities in Atmospheric and Oceanic Modelling. WMO/TD.

KRICHAK, S. O., BREITGAND, J. S. & ALPERT, P. 2009. Trends in frequency of extreme precipitation climate events in the Mediterranean region according to NNRP data for 1961-2000. In: COTE, J. (ed.) Research Activities in Atmospheric and Oceanic Modelling. WMO/TD.

KRICHAK, S. O., KISHCHA, P. & ALPERT, P. 2001. Decadal trends of NAO and EA/WR, SLP anomaly patterns and the Mediterranean precipitation. Open Climate Conference Holland.

KROTMAN, Y. & GOREN, M. 2004. Biodiversity and community structure of the Jordan River system fishes and their relationship to habitat structure and anthropogenic impact. 41st Conference of the Zoological Society of Israel. Haifa.

KUNSTMANN, H. 2006. Was leisten meteorologische Modelle in der Hydrologie? SYNAP Symposium. Technische Universität Dresden.

KUNSTMANN, H., HECKL, A., SUPPAN, P., ALPERT, P., KRICHAK, S., KUNIN, B., BASSAT, K. & KHATIB, I. 2006. Regional Climate Simulations for the Near East and the Jordan River Region. GLOWA Jordan River Status conference. Herrenberg.

KUNSTMANN, H., SUPPAN, P., HECKL, A., KRICHAK, S. & PINHAS, A. 2006. Impact of Climate Change on Water Availability in the Near East. GLOWA-Jordan Statuskonferenz. Esslingen.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2005. Combined High Resolution Climate and Distributed Hydrological Simulations for the Eastern Mediterranean / Near East and the Upper Jordan Catchment. Proceedings of the Conference on International Agricultural Research for Development Stuttgart-Hohenheim.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2005. Coupled High Resolution Climate - Hydrology Simulations for the Upper Jordan Catchment. In: TIELKES, E. & AL., E. (eds.) Proceedings of Tropentag 2005. Hohenheim, Germany.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2006. Regional Climate Change Simulations for the Near East. Geophysics Seminary. Tel Aviv University, Tel Aviv, Israel.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2007. Quantification and Reduction of Predictive Uncertainty for Sustainable Water Resources Management. Proceedings of Symposium HS2004 at IUGG2007. Perugia: IAHS Publ. 313.

KUNSTMANN, H., SUPPAN, P., HECKL, A. & RIMMER, A. 2007. Regional climate change in the Middle East and impact on hydrology in the Upper Jordan catchment. IAHS publication 313, Quantification and reduction of predictive uncertainty for sustainable water resources management. Perugia.

LAMPEI, C. & TIELBÖRGER, K. 2006. Estimating extinction probabilities of annual plant species under climate change: an experimental approach. Annual meeting of the GFÖ. Bremen, Germany.

LAMPEI, C. & TIELBÖRGER, K. 2007. Adaptation of annual plants: what can we learn from climatic gradients? EES summer school of the Ludwig Maximilliam University. Frauenchiemsee, Germany.

LAMPEI, C., TIELBÖRGER, K., PETRU, M., ARIZA, C. & METZ, J. 2006. Evolution versus dispersal: how will annual plant communities respond to a climate change? . StEve-meeting. University of Tübingen, Germany.

LANGE, J., ARBEL, Y., GREENBAUM, N. & GRODEK, T. 2009. Process studies of water percolation in a Mediterranean karst area. Geophysical Research Abstracts.

LANGE, J., GUNKEL, A., SCHÜTZ, T., WIESENDANGER, C., FISCHER, C., SHADEED, S., ALMASRI, M., JAYYOUSI, A., SHAHEEN, H., GRODEK, T. & MORIN, E. 2008. Hydrological Impact Modelling: Applying TRAIN-ZIN in the Lower Jordan River Catchment. MedClivar/GLOWA-workshop. Reading, UK.

LANGE, J., GUNKEL, A., SHADEED, S., FISCHER, C., KRIER, R., MORIN, E., GRODEK, T. & MENZEL, L. 2008. New insights into the variability of water resources in the Jordan River Catchment. Geophysical Research Abstracts.

LANGE, J., GUNKEL, A., SHADEED, S., MORIN, E., GRODEK, T. & MENZEL, L. 2008. New insights into the variability of water resources in the Jordan River Catchment. Fourth environmental symposium of german-arab forum for environmental studies. Marocco.

LANGE, J., KOHN, I. & GUNKEL, A. 2009. Hydrologischer Wandel in Karstgebieten des östlichen Mittelmeerraums: vom Prozessverständnis zu belastbaren Prognosen. Forum für Hydrologie und Wasserbewirtschaftung. in print.

LANGE, J. & MENZEL, L. 2005. Water resources under global change: Process based hydrological modelling for the lower catchment of the Jordan River. presentation of GLOWA-Jordan work at the Deutscher Tropentag 2005. Stuttgart-Hohenheim.

LANGE, J. & MENZEL, L. 2007. Assessing water availability for the lower Jordan River under global change (presentation). GLOWA Jordan River Status Conference. Herrenberg.

LANGE, J., SCHÜTZ, T., GUNKEL, A., GRODEK, T., STEINMANN, A. & MENZEL, L. 2007. Representing dryland runoff generation processes in hydrological models: experiences from a small mediterranean catchment Geophysical Research Abstracts. .

LIANCOURT, P. 2006. Facilitation and ecological speciation: Disruptive or cohesive force" ESF LESC Exploratory workshop". Positive interactions, biodiversity and invisibility in a changing world. Arcachon, France.

LIANCOURT, P., BANGERTER, S., ORAN, S., PRASSE, R. & TIELBOERGER , K. 2007. Impact on grazing cessation on the biomass in Jordan (Poster). GLOWA Jordan River Status Conference. Herrenberg, Germany.

LIANCOURT, P. & TIELBÖRGER, K. 2007. Plant strategies and local adaptation: the role of competition and the length of the vegetation season along an aridity gradient. 37th Annual Conference of the Ecological Society of Germany, Switzerland and Austria (GfÖ). Marburg, Germany (Oral presentation).

MALKINSON, D. & JELTSCH, F. 2005. The use of spatially explicit models to evaluate the importance of facilitation and competition among shrubs along a climatic gradient. IGA meetings. Haifa, Israel.

MARSCHNER, B., HAMER, U., JUESCHKE, E., CHEN, Y. & TARCHITZKY, J. 2005. Is substrate availability a major limiting factor for the degradation of soil organic matter? . Poster presented at the 22. IMOG-conference Sevilla, Spain.

MARSCHNER, B., JUESCHKE, E., TARCHITZKY, J. & CHEN, Y. 2005. Changes of organic matter in soils irrigated with reclaimed wastewater. International Conference of the Israeli Society for Ecology and Environmental Quality Science. Rehovot, Israel.

MATHAJ, M., JELTSCH, F. & KÖCHY, M. 2006. Consequences of climate change for stocking rates of sheep and goats in the Mediterranean. Jahrestreffen der Gesellschaft für Ökologie. Bremen.

MENZEL, L. 2006. Assessment of blue and green water. First Scenario Panel Meeting of the GLOWA-Jordan Project. Waldeck.

MENZEL, L. 2006. Erfassung und Modellierung der Wasserhaushaltskomponenten auf unterschiedlichen räumlichen Skalen. Kolloquium an der Fakultät für Forst- und Umweltwissenschaften der Universität Freiburg. Universität Freiburg.

MENZEL, L. 2006. Modelling of the water balance components on different spatial scales (in German). Colloquium at the Faculty of Forest and Environmental Sciences. University of Freiburg.

MENZEL, L. 2007. Changing water availability in the Upper and Lower Jordan River Region. GLOWA Jordan River 2nd Scenario Panel Meeting. Hofgeismar.

MENZEL, L. 2007. Integrated river basin management: new challenges in hydrology (in German). Colloquium at the Faculty of Civil Engineering and Geodesy. Technical University Munich.

MENZEL, L. 2007. Model based simulation of the water balance of forests on different spatial scales. In: FEGER, K.-H., YANHUI, W., BERNHOFER, C. & SEEGERT, J. (eds.) The role of forests and forest management in the water cycle. Progress in Hydro Sciences and Engineering. TU Dresden: Dresden Water Center, Dresden.

MENZEL, L. 2007. Simulation studies of human impact on the hydrological cycle. Colloquium at the Centre for Agricultural Landscape Research (ZALF). Müncheberg.

MENZEL, L. 2008. Climate change: hydrological effects in the semi-arid and arid parts of the Jordan region. MedClivar / GLOWA workshop. University of Reading, UK.

MENZEL, L. 2008. Environmental change and water scarcity in the Jordan Region: An interdisciplinary model exercise (in German). Colloquium at the Faculty of Chemistry and Geosciences. University of Heidelberg.

MENZEL, L. 2008. Water resources in the semi-arid Jordan basin: What will bring the future? (in German). 16. HGN Hydrogeological colloquium "Climate change and its impact on the groundwater". Halle/Saale.

MENZEL, L., ALKHOURY, W. & WEIß, M. 2006. Green water fluxes, irrigation water demand and environmental change in the Lower Jordan Basin. GLOWA Jordan River Status Conference. Esslingen.

MENZEL, L., ALKHOURY, W. & WEIß, M. 2006. Green water fluxes, irrigation water demand and environmental change in the Lower Jordan Basin. GLOWA Jordan River Status Conference. Esslingen, Germany.

MENZEL, L., FLÖRKE, M., MATOVELLE, A. & ALCAMO, J. 2007. Impact of socio-economic development and climate change on water resources and water stress. First International Conference on Adaptive and Integrative Water Management (CAIWA 2007). Basel.

MENZEL, L., FLÖRKE, M., MATOVELLE, A. & ALCAMO, J. 2007. Impact of socio-economic development and climate change on water resources and water stress. First International Conference on Adaptive and Integrative Water Management (CAIWA 2007). Basel.

MENZEL, L. & LANGE, J. 2006. Assessing water availability for the Lower Jordan River under global change. GLOWA Jordan River Status Conference. Esslingen.

MENZEL, L. & LANGE, J. 2008. Global change and water resources in the Lower Jordan River. GLOWA Jordan River Status Conference. Aqaba, Jordan.

MENZEL, L., LANGE, J., GUNKEL, A., ALKOURY, W. & WEIß, M. 2007. Impact of climate and land management on the water balance in the semi-arid catchment of the Jordan river (in German). Hydrology Day 2007. University of Rostock.

MENZEL, L., SCHLAFFER, S., HECKL, A. & KUNSTMANN, H. 2007. Changing water availability and irrigation water requirements in the Jordan River Region. GLOWA Jordan River 3rd Scenario Panel Meeting. Dead Sea (Jordan).

MENZEL, L., TEICHERT, E. & WEISS, M. 2007. Climate change impact on the water resources of the semi-arid Jordan region. In: HEINONEN, M. (ed.) Proceedings of the 3rd International Conference on Climate and Water. Helsinki.

MENZEL, L. & WEIß, M. 2007. Regional water balance components under climate and land cover change in the Jordan Region. GLOWA Jordan River Status Conference. Herrenberg.

METZ, J. 2007. Mediterranean and Semi-Arid Plant Communities under Climate Change. Oral presentation. StEvE-Meeting. Tübingen, Germany.

METZ, J., STERNBERG, M., KIGEL, J. & TIELBÖRGER, K. 2007. Impact of climate change on annual plant communities in the eastern Mediterranean. Oral presentation. Caress – Conference. Weizman Institute of Science, Rehovot, Israel.

METZ, J. & TIELBÖRGER, K. 2006. Impact of climate change on annual plant communities in the eastern Mediterranean. Annual Meeting of the German Ecological Society (GfÖ) Bremen.

METZ, J. & TIELBÖRGER, K. 2007. Plant – plant interactions along temporal stress gradients. Oral presentation. Annual Meeting of the German Ecological Society (GfÖ). Marburg, Germany.

MORIN, E., ARBEL, S., ARAZI, A., GETKER, M., HARATS, N., YACOBY, Y., GRODEK, T. & DAYAN, U. 2006. Studying the extremes: Hydrometeorological investigation of a flood-causing rainstorm over Israel. 8th Plinius Conference on Mediterranean Storms and extreme events in an era of climate change. European Geosciences Union, Israel.

NADAV, I., A. GILBOA, J. TARCHITZKY, & Y. CHEN 2010. Enhanced Infiltration Regime for Treated Wastewater Purification in Soil Aquifer Treatment (SAT) (oral presentation). XV Meeting of the International Humic Substances Society. Puerto de la Cruz, Tenerife, Canary Islands, Spain.

NAVON, Y. & STERNBERG, M. 2005. Plant litter decomposition under climate change: an experimental approach along an aridity gradient. 35th Annual Conference Ecological Society of Germany, Austria & Switzerland. Regensburg, Germany.

ONIGKEIT, J., ALCAMO, J. & ALPERT, P. 2009. Workshop Documentation. GLOWA Jordan River 4th Scenario Panel Meeting. Tel Aviv, Israel: Center for Environmental Systems Research (CESR), University of Kassel, Germany.

ONIGKEIT, J., ALCAMO, J. & JAYYOUSI, A. 2009. Workshop Documentation. GLOWA Jordan River 4th Scenario Panel Meeting. Ramallah, Palestinian Authority: Center for Environmental Systems Research (CESR), University of Kassel, Germany.

ONIGKEIT, J., ALCAMO, J. & LÜBKERT, B. 2009. The Procedure for Developing the GLOWA JR Scenarios for Regional Development under Global Change. Report Center for Enviromental Systems Research, University of Kassel, Germany.

ONIGKEIT, J., ALCAMO, J. & LUEBKERT, B. 2006. The Glowa JR Scenario Exercise. GLOWA Jordan River Status Conference. Esslingen, Germany.

ONIGKEIT, J., ALCAMO, J. & LUEBKERT, B. 2007. Applying fuzzy-set analysis to generate quantitative model input from qualitative scenario information. GLOWA Jordan River Status Conference. Herrenberg, Germany.

ONIGKEIT, J., ALCAMO, J. & LUEBKERT, B. 2007. Scenarios as an Integration Tool in the Glowa JR Project. 2nd Scientific Coordination Meeting of the SMART-Project. Amman.

ONIGKEIT, J., ALCAMO, J. & SALMAN, A. 2009. Workshop Documentation. GLOWA Jordan River 4th Scenario Panel Meeting. Amman, Jordan: Center for Environmental Systems Research (CESR), University of Kassel, Germany.

OROUD, I. M. 2006. Land Use Changes in the Jordan Valley and the Impact of Climate Change on Irrigation Water Requirements. Climate Change and the Middle East: Past, Present and Future. Technical University, Istanbul , Turkey.

OROUD, I. M. 2007. Two posters presented during the GLOWA Jordan River Status Conference. Herrenberg.

OROUD, I. M. 2007. Presentation during the 4th Jordanian Conference on the Environment.

OSETINSKY, I. & ALPERT, P. 2004. Evaluation of GCM/RCM by the classified synoptic systems' approach. Paper presented in the 84th Annual AMS Meeting. Seattle, WA, USA.

OSETINSKY, I. & ALPERT, P. 2009. South Hemispheric Teleconnection to Eastern Mediterranean synoptic systems. European Geosciences Union General Assembly. Vienna, Austria.

PETRŮ, M. & TIELBÖRGER, K. 2004. Germination behavior of annual plants in variable rainfall conditions: adaptive of passive responses? . International Conference on Seed Ecology. Rhodes, Greece.

PETRŮ, M. & TIELBÖRGER, K. 2004. Responses of annual plants to variable rainfall patterns: an empirical test of three models. Annual Meeting GFÖ Section Plant Population Biology. Regensburg, Germany.

PETRŮ, M., TIELBÖRGER, K. & STERNBERG, M. 2004. Responses of annual plants to variable rainfall patterns: an empirical test of three models. MEDECOS X, Conference on Mediterranean Types Ecosystems.

Rhodes, Greece.

PRANGE, S. G., K., JELTSCH, F. 2010. Feedbacks between vegetation and hydrology with a special view on extreme events in Israel. GfÖ Conference. Gießen, Germany.

PRASSE, R. 2005. Beispiele ökologischer Forschung im Nahen Osten. Festvortrag zur Verabschiedung der Diplomanden des Fachbereichs Umweltforschung der Universität Lüneburg. Universität Lüneburg.

PRASSE, R. 2005. Climate change and local cucumbers - Examples of applied ecological research in Israel and the Palestinian Autonomy. Guest lecture at the Ecology Seminar of Fullerton States University. California.

PRASSE, R. 2005. Grenzüberschreitungen - Beispiele ökologischer Forschung im Nahen Osten. Festive Colloquium for the 75th birthday of Prof. Dr. Reinhard Bornkamm. Technische Universität Berlin.

PRASSE, R. 2006. Examples of ecological research in the Middle East. Fairchild Tropical Botanical Garden, Coral Gables, Florida.

PRASSE, R. 2006. Local drought resistant crop-varieties and intercropping - combining water use efficiency and nature conservation. Triangle Research Center, Kufar Kara, Israel.

PRASSE, R., MASSALHA, J. & BERLINER, P. 2006. Water productivity in agricultural/farming systems. GLOWA meeting. Esslingen.

REGNER, H. J., SALMAN, A. Z., WOLFF, H.-P. & KARABLIEH, E. 2006. Approaches and Impacts of Participatory Irrigation Management (PIM) in Complex, Centralized Irrigation Systems - Experiences and Results from the Jordan Valley. In: ASCH, F. & BECKER, M. (eds.) Tropentag 2006: Prosperity & Poverty in a globalized world: Challenges for Agricultural Research. University of Bonn.

RIMMER, A. 2006. Modelling recession curve of karstic springs – parallel or serial reservoirs? European Geosciences Union General Assembly. Vienna.

RIMMER, A. 2006. System approach hydrology for the UCJR and Lake Kinneret. 5th Rosenberg International Forum on Water Policy. Banff, Canada.

RIMMER, A. 2006. System approach models combining long-term ecological changes, in coherent with field observation data: Lake Kinneret (Israel) and Lake Biwa (Japan). International Workshop for Lake Observation Systems. Otsu, Shiga, Japan.

RIMMER, A. 2007. Hydrological Model for Karst Environment (HYMKE)-Application to the Hermon Mountain (North of Israel). EGU General Assembly. Vienna, Austria.

RIMMER, A. 2009. System hydrology models for managing the salinity of Lake Kinneret, Israel. Proceedings of the IHP Symposium. Capri: IAHS Publ. 327.

RIMMER, A., BOGER, M., AOTA, Y. & KUMAGAI, M. 2004. Modelling long-term salinization process in fresh water lakes. European Geosciences Union 1st General Assembly. Nice, France.

RIMMER, A., BOGER, M., AOTA, Y. & KUMAGAI, M. 2007. System dynamics simulation tool to evaluate and predict lake salinization process. The IAHS meeting within the IUGG meeting. Perugia, Italy.

RIMMER, A. & LECHINSKI, Y. 2007. Decision Support System to predict long term salinity trends in Lake Kinneret. The IAHS meeting within the IUGG meeting. Perugia, Italy.

RIMMER, A. & SALINGAR, Y. 2006. Modelling precipitation-streamflow processes in large karst basin. European Geosciences Union General Assembly. Vienna.

RIMMER, A. & SALINGAR, Y. in press. Modelling precipitation-streamflow processes in Karst basin: The Jordan River sources. Water Engineering, fluids and irrigation.

SARAH, P. 2002. Spatial distribution of enzyme activity in the soil in different climatic zones. Isr. Geogr. Assoc. Annual Meeting. Be’er Sheva.

SCHACHT, K. 2010. GIS-based soil suitability risk assessment for wastewater reuse in the Middle East (Poster). Autumn School of the Marsilius College, University of Heidelberg: "Bridging the water gap

– interdisciplinary perspectives“. International Science Forum (IWH) at Heidelberg, Germany.

SCHACHT, K. 2010. Land evaluation for irrigation with treated wastewater (oral presentation). IWRM - Integrated Water Resources Management Karlsruhe, Germany.

SCHACHT, K., GÖNSTER, S., JÜSCHKE, E. & MARSCHNER, B. 2009. GIS-gestützte Risikobewertung der Bodeneignung für die Bewässerung mit Abwässern in Israel und dem Westjordanland. Böden - eine endliche Ressource. Bonn, Germany.

SCHACHT, K. & MARSCHNER, B. 2011. Benetzungshemmung nach Abwasserbewässerung in Israel - Bestimmung des Repellency Index mittels Mini-Disk-Infiltrometer. Jahrestagung der Deutschen Bodenkundlichen Gesellschaft. Berlin and Postdam.

SCHIFFERS, K. & TIELBÖRGER, K. 2003. Variation of interaction intensity among life history stages – an experimental approach with annual plants along a climatic gradient in Israel. Annual Meeting GFÖ Section Plant Population Biology. Copenhagen, Denmark.

SCHIFFERS, K. & TIELBÖRGER, K. 2004. Many small or few big neighbors? Spatial distribution of plant biomass affects interaction intensity. Annual Meeting GFÖ Section Plant Population Biology. Potsdam, Germany.

SCHLAFFER, S. & MENZEL, L. 2008. Interpolation of observed meteorological data on a high density grid in the Jordan River Region. GLOWA Jordan River Status Conference. Aqaba, Jordan.

SEILER, K.-P. 2004. The role of transient flow in regional flow pattern for water use. 33rd IAH Congress On Groundwater Flow Understanding from Local to Regional Scales. Zacatecas, Mexico.

SEITELBACH, S., REICHMANN, O., BRAND, S., HAIM, A., LITAOR, M. I. & SHENKER, M. 2002. Processes governing P release from rewetted soils of the Hula Valley. Lecture paper presented in the 32nd Annual Meeting of the Israel Society for Ecology and Environmental Quality Sciences (ISEEQS) Tel-Aviv, Israel.

SHADEED, S. & ALMASRI, M. 2007. Statistical Analysis of Long-Term Rainfall Data for a Mediterranean Semi-Arid Region: A Case Study from Palestine. Sustainable Development and Management of Water in Palestine, International Conference on Palestine Water. Amman, Jordan.

SHADEED, S. & J., L. 2009. Best Surface Water Management Options for Faria Catchment: Present Knowledge and Up to Date Modeling Capabilities. 2nd international conference, Water: Values and Rights. Ramallah, Palestine: Palestine Academy for Science and Technology.

SHADEED, S., JAYYOUSI, A., SHAHEEN, H., ALMASRI, M., LANGE, J., GUNKEL, A. & MENZEL, L. 2007. Project 5: Hydrological modelling in Faria catchment (posters). GLOWA Status Conference. Herrenberg.

SHADEED, S., JAYYOUSI, A. & SHAHEEN, H. Q. 2005. Probability Distribution of Faria-Catchment Rainfall. Proceedings of the International Conference "Water: Values and Rights", Palestine Academy for Science and Technology (PALAST) and Palestinian Water Authority (PWA). Ramallah, Palestine.

SHADEED, S. & LANGE, J. 2009. Effects of Land Use and Climate Changes on Storm Runoff Generation in Arid and Semi-Arid Catchments: Up to Date Modeling Capabilities. 2nd international conference, Water: Values and Rights. Ramallah, Palestine: Palestine Academy for Science and Technology.

SHADEED, S., LANGE, J. & GUNKEL, A. 2008. Up To Date Hydrological Modeling in Arid and Semi-Arid Catchment, the Case of Faria Catchment, West Bank, Palestine. Geophysical Research Abstracts.

SHADEED, S. & SHAHEEN, H. 2007. GIS Based SCS-CN method for the Faria Catchment.Sustainable Development and Management of Water in Palestine. International Conference on Palestine Water. Amman, Jordan.

SHADEED, S., SHAHEEN, H. & JAYYOUSI, A. 2007. Management Options of Wadi Faria Baseflow. Proceedings of the 11th International Water Technology Conference (IWTC). Sharm Al-Sheikh, Egypt.

SHAHEEN, H. Q., JAYYOUSI, A., SHADEED, S. & JARRAR, A. 2005. Hydrograph Estimation in Semiarid Regions

Using GIS supported GIUH Model. Proceedings of the 9th International Water Technology Conference IWTC Sharm Al-Sheikh, Egypt.

SHAMIR, S. & SHECHTER, M. 2003. Climate Change and Israeli Agriculture: An Economic Perspective. Agriculture, Climate Change and Economic Consequences: from Description to Mitigation. The Annual Meeting of European Phonological Network Meeting. Copenhagen.

SHECHTER, M. 2006. Economic assesment of climate-change impacts (Workshop). Workshop on the Economic implications of the Greenhouse Effect and Climate Change in Israel Aspects. Rehovot, Israel.

SHECHTER, M. & KAN, I. 2005. Economic Assessments of Climate Change Impact on Agriculture in a Semi-Arid Region. ICCAP Workshop. Kyoto, Japan.

SHECHTER, M., KAN, I. & FLEISCHER, A. 2006. The Economic Aspects of the Greenhouse Effect and Climate Change in Israel. Workshop on the Economic implications of the Greenhouse Effect and Climate Change in Israel Aspects. Rehovot, Israel.

SHECHTER, M. & KAN, I. A., O. 2004. Climate-Change Effects on Open-Space Land Use in Israel. Land Use and Land Cover Change (LUCC) Workshop: Integrated Assessment of the Land System: The Future of Land Use.

SHORE, L. S. 2004. Hormonal parameters of ecohydrology. Proc 4th Int'l Conf. Pharmaceutical and Endocrine Disrupting Chemical in Water. Minneapolis, MN, USA.

SHORE, L. S. & SHEMESH, M. 2002. Naturally Produced Steroid Hormones and their Release into the Environment. International SCOPE/IUPAC Symposium on Endocrine Active Substances. Kimron Veterinary Institute, Yokahama, Japan.

SHORE, L. S., SHEMESH, M., KRONFELD-SCHOR, N., BAREL-COHEN, K. & LITAOR, M. I. 2003. Measurement of natural and synthetic hormones in a watershed. Bestimmung natuerlicher und synthetischer Hormone zur Überwachung organischer Verunreinigungen in einem Wassereinzugsgebiet. Proceedings of the Workshop on Diffuse Input of Chemicals into Soil & Groundwater-Assessment & Management. Technische University Dresden, Dresden, Germany.

SHTIRBERG, I., T. DAYAN, M. STERNBERG, AND V. CHIKATUNOV. 2007. Biodiversity changes in two big beetle families: Carabidae and Tenebrionidae along a rainfall gradient in Israel. XIII European Carabidologist's Meeting. Blagoevgrad, Bulgaria.

SMIATEK, G., KUNSTMANN, H. & HECKL, A. 2011. High resolution climate change simulations for Eastern Mediterranean and Jordan River Region. Geophysical Research Abstracts. EGU2010-11251, EGU General Assembly 2010.

SOGAVKER, U. 2007. Ant-species richness along a productivity gradient: the importance of climate. Evolutionary and ecological consequences of global change workshop, Munich Graduate Program for Evolution, Ecology and Systematics (EES). Frauenchiemsee, Germany.

SOGAVKER, U. 2007. Food resources, foraging behavior and body-size variations in ant species along a productivity gradient. Plant Ecology Lab. Tübingen University, Germany.

SOGAVKER, U. 2007. Granivorous ant assemblages along a productivity gradient: variations in foraging behavior and effects on seed resources and vegetation structure. Plant Sciences Lab. Faculty of Agriculture, The Hebrew University, Israel.

STEINITZ, H., DAYAN, T. & YOM-TOV, Y. 2006. Predicting distributions of Israeli mammals under different climate change scenarios at the species and assemblage levels. Proceedings of the 43rd meeting of the Israeli Zoological Society.

STEINITZ, H., DAYAN, T. & YOM-TOV, Y. 2007. Predicting distributions of Israeli mammals under different climate change scenarios at the species and assemblage levels. Sixth Annual Conference on Active Research by Environmental Science Students.

STEINITZ, H., DAYAN, T. & YOM-TOV, Y. 2008. Projected Shifts In The Distribution Of Israeli Mammals In Different Climate Change Scenarios. Proceedings of the 45th meeting of the of the Israeli Zoological Society

STEINITZ, H., DAYAN, T., YOM-TOV, Y. & FERRIER, S. 2006. Snow Is White But Not All White Is Snow – The Logic Error Of Modeling The Effects Of Global Warming. Proceedings of the1st international workshop of modelling approaches in biodiversity research. Sede-Boqer.

STEINITZ, H., DAYAN, T. & YOM-TOV., Y. 2007. The Effects of Climate Change on the Distribution of Terrestrial Mammals in Israel.

STEINITZ, H. D., T.; YOM-TOV, Y.; ALPERT, P. 2006. Using Natural History Collections To Model Effects Of Climate Change On Mammal Distributions In Israel. Proceedings Of Global Environmental

Change: Regional Challenges ESSP Open Science conference. Beijing, China.

STERNBERG, M. 2005. Is home the best place to decompose? Israel Society for Ecology and Environmental Quality Sciences. International conference: Living with Global Change: Challenges in Environmental Sciences. Weizmann Institute of Science, Rehovot, Israel.

STERNBERG, M., HOLZAPFEL, C., PARAG, H., KONSENS, I. & HAREL, D. 2006. Soil seed banks and climate change: an experimental approach along a climatic gradient in Israel. ESA 91st annual meeting. Memphis, USA.

STERNBERG, M., HOLZAPFEL, C., PARAG, H. A., TIELBÖRGER, K. & KIGEL, J. 2002. Climate control of annual-plant shrub coexistence. Annual Meeting of the Ecological Society of America. Tucson, USA.

STERNBERG, M., HOLZAPFEL, C., PARAG, H. A., TIELBÖRGER, K. & KIGEL, J. 2003. Climate control of annual-plant shrub coexistence. Oral contribution at the 32nd Annual Meeting of Israel Society of Ecology and Environmental Quality Science. Tel Aviv, Israel.

STERNBERG, M., HOLZAPFEL, C., TIELBÖRGER, K. & KIGEL, J. 2003. From Mediterranean to desert ecosystems: An integrated approach in climate change research. Invited talk, Conference of Frontiers of Sciences and Technology; US National Academy of Sciences. Istanbul, Turkey.

STERNBERG, M., TIELBÖRGER, K. & KIGEL, J. 2002. From Mediterranean to desert ecosystems: a new experimental approach for studying the effects of global climate change on plant community. 9th European Ecological Congress. Lund, Sweden.

STERNBERG, M., TIELBÖRGER, K. & KIGEL, J. 2003. From Mediterranean to desert ecosystems: a new experimental approach for studying the effects of global climate change on plant community. 32nd Annual Meeting of Israel Society of Ecology and Environmental Quality Science. Tel Aviv, Israel.

STERNBERG, M., TIELBÖRGER, K., KIGEL, J., JELTSCH, F. & KÖCHY, M. 2007. Vulnerability of eastern Mediterranean ecosystems to climate change: lessons from an integrative study along an aridity gradient. EFIMED Annual Meeting. Palencia, Spain (invited keynote speaker).

STERNBERG, M., TIELBÖRGER, K., KIGEL, J., SARAH, P., LAVEE, H., JELTSCH, F. & KOECHY, M. 2005. From Mediterranean to desert ecosystems: an integrative approach for climate change research. Oral presentation at the 17th International Botanical Congress. Vienna, Austria.

SUPPAN, P., HECKL, A., KUNSTMANN, H., ALPERT, P. & KRICHAK, S. 2007. Climate Change in the Jordan River region. 2nd Scenario Panel Meeting of GLOWA Jordan River Hofgeismar.

SUPPAN, P., KUNSTMANN, H., ALPERT, P., KRICHAK, S. & KHATIB, I. 2006. Regional climate scenarios and modelling. 1st Scenario Panel Meeting of GLOWA Jordan River Waldeck, Deutschland.

SUPPAN, P., KUNSTMANN, H. & HECKL, A. 2006. Impact of Climate Change on Water Availability in the Near East. 3rd German-Arab Society Meeting Frankfurt a. M., Deutschland.

SUPPAN, P., KUNSTMANN, H., HECKL, A. & RIMMER, A. 2006. Coupled High Resolution Climate and Distributed Hydrological Simulations for the Eastern Mediterranean/Near East and the Upper Jordan Catchment. European Geosciences Union General Assembly. Vienna.

TIELBÖRGER, K. 2001. Einfluß von klimatischem Wandel auf verschiedene Ökotypen einjähriger Pflanzen entlang eines Klimagradienten: Ein Test von drei theoretischen Modellen. Annual Meeting GFÖ Section Desert Ecology. Leipzig, Germany.

TIELBÖRGER, K. 2007. Pride or prejudice- how interactions among plant determine the evolution of life histories. Invited keynote lecture. OPTIMA meeting. Pisa.

TIELBÖRGER, K. & ALPERT, P. 2005. GLOWA-Jordan River: Integrative science for managing the water crisis. Water Is Life – 40 Years of Diplomatic Relations Germany-Israel. Jerusalem, Israel.

TIELBÖRGER, K., KIGEL, J. & FLEISCHER, A. 2007. The response of Eastern Mediterranean ecosystems to climate change: lessons learned from the GLOWA Jordan River project. Invited talk. 30 years of binational collaboration Hohenheim-Rehovot. University of Hohenheim.

TIELBÖRGER, K. & PETRŮ, M. 2005. Maternal effects on seed germination of annual plants in variable environments. Annual Meeting GFÖ Section Plant Population Biology. Potsdam, Germany.

TIELBÖRGER, K. & STERNBERG, M. 2005. Green water and natural ecosystems under global change. Proceedings of theTropical Day 2005. Stuttgart-Hohenheim.

TIELBÖRGER, K., STERNBERG, M., BANGERTER, S., JELTSCH, F., KÖCHY, M., KIGEL, J., LAMPEI, C., LIANCOURT, P., MALKINSON, D., METZ, J., ORAN, S. & PRASSE, R. 2007. Fast response to land use change and slow response to climate change in eastern Mediterranean plant communities. GLOWA Jordan River Status conference. Herrenberg, Germany.

TIELBÖRGER, K., STERNBERG, M., KÖCHY, M., PETRŮ, M., ARIZA, C., KIGEL, J. J., F., PARIENTE, S., LAVEE, H. & FLEISCHER, A. 2005. Vulnerability of Eastern Mediterranean ecosystems to climate change: lessons from an integrative study along a steep climatic gradient. Annual Meeting GFÖ. Regensburg, Germany.

TIELBÖRGER, K., STERNBERG, M., ORAN, S. & AL., E. 2006. Developing management strategies of Mediterranean plant communities to global change- an integrated approach. GLOWA Jordan River Status conference. Esslingen, Germany.

TIELBÖRGER, K. & VALLERIANI, A. 2004. Can seeds predict their future? Maternal effects on annual plant germination enable escape from over-crowding. Annual Meeting GFÖ Section Plant Population Biology. Regensburg, Germany.

TIETJEN, B. 2007. Modelling sustainable management of semi-arid and arid grazing systems under climate change. Yearly campus of Heinrich-Böll-Foundation "The future of labour". Bad Bevensen, Germany.

TIETJEN, B., JELTSCH, F. & ZEHE, E. 2006. Semi-arid grazing systems under climate change – present model shortcomings and ways to handle them. Jahrestreffen der Gesellschaft für Ökologie. Bremen.

TÖRNROS, T. 2010. Precipitation trends and suitable drought index in the arid/semi-arid southeastern Mediterranean region. Proc. of the Sixth World FRIEND Conference. Global Change: Facing Risks and Threats to Water Resources. IAHS Publ. Fez, Morocco

TWITE, R. 2010. The Management of Water in the Jordan Basin, Adaptation to Climate Change. The Third International Conference on Drylands, Deserts and Desertification: The Route to Restoration. Sede Boqer Campus, Israel.

TZVIKEL, S. & SARAH, P. 2002. Seasonal variability of soil soluble salts along a climatological gradient. Isr. Geogr. Assoc. Annual Meeting. Be'er Sheva, Israel.

TZVIKEL, S., SARAH, P. & LAVEE, H. 2003. Spatio-temporal changes in Arylsulfatase activity in soils along climatic gradient in Israel. Isr. Geogr. Assoc. Annual Meeting. Ramat Gan, Israel.

WEIß, M. 2006. Model-based scenarios of Mediterranean Droughts. 8th EGU Plinius Conference on "Mediterranean Storms and Extreme Events in an Era of Climate Change". Dead Sea, Israel.

WEIß, M., KOCH, J., SCHALDACH, R., ONIGKEIT, J. & MENZEL, L. 2006. Vulnerability and Management of Water Resources in Eastern Mediterranean Ecosystems. Global Environmental Change: Regional

Challenges. An ESSP Global Environmental Change Open Science Conference. Beijing, China.

WEIß, M. & MENZEL, L. 2007. First steps towards an improvement of the modelling of evapotranspiration in semi-arid areas with global models (in German). Workshop „Fortschritt und Visionen in der großskaligen hydrologischen Modellierung“. Frankfurt/M.

WEIß, M. & MENZEL, L. 2008. Potential and actual evapotranspiration in the Jordan River Region. GLOWA Jordan River Status Conference. Aqaba, Jordan.

WOLFF, H.-P. 2005. GLOWA Jordan River - Challenges and Approaches in Building the Bridge on Water-Related Research between Socio-Economists and Natural Scientists in a Multi-National Environment. Deutscher Tropentag 2005, The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies. University of Hohenheim.

WOLFF, H.-P. 2007. Transboundary water governance in the socio-economic watershed of the Jordan Valley - a way from conjoint research to dissemination among national decision makers (poster presentation). Inauguration ceremony of the North-South-Centre. Swiss Federal Institute (ETH) Zurich.

WOLFF, H.-P., DOPPLER, W. & NABULSI, A. 2005. Shifting the Focus of Research on Water Resources Management from Natural to Socio-Economic Watersheds - The Conceptual Framework of a Research Network on Water Questions in the Jordan Valley. Deutscher Tropentag 2005, The Global Food & Product Chain - Dynamics, Innovations, Conflicts, Strategies. University of Hohenheim.

WOLFF, H.-P., DOPPLER, W. & SALMAN, A. Z. 2006. Widening the scope of IWRM from natural to socio-economic watersheds - the conceptual framework of a research network in the Jordan Valley. World Water Week in Stockholm, Beyond the River - Sharing Benefits and Responsibilities. Stockholm International Water Institute.

WOLFF, H.-P. & HIJAWI, T. 2006. Socio-economics of the preservation of Palestinian agro-biodiversity (Guest lecture). PARC, training center Jenin, PA.

WOLFF, H.-P., SHECHTER, M., FLEISCHER, A., SALMAN, A. Z., HIJAWI, T. & KAN, I. 2007. Evaluation of socio-economic consequences from changing water availability in the Jordan Valley- an example of shared cross-border water resources. World Water Week in Stockholm, Beyond the River - Sharing Benefits and Responsibilities. Stockholm International Water Institute.

WOLFF, H.-P., SHECHTER, M., FLEISCHER, A., SALMAN, A. Z., HIJAWI, T. & KAN, I. 2007. Forecasting social and economic impacts from Climate Change on farming systems in riparian countries of the Jordan River – a combined model-based approach. In: TIELKES, E. (ed.) Tropentag 2007: Utilisation of diversity in land use systems: Sustainable and organic approaches to meet human needs. Universities of Kassel and Goettingen.

WOLFF, H.-P., SHECHTER, M., SALMAN, A., HIJAWI, T., FLEISCHER, A., KARABLIEH, E., KAN, I. & BECKER, N. 2007. Preliminary Estimations on Development in Rural Areas under different Scenario Assumptions and Climate Change. Stakeholder conferences of GLOWA Jordan River 2007. Dead Sea.

WOLFF, H.-P., SHECHTER, M., SALMAN, A., HIJAWI, T., FLEISCHER, A., KARABLIEH, E., KAN, I. & BECKER, N. 2007. Socio-economic consequences of changes in frame conditions for the agricultural sector. Stakeholder conferences of GLOWA Jordan River 2007. Kassel.

YAKIR, D. & AL, E. 2006. Lessons from the edge of forestation (Symposium talk). ILEAPS science conference Boulder CO.

Reports

ALCAMO, J. 2009. GLOWA Jordan River - an integrated approach to sustainable management of water ressources under global change - Phase 2 : Teilprojekt 1a: SAS - Integration - Szenarioentwicklung mit dem "Story and Simulation" Ansatz (SAS) und Landnutzungs-/

Landbedeckungsszenarien; Teilprojekt 4: Ökohydrologische Modellierung, green water ; Abschlussbericht ; Berichtszeitraum: 01.09.2005 bis 30.11.2008.

ALPERT, P. 2005. Modelling system for urban air pollution. Porter school of environmental studies Tel Aviv University.

ANONYMOUS 2011. Future management of the Jordan River basin's water and land resources under climate change - A scenario analysis. Kassel, Jerusalem: Center for Environmental Systems Research (CESR), Israel Palestine Center for Research and Information (IPCRI).

BEN-ASHER, J., ALPERT, P. & SHECHTER, M. 2004. Vulnerability of Water Resources due to Climate Change in Eastern Mediterranean Ecosystems- An Integrated Approach to Sustainable Agricultural Management. Impact of Global Climate Change on Agricultural Production Systems in Arid Areas (ICCAP). Research Institute for Humanity and Nature, Kyodai Kaikan, Kyoto, Japan.

JIN, F. 2011. Climate changes in future atmospheric moisture fields over the Middle-East based on regional climate modeling. Department of Geophysics and Planetary Sciences. Tel Aviv: Tel Aviv University.

KÖCHY, M. & JELTSCH, F. 2006. Projections of green biomass, leaf area index, and carrying capacity of livestock based on regional climate projections (18 km resolution) for the Jordan River catchment. internal GLOWA report; 14 pp.

KÖCHY, M. & JELTSCH, F. 2007. Projections of green biomass, leaf area index, and carrying capacity for livestock based on regional climate projections (50 km resolution, A2 scenario) for the Jordan River catchment. GLOWA Jordan River. Report. Research Group Plant Ecology and Nature Conservation, Potsdam University. Potsdam, Germany. 19 pages.

KÖCHY, M. & JELTSCH, F. 2008. Verbundvorhaben: GLOWA Jordan River Phase 2, Teilvorhaben 5: Wasser-Vegetationsmodellierung : hierarchische Modelle der Auswirkung des Globalen Wandels - von Einzelpflanzen zu regionaler Landnutzung und Einzugsgebieten ; Schlussbericht.

KRICHAK, S., ALPERT, P. & DAYAN, M. 2005. Simulations of the surface climatology over the Eastern Mediterranean region using the RegCM3 model. In: COTE, J. (ed.) Research Activities in Atmospheric and Oceanic Modelling.

KRISHAK, S. 2012. Investigation of climate of the eastern Mediterranean region and hydrodynamic simulation of its expected changes in XXI century (in Russian). Department of Geophysics and Planetary Sciences. Tel Aviv University.

LANGE, J. & GUNKEL, A. 2009. Verbundvorhaben: GLOWA Jordan River Phase 2 – Teilvorhaben 5: Hydrologische Modellierung (blue water) : Abschlussbericht; Bewilligungszeitraum: 01.09.2005 - 31.08.2008.

LÜBKERT, B., ONIGKEIT, J. & ALCAMO, J. 2006. GLOWA Jordan River 1st Scenario Panel Meeting, Waldeck, Germany on on 17th – 19th May 2006, Workshop Documentation. Center for Environmental Systems Research (CESR), University of Kassel, Germany.

LÜBKERT, B., ONIGKEIT, J. & ALCAMO, J. 2006. GLOWA Jordan River 1st Scenario Panel Meeting, Waldeck, Germany on on 17th – 19th May 2006, Workshop Summary Report. Center for Environmental Systems Research (CESR), University of Kassel, Germany.

LÜBKERT, B., ONIGKEIT, J. & ALCAMO, J. 2007. GLOWA Jordan River 2nd Scenario Panel Meeting, Hofgeismar, Germany on 5th – 7th February 2007, Workshop Documentation. Center for

Environmental Systems Research (CESR), University of Kassel, Germany.

LÜBKERT, B., ONIGKEIT, J. & ALCAMO, J. 2007. GLOWA Jordan River 2nd Scenario Panel Meeting, Hofgeismar, Germany on 5th – 7th February 2007, Workshop Summary. Center for Environmental Systems Research (CESR), University of Kassel, Germany.

LÜBKERT, B., ONIGKEIT, J. & ALCAMO, J. 2008. GLOWA Jordan River 3rd Scenario Panel Meeting, Dead Sea, Jordan on 26th – 28th November 2007, Workshop Documentation. Center for Environmental Systems Research (CESR), University of Kassel, Germany.

MARSCHNER, B. & SCHACHT, K. 2008. Abschlussbericht zum Verbundvorhaben: GLOWA Jordan River Phase 2 - Teilvorhaben 3: Abwassermanagement.Bewilligungszeitraum: 01.09.2005-30.11.2008.

ONIGKEIT, J., LUEBKERT, B. & ALCAMO, J. 2007. Quantitative model drivers for the Glowa Jordan River Scenarios, Technical Report. Center for Environmental Systems Research (CESR), University of Kassel, Germany.

PRASSE, R. 2008. Abschlußberichte zum Verbundvorhaben Glowa Jordan River Phase 2 für die Teilprojekte 11a "Intercropping annual fields with perennial plants - A strategy to reduce land degradation in semi-arid regions" und 9.6 "Interaktionen zwischen Pflanzen und Tieren unter dem Einfluss des Klimawandels".

RIMMER, A. & LECHINSKY, Y. 2006. Developing a dynamic model for flow in the UCJR.

RIMMER, A. & LECHINSKY, Y. 2007. Model of solute discharge and salinity of Lake Kinneret.

RIMMER, A. & LECHINSKY, Y. 2008. The evaporation from Lake Kinneret. Final research report Submitted to the Hydrological Service and the Water Authority office.IOLR report T23/2008

RIMMER, A. & SALINGAR, Y. 2005. Developing a dynamic river basin model for contaminants transport in the UCJR using GIS.

RIMMER, A. & SALINGAR, Y. 2005. Dynamic river basin model for the Upper Catchments of the Jordan River (UCJR) using GIS.

TIELBÖRGER, K. 2005. Vulnerability of water resources in eastern mediterranean environments. GLOWA Jordan River, phase I : Vulnerability of water resources in eastern mediterranean environments ; final report ; towards phase II: an integrated approach to sustainable management of water resources under global change. In: (ED.) (ed.).

TIELBÖRGER, K. 2009. GLOWA Jordan River Phase 2 : Teilprojekt der Universität Tübingen ; Schlussbericht ; September 2005 - Dezember 2008. In: (ED.) (ed.).

TIELBÖRGER, K. 2009. An integrated approach to sustainable management of water resources under global change: GLOWA Jordan River ; phase II, final report. In: (ED.) (ed.).

WOLFF, H.-P. 2009. Schlussbericht des Teilprojektes "Sozio-Ökonomie der Wasserallokation" im Verbundprojekt GLOWA Jordan River : Laufzeit des Vorhabens: 01.09.2005 - 31.08.2008.

Annex 2:
List of BSc, MSc, Diploma and PhD theses of all three phases

BSc Theses

BAUMEISTER A (2006) Auswirkung von Abwasser-Beregnung auf Huminstoffe und Bodenatmung einer Avokadoplantage Israels. *Department for Soil Science and Soil Ecology, Ruhr-University Bochum*. Supervised by Marschner B.

BEAUMONT R (2007) The adaptations in germination and life-history traits of annual plant species from different rainfall conditions. *Department of Vegetation Ecology, University of Tübingen, ERASMUS programme*. Supervised by Tielbörger K.

BECK S (2008) Gene flow and genetic diversity along a steep rainfall gradient in Israel. *Department of Vegetation Ecology, University of Tübingen, ERASMUS programme*. Supervised by Tielbörger K.

BEN-MEIR Y (2009) Effects of TWW irrigation on sandy soils. *Department of Soil and Water Sciences, Hebrew University of Jerusalem*. Supervised by Chen Y.

HOFFMANN Y (2010) Hydrophobicity of desert soils induced by plant residues. *Department of Soil and Water Sciences, Hebrew University of Jerusalem*. Supervised by Chen Y.

KUGLER D (2011) Der Effekt von Regenmanipulationsexperimenten auf das Keimungsverhalten von mediterranen Pflanzen. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

LAASER T (2012) Does facilitation promote persistence of maladapted ecotype in stressful environments? - A test with dryland annuals. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

LECHNER N (2012) Phenology shifts in annual plants - Distinguishing between plastic response and genetic changes. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

MÜLLER G (2010) Adaptation to positive interactions in Crithopsis delileana. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

SCHMID M (2011) Determining the water use efficiency of three plant species after 9 years of rain manipulation in Israel using the carbon isotope composition. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

WEBER B (2011) Intraspezifische Unterschiede in Linum strictum und Linum corymbulosum nach neun Jahren Niederschlagsmanipulation? *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

MSc Theses

ABDEL-KAREEM SS (2005) GIS-Based hydrological modeling of semiarid catchments (The case of Faria Catchment). *Water and Environmental Studies Institute (WESI), An-Najah National University.* Supervised by Shaheen HQ and Jayyousi AF.

ABEER K (2010) Developing Rainwater Harvesting Strategy as a Tool for Drought Mitigation. *Faculty of Graduate Studie, The University of Jordan.* Supervised by Al-Karablieh E and Salman A.

ABU HANTASH S (2007) Development of sustainable management options for the West Bank water resources using WEAP. *Water and Environmental Studies Institute (WESI), An-Najah National University.* Supervised by Haddad M and Jayyousi A.

ABU JALBOUSH A (2007) Ecological investigations on the terrestrial biodiversity in the area of Wadi Alfar'a. *Department of Biology and Biotechnology, An-Najah National University.* Supervised by Saleh A and Ali-Shtayeh MS.

ABU-BAKIR M (2007) Wastewater characteristics and the impact of its use in irrigation on soil: The case of Faria Catchment. *Water and Environmental Studies Institute (WESI), An-Najah National University.* Supervised by Almasri M.

ABU-JALBOUSH AIS (2008) Ecological Investigations on the Terrestrial Biodiversity in the Northern Part of the West Bank (Jenin Area). *Department of Biology, Faculty of science and technology, Al-Quds University.* Supervised by Saleh A and Ali-Shtayeh MS.

ADSEROL O (2006) Maternal effect in annual plants. *Dept. of Plant Ecology, University of Tübingen, ERASMUS programme.* Supervised by Tielbörger K and Oran S.

ALI H (2010) Optimum Water Allocation in Al-Azraq basin using WEAP system. *Faculty of Graduate Studies, The University of Jordan.* Supervised by Salman A and Al-Karablieh E.

ALI WMD (2008) Ecological investigations on terresterial arthropod biodiversity under different grassland ecosystems in El-Fara' Area (Palestine). *Department of Biology and Biotechnology, Faculty of Graduate Studies, An-Najah National University.* Supervised by Ali-Shtayeh MS.

ALONI S (2012) Hydrometeorological characterization of droughts - the Golan Heights case study. *Geography Department, Hebrew University of Jerusalem.* Supervised by Grodek T.

ARAFAT A (2007) Integrated water resources planning for a water-stressed basin in Palestine. *Water and Environmental Studies Institute (WESI), An-Najah National University.* Supervised by Jayyousi A and Haddad M.

ATALLAH N (2010) Assessing and mapping of groundwater vulnerability to contamination using the PI- method for the West Bank, Palestine. *Water and Environmental Studies Institute, An-Najah National University.* Supervised by Almasri MN.

BARNEA I (2009) Reexamination of phosphorus fertilizing practices in the altered wetland soils of Hula Valley, Israel. *Department of Soil and Water Sciences, Hebrew University of Jerusalem.* Supervised by Shenker M and Litaor I.

BASSAT K (2004) Model internal variability in regional climates simulations over Israel. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Krichak SO and Alpert P.

BEN-ISHAI O (2006) Variation in flowering patterns of Asphodelus ramosus along a rainfall gradient. *Faculty for Agriculture, Food and Environment, Hebrew University of Jerusalem.* Supervised by Kigel J.

ESHEL G (2004) Hydrogeology of altered wetland, Hula Valley, Israel. *Department of Soil Science, Hebrew University of Jerusalem.* Supervised by Litaor MI and Nativ R.

FUKS D (2005) Global climate change – welfare loss. *Department of Agricultural Economics and Management, Hebrew University of Jerusalem.* Supervised by Fleischer A.

GABAY O (2003) Soil seed banks and climate change: a reciprocal transplant experiment along a climatic gradient in Israel. *Department of Molecular Biology and Ecology of Plants, Tel Aviv University.* Supervised by Sternberg M.

GERSHTEIN G (2008) Application of an advanced numerical weather prediction system based on NCAR WRF model over the Eastern Mediterranean. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Krichak S and Alpert P.

GHANNAM M (2007) Profitability of Olive and Almond Farming in Palestine: A comparative Study. *Department of Biology, Faculty of science and technology, Al-Quds University.* Supervised by Saleh A.

GHNMEEIN T (2007) The impact of greenhouses in saving irrigation water in Jordan. *Department of Geography, Mu'tah University.* Supervised by Oroud IM.

GÖTZ H (2012) Remote sensing of agricultural areas in Israel for hydrological modelling. *Institute of Geography, University of Heidelberg.* Supervised by Menzel L.

GUTMAN I (2009) Effects of wastewater on aggregate stability in soils. *Department of Soil and Water Sciences, Hebrew University of Jerusalem.* Supervised by Chen Y.

HAERING MA (2008) Vulnerability of Irrigated Agriculture due to Climate Change in the Lower Jordan River Basi. *Faculty of Graduate Studies, The University of Jordan.* Supervised by Salman A and Al-Karablieh E.

HAIM A (2004) The influence of redox potential on P solubility in altered peat soils, Hula Valley, Israel. *Department of Soil Science, Hebrew University of Jerusalem* Supervised by Litaor MI and Shenker.

HAIM D (2005) Economic Impacts of Climate Changes – Estimation of Net Revenue Changes in the Israeli Agricultural Sector as a Function of Precipitation and Temperature. *Department of Natural Resource and Environmental Management (NRERC), Haifa University.* Supervised by Shechter M.

HAJHAMAD L (2007) Management of nitrate contamination of Gaza coastal aquifer. *Water and Environmental Studies Institute (WESI), An-Najah National University.* Supervised by Almasri M.

HAR-EDOM O (2007) Climate change and community resistance to invasion: a study case with Conyza canadensis along a rainfall gradient. *Department of Plant Sciences, Tel Aviv University.* Supervised by Sternberg M.

HAUSINGER I (2009) Application and validation of TRAIN at the Yatir forest. *Department of Ecological Modelling, University of Bayreuth.* Supervised by Menzel L.

HECKL A (2006) Hydrologische Modellierung des Einzugsgebietes Oberer Jordan mit WaSiM-ETH auf Basis gemessener und modellierter Klimadaten. *Department of Regional Climate and Hydrology, University of Augsburg.* Supervised by Kunstmann H.

HESUS J (2008) Spatial variability as a new method for evaluation of principle component in agricultural production under arid conditions. *Department of Geography and Environmental Development, Ben-Gurion University of the Negev.* Supervised by Ben-Asher J and Blumberg D.

HOCHMANN A (2009) Reconstructing climate fluctuations and trends of the Eastern Mediterranean and Israel. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P.

KALMIKOV A (2006) Generation mechanisms of elevated inversions in the Eastern Mediterranean. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P.

KANAS D (2007) Sex ratio changes in Sarcopoterium spinosum (L.) spach: an experimental approach along a rainfall gradient in Israel. *Department of Molecular Biology and Ecology of Plants, Tel Aviv University* Supervised by Sternberg M.

KHATATNEH A (2010) Water production in the north western Mujib catchment area. *Dept. of Geography, Mu'tah University.* Supervised by Oroud IM.

KROTMAN Y (2004) Biodiversity and community structure of Jordan system fishes and their relationship to the habitat structure and anthropogenic impact. *Tel Aviv University.* Supervised by Dayan T.

KUNIN P (2009) Analysis of possible climate consequences in the Middle East area due to potential operation of the Red Sea/ Dead Sea canal. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Krichak S and Alpert P.

LERNER O (2003) Effects of irrigation with reclaimed wastewater on soil water transport. Moshav Gibton, Israel. *Department of Soil and Water Sciences, Hebrew University of Jerusalem.* Supervised by Chen Y.

LICHTAMN I (2006) The impact of global climate change on profitability in agriculture. *Department of Agricultural Economics and Management, Hebrew University of Jerusalem.* Supervised by Fleischer A.

LUBCHIK A (2009) Modeling of sea-salt aerosols over the Mediterranean region. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P and Kishcha P.

MAAITEH M (2010) Jordanian public awareness towards environmental commons *Department of Geography, Mu'tah University* Supervised by Oroud IM.

MAHMOUD H (2011) Minimizing unmet demand by IWRM approach on watershed level using WEAP: Al Qilt and Al Nueimah watersheds lower part as a case study. *Water and Environmental Studies Institute, An Najah National University.* Supervised by Jayyousi A.

MARCUS T (2011) Influence of study extent and environmental sources on spatial distribution modeling of mammals in Israel. *Department of Zoology, Tel Aviv University.* Supervised by Dayan T.

NAIERAT S (2007) The Socio Economic Impact of Using different Irrigation Water qualities in different Farming Systems (The Case of Al Faria"a basin). *Department of Development Studies, Al-Quds University.* Supervised by Hijawi T.

NAOR R (2011) The impact of the Red-Sea Dead-Sea canal on the Dead-Sea area climate and on the evaporation in Sdom. *Porter School, Tel Aviv University.* Supervised by Alpert P and Potchter O.

NAWASREH A (2006) The impact of Dead Sea lowering on the geomorphology of selected wadies. *Department of Geography, Mu'tah University* Supervised by Oroud IM.

PORAT Y (2011) Different land management practices and their impact on reptile communities. *Department of Zoology, Tel Aviv University.* Supervised by Dayan T.

RADIAN R (2012) Urban effects - radar and Cellular rainfall study. *Dept. of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P.

RAPPAPORT-ROM M (2007) Economic Assessment of Climate Change Impacts on the Vegetative Agriculture in Israel. *Department of Natural Resource and Environmental Management (NRERC), Haifa University.* Supervised by Shechter M.

RAWASHDEH SH (2006) Domestic water use efficiency in Jordan. *Department of Geography, Mu'tah University.* Supervised by Oroud IM.

RAYITSFELD A (2010) Monitoring and analysis of rainfall using microwave grids from cellular antennas in Israel. *Department of Geophysics and Planetary Sciences, Tel Aviv University* Supervised by Alpert P.

RYB T (2012) The natural level fluctuations of the Dead Sea in response to annual variations in precipitation. *Department of Geography, Hebrew University of Jerusalem.* Supervised by Grodek T.

SADE R (2007) Differentiation of groundwater to elucidate P transport mechanisms from agricultural fields to drainage canals in the Hula Valley, Israel. *Department of Soil and Water Sciences, Hebrew University of Jerusalem* Supervised by Shenker M and Litaor MI.

SALAHAT A (2007) The impact of grazing and land reclamation on plant biodiversity in the Northern West Bank. *Department of Biology and Biotechnology, An-Najah National University.* Supervised by Ali-Shtayeh MS.

SAMOCHA Y (2005) Effects of Capsodes infuscatus on life traits of Asphodelus ramosus populations: an experimental approach along a climatic gradient in Israel. *Department of Molecular Biology and Ecology of Plants, Tel Aviv University.* Supervised by Sternberg M.

SARIEREH R (2006) The geographic distribution of frost and its economic impacts in Jordan. *Department of Geography, Mu'tah University.* Supervised by Oroud IM.

SAWALMEH M (2010) Water fluxes in three watersheds in northern Jordan. *Department of Geography, Mu'tah University.* Supervised by Oroud IM.

SCHULER P (2011) Hydrological balance of the Jeita spring catchment. *Institute for Technology and Resources Management in the Tropics and Subtropics, Cologne University of Applied Sciences.* Supervised by Roehrig J and Al-Omari A.

SEGEV U (2008) Granivory and vegetation diversity along rainfall gradient. *Institute for Plant Science, Hebrew University of Jerusalem.* Supervised by Kigel J.

SHAKHSHEER M (2006) Farming and Rural System Analysis in Palestine (The Case of Al Faria Basin). *Department of Development Studies, Al-Quds University.* Supervised by Hijawi T.

SHARKAWI R (2010) Optimum water allocation in the Jordan Valley. *Faculty of Graduate Studies, The University of Jordan.* Supervised by Salman A and Al-Karablieh E.

SHEMESH O (2005) The economic value of agricultural landscape. *Department of Agricultural Economics and Management, Hebrew University of Jerusalem.* Supervised by Fleischer A.

SHERMAN G (2012) Synoptic systems objective analyses in the Med. Sea and Europe in winter and its application in climate models for the 21st century. *Dept. of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P.

SHIFRIN I (2007) Global climate change – technology adoption in agriculture. *Department of Agricultural Economics and Management, Hebrew University of Jerusalem.* Supervised by Fleischer A.

SHILO R (2009) Evolution of agricultural land-use and water consumption in the Jordan Valley; a remote sensing based reconstruction. *Department of Geography and Environmental Development, Ben-Gurion University of the Negev.* Supervised by Blumberg D and Ben-Asher J.

SHOLOCHMAN T (2006) Theoretical investigation of the factor separation method. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P.

SHOMRON M (2006) Methods for cooling the greenhouses of leafy crops with relevancy to the crops of lower Jordan river basin. *Department of Geography and Environmental Development, Ben-Gurion University of the Negev.* Supervised by Blumberg D and Ben-Asher J.

SHWEINSHTEIN O (2012) Urbanization effects on solar isnolation and aerosol distribution. *Department of Geophysical, Atmospheric and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P.

TALMON Y (2009) Soil respiration and evaporation responses to precipitation change in Mediterranean and desert ecosystems. *Faculty of Agriculture, Food and Environment, Hebrew University of Jerusalem.* Supervised by Gruenzweig J and Sternberg M.

TAMIR G (2005) Spatial variability as a new method for evaluation salinity distribution under arid conditions. *Department of Geography and Environmental Development, Ben-Gurion University of the Negev.* Supervised by Ben-Asher J and Blumberg D.

UZAN L (2007) Investigation of the thermal boundary layer over Hadera from a LAP-3000 profiler under different synoptic and air pollution conditions. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P.

VARDI N (2007) The economic value of species diversity in Pinus halepensis community in the Carmel National Park on different times after fire and examining the correlation between precipitations amount and the growth of Pinus halepensis in the first year after fire. *Department of Natural Resource and Environmental Management (NRERC), Haifa University.* Supervised by Shechter M.

YAGIL I (2008) Correlation between winter precipitation, summer and winter extremes and synoptic systems in the EM region based on a semi-objective classification. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P.

YOSEF G (2009) Effects on daily climate of semi-arid region caused by forest. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P and Krichak S.

YOSEF Y (2007) Rainfall quantity and distribution trends in Israel as a function of daily rainfall 1950/1- 2003/4. *Department of Geophysics and Planetary Sciences, Tel Aviv University.* Supervised by Alpert P and Saaroni H.

ZIV I (2012) Dew projections to the 21st Century. *Department of Geophysical, Atmospheric and Planetary S*

Diploma Theses

EBERHART A (2006) Do siblings avoid each other? An empirical test of the sibling competition hypothesis along a steep climatic gradient. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

FISCHER C (2007) Hydrological modeling of the Water Resources in the Nahal Harod, Israel. *Department of Hydrology, University of Freiburg*. Supervised by Lange J and Leibundgut C, http://www.hydrology.uni-freiburg.de/abschluss/Fischer_C_2007_DA.pdf, accessed: 24.07.2012.

GIEBL B (2008) Klimaszenarien und historische Extreme im Jordan-Einzugsgebiet. *Department of Hydrology, University of Freiburg*. Supervised by Lange J, http://www.hydrology.uni-freiburg.de/abschluss/Giebl_B_2008_DA.pdf, accessed: 24.07.2012.

HARTMANN A (2008) Process-based modelling of karst springs in Mt. Hermon, Israel. *Department of Hydrology, University of Freiburg*. Supervised by Weiler M and Lange J, http://www.hydrology.uni-freiburg.de/abschluss/Hartmann_A_2008_DA.pdf, accessed: 24.07.2012.

KOHN I (2008) Wasserhaushaltsmodellierung zur Abschätzung der Perkolation in einem gebirgigen Einzugsgebiet im östlichen Mittelmeerraum - Nahal Oren, Karmel, Israel. *Department of Hydrology, University of Freiburg*. Supervised by Lange J.

KRIER R (2007) Niederschlagsradardaten zur Regionalisierung von Klimaparametern. *Department of Hydrology, University of Freiburg*. Supervised by Leibundgut C and Lange J, www.hydrology.uni-freiburg.de/abschluss/Krier_R_2007_DA.pdf, accessed: 24.07.2012.

LUTZ M-T (2011) The economic value of mesic mediterranean landscape under global climate change: a case study in the Jordan River basin. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

MATHAJ M (2007) Modellierung von Vegetationsentwicklung und Erosion entlang eines Klimagradienten von mediterran bis semiarid. *Biochemistry and Biology, University of Potsdam*. Supervised by Köchy M, http://nbn-resolving.de/urn:nbn:de:kobv:517-opus-27863.

NACHREINER J (2004) Reproductive allocation and other life-history traits of annual plants along a climatic gradient in Israel. *Biochemistry and Biology, University of Potsdam*. Supervised by Tielbörger K and Jeltsch F.

SCHIFFERS K (2003) Interactions of annual plants: empirical investigations along a climatic gradient in Israel. *Biochemistry and Biology, University of Potsdam* Supervised by Tielbörger K and Jeltsch F.

SCHÜTZ T (2006) Prozessbasierte Niederschlags-Abflussmodellierung in einem mediterranen Kleineinzugsgebiet, Nahal Anabe, Israel. *Department of Hydrology, University of Freiburg*. Supervised by Leibundgut C and Lange J, www.hydrology.uni-freiburg.de/abschluss/Schuetz_T_2006_DA.pdf, accessed: 26.07.2012.

SIEWERT W (2008) The dispersal dormancy trade-off in annual plants: putting model predictions to the test. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

WIESENDANGER C (2007) Ereignis-basierte Datenkorrektur der Radarniederschlagsmessung – eine Anwendung im Einzugsgebiet des Unteren Jordans. *Department of Hydrology, University of Freiburg*. Supervised by Leibundgut C and Lange J, http://www.hydrology.uni-freiburg.de/abschluss/Wiesendanger_C_2007_DA.pdf, accessed: 26.07.2012.

PhD Theses

ABUSAADA MJ (2011) Flow dynamics and management options in stressed carbonate aquifer system, the Western Aquifer Basin, Palestine. *Fakultät für Geowissenschaften und Geographie, University of Göttingen*. Supervised by Sauter M and Ptak T, http://nbn-resolving.de/urn:nbn:de:gbv:7-webdoc-3030-6.

ARGAMAN E (2007) A new methodology to estimate potential and actual evapotranspiration in the Upper Jordan River Basin. *Department of Geography and Environmental Development, Ben-Gurion University of the Negev*. Supervised by Ben-Asher J and Blumberg D.

ARIZA CL (ongoing) Interactions of plants along a climatic gradient in Israel: plasticity and evolution of competitive ability under climate change. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

ARYE G (2007) Effects of humic substances on water retention and transport in soils. *Department of Soil and Water Sciences, Hebrew University of Jerusalem*. Supervised by Chen Y.

BANGERTER S (ongoing) The effect of grazing cessation on semi-arid to sub-humid rangelands under climate change. *Department of Environmental Planning, University of Hannover*. Supervised by Prasse R.

BARKAN Y (2006) The sources of the Saharan dust and the synoptics of its transportation toward the American and European continents. *Department of Geophysics and Planetary Sciences, Tel Aviv University*. Supervised by Alpert P.

BONZI C (ongoing) Developing water management strategies under climate change with WEAP: the contentious setting of the Jordan River basin. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

BRAND S (ongoing) Salinity processes in altered wetland soils. *Department of Soil Science, Hebrew University of Jerusalem* Supervised by Litaor MI.

CARMONA I (2009) The effect of aerosols on errors in weather and climate predictions. *Department of Geophysics and Planetary Sciences, Tel Aviv University*. Supervised by Alpert P.

GENIS A (2008) Modeling minimum energy of root growth and water uptake. *Department of Geography and Environmental Development, Ben-Gurion University of the Negev*. Supervised by Ben-Asher J, Blumberg DG and Kafkafi U.

GUNKEL A (ongoing) A coupled, process-based simulation model for water resources in the Lower Jordan River Catchment. *Department of Hydrology, University of Freiburg*. Supervised by Weiler M and Lange J.

HÄNEL S (ongoing) The potential of microevolution in Mediterranean annual plants due to climate change. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

HAREL D (2009) Effects of climate change on germination strategies of annuals along rainfall gradient in Israel. *Department of Molecular Biology and Ecology of Plants, Tel Aviv University* Supervised by Sternberg M.

HARTMANN A (ongoing) Modelling karst hydrology and hydrochemistry in different scales and climates considering prediction uncertainty. *Department of Hydrology, University of Freiburg*. Supervised by Lange J.

HECKL A (2011) Impact of climate change on the water availability in the Near East and the Upper Jordan River Catchment. *Department of Regional Climate and Hydrology, University of Augsburg*. Supervised by Kunstmann H, http://nbn-resolving.de/urn:nbn:de:bvb:384-opus-18095.

HEINKIN N (ongoing) Study of air-pollution behavior in an urban environment using a system of atmospheric models. *Department of Geophysics and Planetary Sciences, Tel Aviv University*. Supervised by Alpert P.

HIJAWI T (2003) Economics and management of the use of different water qualities in irrigation in the West Bank *Department of Social and Institutional Change, University of Hohenheim*. Supervised by Doppler W.

HIRSCH- ESHKOL T (2009) Climate analyses related to land use change feedbacks, with focus over the Eastern Mediterranean Region. *Department of Geophysics and Planetary Sciences, Tel Aviv University*. Supervised by Alpert P.

JÜSCHKE E (2009) Effluent irrigation and agricultural soils effects on the dynamics of organic carbon and microbial activity in agricultural soils in Israel. *Department of Geography, Ruhr-University Bochum*. Supervised by Marschner B and Chen Y.

KOCH J (2010) Modeling the impacts of land-use change on ecosystems at the regional and continental scale. *Faculty of Electrical Engineering and Computer Science, University of Kassel*. Supervised by Alcamo J, http://nbn-resolving.org/urn:nbn:de:0002-9656.

LAMPEI C (2010) Annual plant populations under global climate change: their adaptations to aridity and potential for evolution. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

LEVY O (aaa2010 please check entry for mistakes) The evolution of diurnality in golden spiny mice: from basic principles to community structure. *Tel Aviv University*. Supervised by Dayan T and Freidberg A.

METZ J (2010) The sensitivity of Eastern Mediterranean plant communities to variations in rainfall and their vulnerability to global climate change. *Department of Plant Ecology, University of Tübingen* Supervised by Tielbörger K and Kigel J.

NADAV I (ongoing) Water repellency induced by organic matter in treated wastewater infiltration ponds and irrigation (Reporttitle). *Department of Soil and Water Science, Hebrew University of Jerusalem*. Supervised by Chen Y.

NAVON Y (2007) Plant litter decomposition in natural ecosystems under climate change: an experimetal approach along a climatic gradient in Israel. *Department of Molecular Biology and Ecology of Plants, Tel Aviv University* Supervised by Sternberg M.

NOAM D (ongoing) Monitoring of moisture and rainfall by cellular networks. *Department of Geophysics and Planetary Sciences, Tel Aviv University*. Supervised by Alpert P.

OSETINSKY I (2006) Climate changes over the E. Mediterranean - a synoptic systems classification approach. *Department of Geophysics and Planetary Sciences, Tel Aviv University* Supervised by Alpert P, http://primage.tau.ac.il/libraries/theses/exeng/free/2079562.pdf.

PALATNIK R (2008) Analysis of the impact of economic incentives to control greenhouse gas emissions within the framework of a general equilibrium model of the Israeli economy. *Department of Natural Resource and Environmental Management (NRERC), Haifa University*. Supervised by Shechter M, http://lib.haifa.ac.il/theses/general/001456124.pdf.

PETRŮ M (2006) Life history expressions of annual plants in unpredictable environments: from theoretical models to empirical tests. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K, http://nbn-resolving.de/urn:nbn:de:bsz:21-opus-22861.

PRANGE S (ongoing) Feedbacks between vegetation and hydrology with a special view on extreme events in Israel. *Department of Vegetation Ecology and Nature Conservation, University of Potsdam*. Supervised by Geissler K.

REICHMAN O (ongoing) Factors and processes affecting the water quality of the Jordan River. *Department of Soil Science, Hebrew University of Jerusalem* Supervised by Litaor MI.

RYSAVY A (ongoing) Biotic and abiotic effects on species interactions in a water stressed ecosystem: the effect of grazing and rainfall on the establishment and growth of Sarcopoterium spinosum. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K and Sternberg M.

SALAH A (2008) Intercropping annual fields with perennial plants - A strategy to reduce land degradation in semi-arid regions. *Department of Environmental Planning, University of Hannover*. Supervised by Prasse R and Marschner B, http://nbn-resolving.de/urn:nbn:de:gbv:089-5668667221.

SAPIR J (2008) The effect of global warming on the changes in vegetation density around Yatir Forest from 1945 to 2005. *Department of Geography and Environmental Development, Ben-Gurion University of the Negev*. Supervised by Ben-Asher J and Blumberg D.

SCHACHT K (ongoing) Evaluation of soil suitability for wastewater irrigation in the Middle East. *Department of Geography, Ruhr-University Bochum*. Supervised by Marschner B.

SCHECHNOWITZ Y (2006) The effect of arid land afforestation on local water balances: the Yatir case. *Department of Geography and Environmental Development, Ben-Gurion University of the Negev*. Supervised by Berliner P and Laron Y.

SEGEV U (2012) Variability in abundance, size and foraging efficiency of colonial organisms along an environmental gradient. *Institute for Plant Sciences, Hebrew University of Jerusalem*. Supervised by Kigel J, Lubin Y and Tielbörger K.

SHADEED S (2008) Up to date hydrological modeling in arid and semi-arid catchment, the case of Faria catchment, West Bank, Palestine. *Dept. of Hydrology, University of Freiburg*. Supervised by Leibundgut C and Shaheen H, http://nbn-resolving.de/urn:nbn:de:bsz:25-opus-54205.

SHAMIR S (2009) Setting biodiversity conservation priorities: an ecological-economic analysis. *Dept. of Natural Resource and Environmental Management (NRERC), Haifa University*. Supervised by Shechter M and Shitovitz B.

SHOLOKHMAN T (2012) The factor separation method in the atmosphere- theoretical Investigation and analysis of present applications. *Department of Geophysics and Planetary Sciences, Tel Aviv University*. Supervised by Alpert P.

SIEWERT W (ongoing) Modeling extinction risks of plant populations under climate change: a multi-species approach. *Dept. of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

SKUTELSKY O (2012) Biodiversity conservation in biosphere reserves of Israel: the switch from a market led to conservation oriented agriculture. *Porter School of Environmental Studies, Tel Aviv University*. Supervised by Dayan T.

SPRINGER B (ongoing) Fluctuating asymmetry in plants along steep and subtle environmental gradients - a role of biotic interactions. *Department of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

STEINITZ H (2010) The effects of global climate change on the distribution of terrestrial mammals in Israel. *Dept. of Zoology, Tel Aviv University* Supervised by Dayan T.

TABIEH MAS (2009) An optimal irrigation water allocation model: management and pricing policy implications for the Jordan Valley", mathematical and econometrics approaches. *Dept. of Agriculture and Agribusiness, University of Jordan*. Supervised by Salman A.

TIETJEN B-K (2009) Drylands under climate change - a novel ecohydrological modelling approach. *Deptartment Plant Ecology and Nature Conservation, University of Potsdam*. Supervised by Köchy M.

TOMIOLO S (ongoing) The role of biotic interactions in determining local adaptation to climatic conditions- consequences for adaptation to climate change. *Deptartment of Plant Ecology, University of Tübingen*. Supervised by Tielbörger K.

TÖRNROS T (ongoing) Assessing the impact of climate variability on the hydrological fluxes in the south-eastern Mediterranean. *Institute of Geography, University of Heidelberg*. Supervised by Menzel L.

WEIß M (2009) Modelling of global change impacts on hydrology with focus on Europe and Africa. *Department of Electrical Engineering and Computer Science, University of Kassel*. Supervised by Alcamo J, http://nbn-resolving.org/urn:nbn:de:0002-7592.

ZINEVICH A (2010) Spatio-temporal monitoring of precipitation by microwave networks. *Department of Geophysics and Planetary Sciences, Tel Aviv University*. Supervised by Messer-Yaron H and Alpert P.

ZIV I (2012) Dew projections to the 21st Century. *Dept. of Geophysics and Planetary Sciences, Tel Aviv University*. Supervised by P A.

ZWIKEL S (2005) Spatial patterns of soil properties that affect water regime (rainfall – overland flow relationships) in ecogeomorphic systems, along a climatic transect, from the Galilee Mountains to the Negev Highlands. *Dept. of Geography and Environmental Studies, Bar-Ilan University*. Supervised by Lavee H and Sarah P.

Annex 3: Expression of Intent

In the light of the growing evidence that global change is going to have a severe impact on our region, the participants from Israel, Jordan, the Palestinian Authority of the Workshop held in Cyprus on September 3-4, 2012 acknowledge the importance of the creation of a regional Centre for adaptive resource management (Middle East Centre for Sustainable Solutions to Global Change). The proposed centre will focus attention on the difficulties the region is facing in relation to global change and associated land use changes. These in turn will present problems in satisfying demand for water, adjusting agricultural practices, protecting biodiversity, improving methods for risk management, and responding to global changes.

The participants propose that the centre should serve as a regional resource for implementing global change adaptation in relation to natural transboundary resources. It will gather and generate data with regard to water supply, land use change, and other significant concerns with a regional aspect. As such, the Centre would help in more effective adaptive management and promote the transdisciplinary dialogue among scientists and stakeholders in the region.

Specifically, the Centre will:

- Promote **trans-boundary co-operation** in global change adaptation
- Develop and host an accessible **up-to-date database** of transboundary natural resources
- **Contribute to sharing of** and **exposure to knowledge** (capacity building)
- **Be a regional resource for international bodies** concerned with global change
- Develop and communicate **solutions that can be transferred** to other countries
- **Conduct multilateral research** about areas of concern and make available **cutting-edge research** relevant for decision makers

The Centre will be jointly managed by a Board made up of representatives of Israel, Jordan and the Palestinian Authority together with German representatives. It will operate in premises located in all three of the countries of the region.

It is recommended that before a final commitment is made by any of those directly involved in long-term support of the proposed Centre, an initiation phase be spent on for demonstrating the successful role and mode of operation of the Centre.

Annex 4: One page overview SAGE Centre

*S*ustainable *A*daptation to *G*lobal Change in the Middle *E*ast –The SAGE Centre

In the past decade, the **GLOWA Jordan River project** (GLOWA JR, www.glowa-jordan-river.de), financed by the German Federal Ministry of Education and Research (BMBF) and coordinated by the University of Tübingen, involved numerous partners from Israel, Jordan, the Palestinian Authority as well as from Germany, both scientists and stakeholders. GLOWA JR was designed to study the impact of global change on the water and land resources of the Jordan River Basin. It has many achievements to its credit, which are evident on two complementary fronts: high-end scientific research results and the promotion of a trans-boundary science-stakeholder dialogue.

On the political realm, a unique atmosphere of mutual trust, genuine collaboration and friendship among top scientists and key governmental representatives from Jordan, the Palestinian Authority, and Israel has been created. Such relationships are critical for promoting and implementing sustainable resource management in an era of global change. At the same time, they are rare in a region with great political complexity where biodiversity, land and water resources are all volatile and liable to promote conflicts.

The trans-disciplinary forum generated by GLOWA JR created a momentum for establishing a new initiative for transnational science-stakeholder dialogue. This will ensure effective exchange of information between science and action and enable a trans-boundary - and thus more sustainable - development of adaptive strategies for dealing with global change.

The initiative aims at creating a regional **Centre** for **Sustainable Adaptation to Global Change**, in which the countries of the region will share in the management together with the government of Germany as a partner with special responsibility. The main focus is on empowering the region with scientifically based knowledge enabling them to manage biodiversity, land and water resources in a sustainable manner. The Centre's aims will be to stimulate regional dialogue in the region via applied trans-boundary research, to empower future generations to address the challenges posed by global change, and to host and maintain a regional information system for trans-boundary resources.

In September 2012, a first workshop took place with senior stakeholders and scientists from Israel, Jordan, the Palestinian Authority and Germany where the structure, management, permanent activities and first pilot projects of the Centre were defined. A schedule for elaborating a concept for the establishment of the centre was created.

In March 2013, a second workshop took place in East Jerusalem, where the first draft concept was reviewed, and key aspects were refined and agreed on. Among the key aspects dealt with were the structure of the Centre and the way in which it can develop in the future.

Three key elements were identified for the first five year period – the creation of a regional information service dealing with trans-boundary natural resources, including monitoring of hydrological and biodiversity data, and two research projects. One addresses adaptive management of biodiversity and ecosystem services under global change, enabling the establishment of a regional early warning system. The second is concerned with efficient water management. Also discussed were the role of the science–stakeholder dialogue, decision support tools and capacity building in the region. It was agreed that the Centre could act as a "platform" for new projects concerned with climate change adaptation and seek funds from international donors.

An initiation phase of five years is envisaged during which the SAGE Centre will be managed jointly by the regional partners and the University of Tübingen. The latter will gradually pass leadership to the region. All Governments involved -Israel, Jordan, the Palestinian Authority and Germany- would support the Centre but over the five-year period the proportion of financial support given of the regional Governments will increase. At the end of the five years the methods of working, structure and role of the Centre will be clearly established. The German Government will act as a neutral partner in the event of there being differences between the regional partners as to policy and programs.

For more information please contact: coordination@glowa.uni-tuebingen.de

Annex 5: Medium term effects of climate change and land use change on structure and function of natural ecosystems

Rüdiger Prasse and Ayman Saleh, University of Hannover

Note that these findings represent a key result of the overall GLOWA Jordan River project and thus they are presented here as a summary. They were not part of phase 3 and are thus not included in the main text, yet they are important for appreciating the use of rainfed land use practices for saving water and protecting natural biodiversity. The full findings can be found in the Ph.D. Thesis of A. Saleh (see Annex List of Theses, Saleh 2008)

1.1 Aim

Surface runoff and erosion are major contributors to soil degradation worldwide. These processes are especially severe in regions with sparse vegetation cover, low annual precipitation but often intense rainfall events. The study region- Israel, the West Bank and Jordan, are situated in an area with - despite of a low overall precipitation - sometimes heavy rainfall events (especially during the early growing season when vegetation cover is still scarce). However, little quantitative information is available for this region on soil erosion and unproductive water-losses. Consequently, existing agricultural practices are not addressing these problems. A two--year experiment was set up in the West Bank to quantify soil loss as well as water loss from arable fields and to test for the mitigating effects of intercropping arable fields with useful native perennial plant species, as a means to both protect these species in the wild and to increase the benefit from rainfed farming of arable crops.

1.2 Description of research

1.2.1 Material and methods

The study was conducted in vegetable fields of the Al-Khalil district in the southern part of the West Bank. The monthly average temperature ranges from 7.5ºC in winter to 22ºC in summer. The climate of the district is mostly semi-arid to Mediterranean (250 mm to 600 mm) with the wettest parts in the north and an increasing aridity towards the south (Negev desert) and the east (Jordan Valley). In order to test the influence of changes in climatic conditions on our proposed mitigation strategy we conducted our experiments at two sites differing in mean annual precipitation:

i) Al-Dhahriya: receives a mean annual precipitation of 425 mm, and is situated at 610 m above sea level. Four arable fields were chosen at this site for the experiment.

ii) Halhul: receives a mean annual precipitation of 590 mm and is located between 910 m and 960 m a.s.l.. Three arable fields were chosen at this site for the experiment.

The selected fields for our experiments share comparable features. They were located on moderate slopes with inclination between 8% and 10%. The soil of the investigation sites is classified as brown Terra Rossa.

To test the hypotheses a randomised block design was used with 4 blocks in Al-Dhahriya and 3 blocks in Halhul. Each block contained three intercropping treatments and a control. Each treatment plot was 5 m wide x 22 m long. In the intercropping treatment parallel strips of the selected native perennial plants (*Majorana syriaca*, *Salvia fruticosa*, and *Salvia hierosolymitana*) were planted across the path of overland flow. The width of each strip was 0.5 meter. The strips were planted with a distance of six meters in order to allow the use of regionally typical machinery and other necessary agricultural treatments. The area assigned to the native plants was 10% of the total area of each treatment plot. The decision for the cash-crop used in the experiments was left to the local farmers involved in the project. Therefore, the crop rotation followed the local tradition: Snake cucumber (*Cucumus melo*, var. *flexuosus*) in the first year (2004/5) and bean (*Phaseolus vulgaris*) in the next year (2005/6) of study.

Measurements:

- Run-off: The accumulative runoff volume over each rainy season received from intercropping plot was measured and compared with the volume received in the control plots. Water loss was calculated as a percentage of total rainfall amount received during the measuring period.

- Erosion: All sediments in the run-off collection tank were stirred up, representative subsamples taken, filtered, oven-dried and the total soil loss in the whole season calculated and used to estimate the soil erosion as kilogram dry soil per hectare (kg/ha).

- Soil-moisture was measured gravimetrically in all plots after rain storms and the results from the treatment plots were compared to the results from the control plots by oven drying replicated and representative soil samples weighing them. Percent soil moisture by weight (% Moisture content) was calculated.

1.2.2 Results

Intercropping with native perennial plants reduced surface-runoff:

The total runoff in all intercropped treatments was significantly lower compared to the control in all seasons of investigation and at all sites. The total runoff reduction by intercropping varied among treatments between from 34% to 41% (1st season) and from 52% to 89% (2nd season).The intercropping reduced runoff already during the extremely rain events of the first season. The reduction of water loss in the intercropped plots was observed already during the early rain events of autumn when only the root systems and residues of semi-dry aboveground parts of the native plants were present.

Intercropping with useful native perennial plants reduced soil erosion:

Total soil erosion in all intercropped treatments was significantly lower if compared to the control in all seasons of investigation and at all sites. The overall reduction of soil loss in intercropped plots was 45% to 68% (first season) and 74% to 94% (second season) of the amount recorded in the control.

Intercropping with useful native perennial plants increased the retention of water in the soil:

During the first season (2004/2005) soil moisture in intercropped treatments was significantly higher than in the not intercropped control plots. In the second season, no significant difference in mean soil moisture content between the intercropping treatments and the control plots was found.

The efficiency of intercropping with useful native perennial plants in mitigating runoff and erosion was consistent under different climatic conditions:

The amounts of runoff and soil erosion in the intercropped plots were lower than in the controls independent of the geographic locations of the experiment, and independent of the inter-annual variation. However, geographic location and season determined the magnitude of the difference. The reduction of runoff and erosion by intercropping was more pronounced at the drier site than at the wetter site. In addition, at both sites, the reduction of runoff and erosion by intercropping was also higher in the drier season than the wetter season at all sites.

The efficiency of intercropping with useful native perennial plants in reducing runoff and erosion was not species-specific:

All tested species of native perennial plant intercrops reduced the mean runoff volumes and soil losses in all seasons and the measured differences in mean reduction of runoff and soil erosion between species were never statistically significant.

The farmer faced no financial loss by intercropping the field with useful native perennial plants:

Even so 10% of the experimental fields were designated to the native plant species the farmers faced no financial loss as selling the products of the native perennial plants on the local markets fully or more than fully compensated for the loss of income from cash crops. In a year of drought the farmers even earned most of their income from selling the products of the native perennial plants as the cash crop largely failed to produce marketable products.

1.2.3 Discussion and conclusion of scientific highlights and outlook

The results confirm the importance of the permanent vegetation cover in controlling water loss by runoff (BARTON et al. 2004, ADEKALU et al. 2006, SEEGER 2007). However, the fact that the planted native perennial plants reduced the runoff already during the beginning of the season may point to the great importance of the root system in reducing runoff. This is especially important during the first rain event when the annual fields are usually free of any type of vegetation. As quantitative data on the effect of intercropping on runoff in semiarid regions are missing, it is impossible to compare our results to other data. However, KINAMA et al. (2007) used in a semiarid region a complex system with crop rotation, perennial hedgerows and grass strips. That system achieved almost 55% to 80% reduction in runoff which is very close to the performance of our much simpler system. The benefit of the system described here in comparison to the system of KINAMA et al. (2007) is mainly the fact, that our farmers faced no loss of productive area as they were selling the harvest from the intercropped areas on the local markets.

The observed reduction in soil erosion was probably due to the enhanced surface roughness achieved from the planted intercrops and due to better infiltration rates, so less water ran down the slopes removing and dislocating soil-particles. The velocity of surface runoff in parts of the arable field between strips of useful native perennial plants was probably reduced, less surface were removed and some of the dislocated sediment was re-deposited downslope behind the next strip of the native perennial plants. The intercropping with useful native perennial plants in controlling soil loss appears to be efficient and a promising mechanism in soil protection if compared to other management practices. The applied simple intercropping practice was efficient as much as a complicated system (crop rotation, perennial hedgerow and grass strips) applied by KINAMA et al. (2007) in comparable conditions in semiarid area. The efficiency of intercropping with useful native perennial plants appears to be higher than other practices such as mulch cover and crop rotation. For the applied intercropping practice a perennial ground cover of only 10% was enough to protect soil, which is lower than the ground cover needed to achieve similar benefits by mulch cover or crop rotation used by ADEKALU et al. (2006).

The strips of native plants intercepted rain water ways and slowed down the surface water flow. Our measurements showed that a ton of the top soils in the intercropped plots retained almost 27 kg (litre) water more than the bare plots when rainfall is around the long-term average. Therefore, a hectare of the intercropped field may conserve more than 80m^3 water in the top 25cm of soil (assuming a soil density of 1.2 g cm^{-3}) compared to the top soils in normal fields. The estimated amounts of retained water is lower than expected from the estimated increase in infiltration, as a considerable amount of infiltrated water has probably taken its way to the ground water. That allows to conclude, that intercropping does not only benefits the farmer (more plant available water) but may help in maintaining the ground water recourses. The increase of soil moisture under intercropping in the semiarid areas was also reported by FU et al. (2003).

The beneficial effects of intercropping with useful native perennial species were not only consistent under the two investigated rainfall regimes but its effect was also more pronounced at the arid research site and at both sites more pronounced in the drier season. Therefore, we conclude that intercropping is especially important in dry areas and it is an agricultural scheme of great importance as it will still continue to be effective in controlling water and soil losses if the climate changes as predicted.

As no species-specific effect on the efficiency of intercropping in reducing runoff and erosion were found, we have to conclude that other useful native perennial plants sharing the same characteristics as the species used, are probably suitable for intercropping practices as well. Most important seems to be that each perennial species is adapted in its own way to the environmental conditions of semiarid areas and the perennial life history. The perennial species develop a strong root system and at least parts of the above ground shoot-system appear all a year round. Planting such species as intercrops and marketing their products will probably also decrease the pressure on the wild populations and benefit biodiversity conservations.

1.3 Applied value of results

The intercropping of traditionally used agricultural crops with useful perennial native plants appears to be a simple sustainable strategy to maintain soil fertility, farmer's income and to benefit biodiversity conservation even under the predicted climate change. The simplicity and sustainability of the new system encouraged already the adaptation of the system by the local farmers in the region. The perennial native plants need to be planted only once at relatively low costs and their advantages for soil protection and water use efficiency are permanent.

1.4 References

BANIN A, AMIEL A (1970) The correlative study of the chemical and physical properties of a group of natural soils. Geoderma *3:185-198.*

ADEKALU KO, OKUNADE DA, OSUNBITAN JA (2006) Compaction and mulching effects on soil loss and runoff from two southwestern Nigeria agricultural soils. *Geoderma* 137: 226-230.

BARTON AP, FULLEN MA, MITCHELL DJ, HOCKING TJ, LIU L, BO ZW, ZHENG Y, XIA ZY (2004). Effects of soil conservation measures on erosion rates and crop productivity on subtropical Ultisols in Yunnan Province, China. *Agriculture, Ecosystems & Environment* 104: 343-357.

DE BELLO F, *et al*. (2006). Variations in species and functional plant diversity along climatic and grazing gradients. *Ecography* 29(6): 801-810.

JANKAUSKAS B, JANKAUSKIENE G (2003) Erosion-preventive crop rotations for landscape ecological stability in upland regions of Lithuania. *Agriculture, Ecosystems and Environment* 95: 129-142.

KINAMA JM, STIGTER CJ, ONG CK, NG'ANG'A JK, GICHUKI FN (2007) Contour Hedgerows and Grass Strips in Erosion and Runoff Control on Sloping Land in Semi-Arid Kenya. *Arid Land Research and Management* 21: 1-19.

NOY-MEIR I, KAPLAN D (2002). Species richness of annual legumes in relation to grazing in Mediterranean vegetation in northern Israel. *Israel Journal of Plant Sciences* 50: S95-S109.

OSEM Y, *et al.* (2002). Grazing effect on diversity of annual plant communities in a semi-arid rangeland: interactions with small-scale spatial and temporal variation in primary productivity. *Journal of Ecology* 90(6): 936-946.

SEEGER M (2007) Uncertainty of factors determining runoff and erosion processes as quantified by rainfall simulations. *Catena* 71: 56-67.

Annex 6: List of stakeholders

List of stakeholders involved in GLOWA Jordan River phase III and/or the preparatory workshops for drafting the SAGE Centre concept paper.

Israel

Institution	Person	Position
Ministry of Environment	Dr. S. Netanyahu O. Matzner	Chief Scientist Staff member Science Division
Ministry of Agriculture	T. Grinhut	Office of Chief Scientist
Ministry of Regional Cooperation	Yaniv Stern	Director Regional Projects
Water Authority	Dr. G. Weinberger Dr. A. Givati	Head Hydrological Service Chief Scientist Hydrological Service
Ministry of Science and Technology	Dr. U. Gazit	Chief Scientist
Nature Parks Authority	Dr. Y. Shkedy D. Rotem	Chief Scientist Staff member Science Division
Arava Institute	Dr. C. Lipchin S. Kronich	Director of Research Associate Director
Migal	Dr. D. Cohen	Development Manager
Dead Sea & Arava Science Center	Dr. E. Groner	Academic Director

Palestinian Authority

Institution	Person	Position
Ministry of Environment	A. Abu Thaher	Secretary General
Ministry of Agriculture	Dr. I. Nofal	Secretary General
Palestinian Water Authority	Dr. A. Jarrar Dr. K. Assaf Dr. B. Shonnar	Director General Personal Consultant to Head of PWA Director Data Bank Department
Ministry of Planning	T. Hithnawi	Director General

Jordan

Institution	Person	Position
Ministry of Environment	Ahmad al-Qatarneh Hussein Badarin	Secretary General Director of Monitoring & Assessment
Ministry of Water and Irrigation	A. Subah Dr. J. Stork	Deputy Secretary General Consultant (via CIM-GIZ)
Ministry of Agriculture	W. Alrashdan	Director Rangeland Management
Royal Scientific Society for the conservation of nature	Hussien Al Kisswani	Climate Change Officer
Royal Scientific Society	Dr. R. Ardah Eng. W. Suleiman	Studies and Consultation Specialist Head of Water Studies Division
Royal Botanical Garden	T. AbuTaleb Hatem Taifour	Executive Director Head Botanist
National Centre for Agricultural Research and Extension	Dr. N. Haddad	Director Research Department

Multi-national (NGOs)

Institution	Person	Position
IPCRI	Dr. R. Twite	Head
Friends of the Earth Middle East (FoEME)	M. Mehyar N. Khateb Dr. Y. Arbe	Jordanian Director Palestinian Director Water Officer- Israel

View publication stats