# GLOWA JORDAN RIVER

# AN INTEGRATED APPROACH TO SUSTAINABLE MANAGEMENT OF WATER RESOURCES UNDER GLOBAL CHANGE

*Proposal for a third project phase – Complementary Strategy Document*
*(1. December 2008 - 31. November 2011)*


Submitted to the BMBF by the Eberhard-Karls-University of Tübingen, Germany, in collaboration with the University of Kassel and the Tel Aviv University:

*Forschungszentrum Karlsruhe (IMK-IFU Garmisch-Partenkirchen), Stockholm Environment Institute, University of Bochum, University of Freiburg, University of Hannover, 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-Hai College, Weizman Institute*

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

*An-Najah National University, Arab Agronomist Association (AAA/PARC), University of Bethlehem, Biodiversity & Environmental Research Center, House of Water and Environment, Ministry of Agriculture, Palestinian Hydrology Group, Palestinian Water Authority*

# Table of Contents

## Summary

The main goal of Phase III is to develop new, science-based, strategies and adaptation options for coping with the impact of global and regional change on regional water resources and water scarcity, and to communicate these to the key stakeholders in the region.

The **main product** of Phase III will be:

***An integrated analysis of global change effects on the regional water resources and, based on this assessment, adaptation options and strategies for sustainable water management under change***

For this purpose, the following other products will be produced:

- WEAP established as DSS with key stakeholders in the region
- Dialogue between scientists and stakeholders in the region, beyond GLOWA JR
- Credible water balances for the region and sub-basins
- Set of scenarios depicting adaptive water management under global and regional change
- Tools for combined blue and green water management
- Trained young scientists and experts to carry on WEAP and scenario analysis in the region
- Scientific products (publications, data bases, conferences) that consolidate and summarize the innovative international research carried out in the GLOWA-JR project.
- Other products (e.g. scenario viewer, fact sheets, monitoring platforms, geodatabase, training workshops) supporting outreach to the stakeholders in the region and in other regions with similar settings
- Transboundary scientific collaboration

Box 1a summarizes briefly in a hierarchical top-down approach how the various subprojects interact and are essential for generating these end-products.

Phase III will be 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?

These questions were selected because they provide a new global change perspective to the critical water problems in the region. It should be noted that these questions are closely interlinked since they all contribute to the overarching question. A novelty is that blue and green water management options will not be treated separately but comprehensively in our analyses, and climate extremes will, together with analyses of climate change trends, be an integral part of the analyses of blue-green management options. We will treat the climate

extreme question with special attention, because it has been raised as a major concern by key stakeholders.

For addressing our main question, phase III will center around three main interacting activities:

a) Conducting a stakeholder-driven scenario analysis that will examine a wide range of alternative water management strategies with respect to their sustainability
b) Developing regional and sub-regional water balances and sustainability analyses using WEAP (Water Evaluation and Planning tool) linked to the scenario exercise and also stakeholder-driven (Project 1.2).
c) Disseminating the tools and results of the study to a wide audience in the region.

In addition, we will continue with our capacity building via intensive training of young regional scientists and stakeholders. A new focus in phase III will be on training in the integration and modeling tools.

Interrelated subprojects on “New Water”, “Green Water Management/Land Use” and “Climate and Hydrology” support the above activities.

# 1 Introduction and Goals of Phase III

Phase I of the GLOWA-Jordan River project (abbreviated in this document as “GLOWA-JR”) provided new process understanding and a wealth of new data and information for specific locations.

Phase II built a framework for analyzing region-wide questions about global change and water resources. This framework consisted of two main components:

- A scenario building process in which experts from the region and Germany interacted with stakeholders from the region. This interaction produced 4 “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 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.

Phase III will build on the scenarios, WEAP, tool-development, and new findings of Phase II by developing new strategies for coping with the impact of global and regional change on regional water resources and water scarcity. New data collection will be minimized and a focus will be on making use of data and models from previous project phases.

Sustainable water strategies will be depicted in three main forms in Phase III:

a) As scenarios developed under a continuation of the GLOWA-JR scenario exercise from Phase II
b) As regional and sub-regional water balances, accompanied by simple sustainability and economic analyses with the WEAP model
c) Detailed cost-benefit analyses of specific management options for a set of focal areas

### Uniqueness of GLOWA-JR Approach

The GLOWA-JR approach is unique within the large set of water-related studies in the region because:

a) It is science-based and at the same time stakeholder-driven
b) It applies an integrated approach to water management as opposed to the traditionally fragmented approaches
c) It has an explicit focus on global and regional change processes
d) It combines comprehensive scenario analysis and water balance approaches
e) It combines the standard approach of management and conservation of "blue water" with managing land use ("green water") to conserve and derive value from scarce water resources.
f) It addresses the importance of nature and its diversity for water management

## 2 Aim of this Document

The aim of this document is to present the overall strategy of the project and how its various components are integrated and crucial for attaining our main goals and products. This document complements, and in some cases supersedes the full proposal "GLOWA Jordan River: an integrated approach to sustainable management of water resources under global change" Submitted May, 2008. Readers are referred to the full proposal for details about the methodology of individual subprojects. Subproject numbers in this concept document refer to the subproject numbers of the full proposal.

## 3 Guiding Sub-Questions of Phase III

The sustainable water strategies to be designed in Phase III will address **three guiding questions** that deal with a critical water resource issues in the region, as identified in the earlier GLOWA JR phases. These questions were selected because they provide a new global change perspective to the critical water problems in the region and provide a unifying basis for the work to be carried out in Phase III. The questions are inseparable, but form a useful framework for better illustrating our integrated approach:

*Sub-question 1: The "New Water" Question* – Under expected global change, how can "new water" sources be combined with conventional water resources and green water resources (question 2) and provide adequate water for society and nature in the region? This question deals with society's needs for water for agriculture, industry, and households, and also for nature's water requirements (e.g. environmental flows). These questions will be addressed by making use of information generated in Projects 2 and 4.3 and its application to the scenario exercise in Project 1.1 and WEAP-generated water balances in Project 1.2.

*Sub-question 2: The "Land Use" Question* – Under expected global change, how should green water resources be managed in combination with blue water (question 1) for providing adequate water for society and nature in the region? What are future economic benefits, including ecosystem goods and services, provided by blue water uses in the region (question 1) vs. green water uses (e.g. ecosystem services). What actions can be taken to reduce water use (e.g. by reallocation to rainfed land use)? These questions will be addressed with information from Project 3 i.e. by estimating future ecosystem goods and services and water requirements for different land uses and its application to the scenario exercise in Project 1.1 and WEAP-generated water balances in Project 1.2.

*Sub-question 3: 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? How will the climatic extremes (in particular, extended droughts) affect water management options under the different GLOWA-JR futures? Where will the water resource system be particularly vulnerable to a change in drought frequency? Which strategies (questions 1 and 2) could be effective in coping with droughts? These questions will be addressed by making use of information generated in Project 4 and its application to the scenario exercise in Project 1.1 and WEAP-generated water balances in Project 1.2. The analysis to address this question will focus on the impact of climate extremes on water resources, in particular the changed frequency of droughts, and analyses of actions such as new water sources, adaptive land and water use (i.e. questions 1 and 2), and other adaptation options.

# 4 Expected Results of Phase III

- New sustainable water management strategies for coping with the impacts of global and regional change on water scarcity: (a) The strategies will be depicted in the form of scenarios which will be both qualitative (storylines) and quantitative (model calculations.) The scenarios will be communicated through various media such as stakeholder-oriented reports, an interactive DVD-based "Scenario Viewer", WEAP demonstrations and verbally at various direct briefings and meetings with stakeholders. (b) The new strategies will also be embodied in a set of regional and sub-regional water balances and analyses computed by the WEAP model. These calculations will also be communicated directly to stakeholders in various forms.
- Through extensive training activities WEAP will be established in the region as an operational tool for ongoing analysis of water scarcity problems.
- New consolidated knowledge about the potential for "new water" sources to meet the water needs of the region.
- New strategies for land management / green water management that would conserve the region's scarce water resources and derive higher value from the use of water
- New knowledge about the future impact of climate change and land use change on water resources in the region, and approaches for coping with these changes
- A continued extensive capacity building program for young scientists in the region. This will produce many new young experts who will be able to continue with the innovative approaches to water scarcity in the region introduced by the GLOWA-JR project (Table 1)
- Ongoing transboundary scientific collaborations

## 5 Organization and Main Activities of the Project

The project organization is presented in Box 1b. Phase III involves three main activities:

**1)** Conducting a **stakeholder-driven scenario exercise** which will produce rich scenarios that examine a wide range of alternative water management strategies with respect to their sustainability via WEAP (Project 1).

The scenario exercise will follow the "Story and Simulation Approach" (SAS) which involves an intensive interaction between stakeholders from the region and scientists from the project. The SAS approach was already used in Phase II to promote discussion between stakeholders and experts from Jordan, Israel and the PA and for producing the GLOWA-JR “regional development scenarios". The scenario exercise in Phase III will build on these scenarios. Project scientists will present the stakeholders with a wide range of analyses and quantitative information concerning the project's three guiding questions (new water, land use, climate extremes) using the four regional development scenarios as a reference point. This information will be derived from models and data bases compiled in the different subprojects (see Boxes 1a through 4). Stakeholders will use this information in their development of new qualitative scenarios (storylines) that lay out steps for coping with the impacts of global change on water availability in the region. The qualitative scenarios will be complemented by quantitative analyses conducted by WEAP, LandSHIFT, TRAIN-ZIN, WADISCAPE and other models and tools employed in the project (see Boxes 2 through 4). The main output of the exercise will be a consistent set of qualitative and quantitative scenarios that depict new sustainable water management strategies for coping with the impacts of global and regional change on water scarcity.

**2)** Developing regional and sub-regional **water balances using WEAP** (Water Evaluation and Planning tool) and providing analyses of sustainability of management options for linking to the scenario exercise and also stakeholder-driven (Project 1.2).

The WEAP analyses will generate informative and useful water balances, also for a wide range of alternative water strategies with respect to their sustainability, building on the successful implementation of WEAP in the region in Phase II. WEAP will play a key role in synthesizing quantitative information from the subprojects and in analyzing the sustainability of the strategies produced by the scenario exercise (Box 1a). For example, it will be used to synthesize detailed hydrologic calculations from Project 4 and water productivity estimates from Project 3 in the form of regional and sub-regional water balances. These water balances will evaluate key aspects of the project's three guiding questions – the effectiveness of new water sources in meeting future water needs, the role of land use management in deriving value from scarce water resources, and the impact of changes in climate and land use on future water availability. The successful training of new WEAP model users, begun during Phase II, will be continued in Phase III. As a result, many institutes and key stakeholders and experts in the region will have the competence to use the WEAP model for analyzing water scarcity problems after the completion of the GLOWA-JR project. Currently, several key stakeholders have participated in the training programs and will use WEAP in the future. Subregional WEAP systems (a- Upper Catchment with focus on Kinneret, b- West Bank, c- Jordan River Valley) address country-specific adaptation options in larger detail.

An important aspect of Phase III is the interaction between its two main activities - the WEAP analyses and the scenario exercise: WEAP will produce water balances that evaluate the key questions of Phase III. This information will be presented directly to stakeholders at scenario meetings who will use these data as input to the development of management scenarios. It is expected that the stakeholders will also commission further analyses with WEAP to assist in their evaluation of management strategies. Hence the WEAP team, one of the main synthesizers of quantitative information in the project, will interact with the stakeholders responsible for the development of new GLOWA-JR scenarios. In this way the two integrating threads of the project will be brought together.

**3) Dissemination**

Making available, in full detail (i.e. beyond the integration tools), the wealth of scientific and applied results about global change effects and adaptation options in the water sector. A major component of these activities is capacity building through which young scientists from the region will be trained in the innovative tools and methodologies used for analysing global change and water resources in the GLOWA-JR project (cross-cutting through Projects 1 to 4). (see Table 1 for further information). Dissemination activites started in phase II (fact sheets, geodatabase, direct stakeholder contacts, scientific publications, website) will be intensified in phase III and complemented by new activities (e.g. special issues in applied journals, workshops, wrap up conference).

Other subprojects will support the above three main activities:

- The project “New Water” (Project 2) will assemble information needed to address “Guiding Question 1”.
- The project “Green Water Management/Land Use” (Project 3) provides the analysis of land use – water relationships needed to address “Guiding Question 2”.
- The project “Climate and Hydrology” (Project 4) carries out analyses to address “Guiding Question 3”.
- The project “Coordination and Dissemination” (Projects 0; 1.3) cuts across all projects.

# 6 Analysis of the New Water Question

## 6.1 Introduction and Goals

The goal of this analysis is to address the guiding question: Under expected global change, how can “new water” sources be combined with conventional water resources and provide adequate water for society and nature in the region? This supply-oriented question is complemented by the more demand-oriented approach of question 2.

Sub-questions to be addressed are:

- What are the future needs for water in the region for society and nature under different global change scenarios?
- How much can “new sources”, versus other sources of water, cover future water needs?

## 6.2 Approach

The approach for addressing the new water question is shown in Box 2. The analysis of new water options is carried out in the integration project (P1) by developing new water balances with WEAP (P1.2) and new scenarios (P1.1). Our past experience has shown that constraints on data sharing dictate a new approach to obtaining information on the various water sources, especially in the Upper Catchment. Project 2 will consolidate the missing information which is fed in to the scenario exercise and WEAP analysis. Information on other water sources (water harvesting, managed aquifer recharge, treated wastewater) is assembled in Project 3.4 and 4.3 and fed into the scenario exercise and WEAP analysis.

The scenario exercise and the WEAP analysis of water balances will be interconnected in that the scenario exercise will provide information on future driving forces of water resources for the region (e.g. population, economic indicators, management options) while the WEAP analysis will use the driving forces for providing regional and sub-regional water balances that can be used by the stakeholders to evaluate management options.

## 6.3 Tasks

- Future demands for water in the region are identified for the domestic, manufacturing and electricity sectors (using driving forces from the GLOWA-JR regional development scenarios) and the agriculture sector (using input from the land use scenarios, Project 3.3, and studies of water crop water use, P3.4). WEAP and other models (P1.2) will be used for these estimates and input assumptions will be derived as part of the scenario exercise (P1.1).
- As part of the WEAP analysis (P1.2) and scenario exercise (P1.1) we assemble the following classes of information about "new water" sources:
    - Water transfers – various proposals including the Red Sea - Dead Sea canal, water transfers from Turkey, others. Information from existing studies is used here; no new analyses are carried out (P2)
    - Desalination – current and future capacity is estimated from existing sources (P2)
    - Wastewater reuse – current and future potential is estimated (P3.4)
    - Rainwater harvesting – current and future potential under climate change is estimated (P4.3)
    - Managed aquifer recharge – current and future potential under climate change is estimated (P4.3)
    - Water demand management (P1.2)
    - Virtual water (P2)

- The preceding information on new water sources is used by the WEAP model to compute regional and sub-regional water balances with and without the single or combined above new water options (P1.2). Information about water availability under climate change, including climate extremes (P4), is incorporated into this analysis. WEAP computes these water balances using assumptions of the four GLOWA-JR regional development scenarios.
- Environmental flow requirements of the Jordan River and inflows to the Dead Sea are defined based on existing information. The water balances derived above are tested against these flow requirements to determine if new water sources will permit the restoration of the aquatic ecosystem of the Jordan River and maintain the level of the Dead Sea (P1.2). Green water management options (P3) will be included in these analyses (see question 2).
- Results of the WEAP analysis are presented during the scenario exercise to stakeholders (P1.1) who decide on further combinations of new sources (including green water management options) to be analyzed by the WEAP model (P1.2). The results of the WEAP analyses are combined with information from the GLOWA-JR regional development scenarios to produce new scenarios of future water management in the region (P1.1).

## 6.4 Output/Deliverables

- New estimates of future water needs of all important water-using sectors in the region under different scenarios.
- New regional water balances combining the detailed hydrologic water balances under climate change (P4.2) and the evaluation of new water sources (P2-4).
- New regional scenarios depicting water use and availability in the region under global change.
- New regional scenarios depicting strategies for coping with impacts of global and regional change on water resources.

# 7 Analysis of the "Land Use Question"

## 7.1 Introduction and Goals

The goal of this analysis is to address the guiding question: Under expected global change- to what extent should land use planning, i.e. green water management, become an integral part of water management under different scenarios? For addressing this question, we need to compute water productivity of all major land use types under changing conditions.

The overall approach to the Land Use Question is illustrated in Box 3. We address this question in four parts:

a) Identifying the impact of land use change on water availability (P3.3, with P4).
b) Determining agricultural water productivity under climate change (P3.4; phase 2 results).
c) Assessing the economic value and water requirements of future land use (ecosystem services) (P3.1; 3.2)
d) Determining water productivity in natural and semi-natural ecosystems via reliable estimates of ecosystem functional variables and their associated value under climate and land-use change (P3.1)
e) Determining climate change and land use change effect on the water balance in natural and semi-natural ecosystems (P3.1)

## 7.2 Identifying the impact of land use change on water availability (Project 3.3)

### Main Question

What impacts will changing land use have on the demand and availability of water in the region?

### Approach

The approach to this analysis is shown in Box 3. Since land use and land cover have such an important effect on the region's water balance, it is important to estimate future land use patterns. This task will be accomplished by the LandSHIFT model (P3.3). The LandSHIFT model must take into account future changes in agricultural production as computed by economic models (P3.3), and other driving forces from the scenario exercise (P1.1). The land use scenarios, together with climate scenarios (P4.1) provide the main input to estimating future availability of water in the region (P3.1; 4.2). Estimates of water availability will then provide essential input to the WEAP analysis of regional and sub-regional water balances (P1.2) and the development of scenarios of sustainable water management strategies (P1.1).

The land use scenarios will also provide important input to the assessment of ecosystem services (see below).

#### Tasks

- We first prepare the input data needed by the LandSHIFT model for the simulation of future land use. These include:
    - future agricultural production in Israel from the VALUE model (P3.3)
    - future agricultural production in PA and Jordan from phase II models and other scenario studies (Millennium Ecosystem Assessment) (P3.2; 3.3)
    - future comprehensive ecosystem services provided by the dominating land use type (P3.1; 3.2)
    - future sustainable stocking densities for rangeland under climate change (P3.1.1)
    - potential area suitable for using wastewater for irrigation (P3.4.2)
- The LandSHIFT model is then run to produce land use scenarios according to the above inputs and other assumptions of the GLOWA-JR scenarios (P1.1)

#### Outputs/ Deliverables

As output, the land use scenarios provide …

- Input to computation of regional water balances (P1.2; 3.1.1; 4.2)
- Input to scenario exercise in developing land use strategies that conserve water (P1.1)

### 7.3 Determining agricultural water productivity (Project 3.4)

#### Main Question

How can how can more value be extracted from the use of a unit of water in agriculture?

#### Approach

The approach to this analysis is shown in Box 3. Since agriculture accounts for such a significant fraction of regional water use, special attention has been to assessing the potential for increasing water use efficiency in agriculture (phase II data complemented by P3.4.1). This information provides input to the calculation of crop water requirements (P4.3 and phase II) which will be used in the WEAP analysis of regional water balances (P1.2) and in the evaluation of sustainable water management strategies in the scenario exercise (P1.1). An important potential source of water for agriculture is treated wastewater. The potential for using treated wastewater for irrigation in the region is evaluated here (P3.4.2, based on phase II) and serves as input to the allocation of future agricultural land simulated by the LandSHIFT model (P3.3).

#### Tasks

- Field experiments were carried out for parameterizing and validating models in phase I and II to derive relationships between agricultural management practices and water productivity of crops.
- Cotton and wheat models have been tested and verified and these models are used to compute future crop yields in the region under climate change. Phase III will expand this approach to other major crops (P3.4.1).
- Using field data from Phase II, maps are produced of the suitability of soils for using treated wastewater for irrigation. Maps are based on phase II data but will be refined to a scale relevant for stakeholders (P3.4.2).

- Water productivity of rangelands under climate and land use change will be provided by P3.1.1 and P3.1.2.

#### Output/Deliverables

- Computed crop yields, combined with phase II economic evaluations, are input to the simulation of future land use with LandSHIFT (P3.3)
- Information on crop water use is input to the computation of regional crop water requirements, and thereby the regional water balances (P4.2).
- Maps of potential for using treated wastewater for irrigation serve as input to the simulation of future land use by LandSHIFT (P3.3).
- Maps of water use and water productivity (biomass yield per unit water, P3.1) of rangelands combined with phase I and new economic evaluations (P3.2) as input for land use simulation with LandSHIFT (P3.3.)

### 7.4 Assessing the economic value and water requirements of future land use (ecosystem services) (Project 3.2)

#### Main Question

How can land use decisions and management increase the “productivity of water”, i.e. the benefits to society in the region?

#### Approach

The approach to this analysis is shown in Box 3. Land use decisions have an important impact on water use in the region because different land uses have greatly different water requirements. A main focus will be on rainfed land use (agriculture and open space) because of its large spatial extent and its tremendous potential for water saving. We quantify and compare the economic value of different types of future land use in the region as “ecosystem services”. This information, together with information on the water required for this land use (from P4.2), is then input to the scenario exercise and WEAP (P1.1; P1.2). A novelty is the explicit consideration of open space (‘nature’), which accounts for up to 90% of the land cover in the different countries and thus has a major impact on the water resources.

#### Tasks

- Using the benefit transfer method, we estimate the economic value per hectare of ecosystem services associated with natural and open land uses in the region (P3.2). This analysis takes into account not only conventional sources of economic value such as livestock raising, but also other factors that are often overlooked in assessing the future value of land despite their potential for a much larger revenue (i.e. recreational value, non-market value, biodiversity, erosion control, direct use value, option value, etc.). This assessment depends critically on reliable estimates of ecosystem properties (biodiversity and erosion risk) under climate and land use change (from P 3.1).
- Information on economic value per hectare from the previous task and from phase II (agricultural revenues) is applied to the four GLOWA-JR scenarios in order to identify the total ecosystem services and other revenues for these scenarios (Project 3.3) This analysis takes into account the distribution of land depicted in the land use scenarios (Project 3.3), the economic value of the agricultural land (from Phase II), the economic value of the natural and open land based on predicted ecosystem properties (from Project 3.1). The economic values of these land uses are compared to their water requirements (computed in Projects 3.1 & 4.2).

### Outputs/Deliverables

Information on the analysis of ecosystem services (economic value of different future land uses and their water requirements) are fed into LandSHIFT and consecutively into WEAP and the scenario exercise (Project 1.1). This information provides a unique basis for assessing the effectiveness of green water management (land use management) as an alternative (or complement) to "new water" for addressing water scarcity in the region.

## 7.5 Determining water productivity under climate and land use change for natural and semi-natural ecosystems (Project 3.1)

### Question

What impact will climate change combined with land use change have on structure and function of natural and semi-natural ecosystems, how will this in turn affect ecosystem services and the regional water balance?

### Approach

The approach to this analysis is shown in Box 1a and 3. Climate change will not only directly affect water availability in the region (because of changed precipitation and temperature) but also indirectly through its impact on land use. Vice-versa, land use has tremendous effects on ecosystem functioning and ecosystem response to climate change (phase II results). Here we examine key factors by which climate change will influence ecosystem functioning and land use (feedback mechanisms) and thereby regional water availability. These factors include: (i) the impact of climate change on ecosystem functioning (e.g. biodiversity, stocking capacity, erosion control), i.e. all variables affecting ecosystem services of open space, its water requirements and effects on the hydrology (P3.1). (ii) The impact of climate change on terrestrial ecosystem parameters (P3.1.2) that provides input to the assessment of the economic value future land use (P3.2). Our approach is modeling (P3.1.1; P3.1.2; P3.1.3) parameterized and validated by a globally unique set of experimental data (P3.1.2).

### Tasks

- Using the model WADISCAPE and ecohydrological models derived in Phase II for open space (arid shrubland, rangeland and forests), the following will be determined for different climate (P4.1) and land use (P3.3) scenarios: future vegetation cover, biodiversity, erosion risk, fire risk and effects, productivity and sustainable stocking capacity. A focus will be on climatic extremes and interactions of climate with land use effects. (P3.1.1; 3.1.2)
- For obtaining reliable estimates of ecosystem properties, we must distinguish signal (climate effects, grazing effects) from noise (natural climatic variation) by continuing the very basic field monitoring along the two gradients. These estimates yield the fundamental information needed for the economic assessments (ecosystem services) in P3.2.
- Using the extensive phase I and phase II dataset, we will model reliable biodiversity estimates by calculating extinction risks (P3.1.2) and predicting distribution patterns for the majority of plant and animal species (P3.1.3)
- Using WADISCAPE (P3.1.1) and longer-term field data, we will evaluate the data integratively with the aim of analyzing land management options as a means to increase resistance of open space ecosystem services to climate change (P3.1.1; 3.1.2, 3.2) and thus increase water productivity of this dominant land use type

#### Output/Deliverables

- Reliable estimates of ecosystem properties, based on sound and unique field data and multi-species modeling (P3.1.2), needed for analyzing their revenue (P3.2) and for validating WADISCAPE
- Maps describing future vegetation cover, biodiversity, erosion risk, biomass productivity and sustainable stocking capacity (P3.1.1) will be delivered to LandSHIFT simulations of land use scenarios (P3.3)
- Results (maps) from ecohydrological models and WADISCAPE (P3.1.1) will be delivered to TRAIN (P4.2) for deriving region-wide water balances under climate and land use change
- Indicators (early warning system) for climate and land use effects on water productivity in open space will be provided directly to the relevant stakeholders

# 8 Analysis of the “Climate Extreme Question”

## 8.1 Introduction and Goals

The goal of this analysis is to address the guiding question: What will be the effect of climatic extremes on the regional water balance and sustainable management of water resources in the region? It is closely linked to the first two questions because climate extreme effects will be analyzed with respect to the possible adaptation options via green and blue water management.

Sub-questions include:

- How will the climatic extremes (in particular, extended droughts) affect water management options under the different GLOWA-JR futures?
- Where will the water resource system be particularly vulnerable to a change in drought frequency and severity?
- Where will the land use system be particularly vulnerable to climatic extremes (in particular, comparison of irrigated vs. rainfed land use)
- Which strategies could be effective in coping with droughts?

The approach to the Climate Extreme Question is illustrated in Box 3. We address this question in three parts:

- Computing future changes in regional climate (Projects 4.1)
- Downscaling of extreme climatic events over specific targeted areas
- Simulating the impact of changes in climate and land use on future water balances in the region (Projects 4.2 and 4.4)
- Simulating the impact of changes in climate extremes and land use on ecosystem properties and services in the region (Project 3.1, started in phase II, P 3.2)
- Identifying strategies for coping with droughts (via the other two questions)

## 8.2 Computing future changes in regional climate (Project 4.1)

#### Main Question

What will be the characteristics of future average climate and climate extremes in the region?

#### Approach

The approach to this analysis is shown in Box 4. In order to address the climate extreme question it is necessary to produce an ensemble of regional climate scenarios that cover the feasible range of possible future climates in the region up to 2050. To do so we must complement the phase II simulations and run two different regional climate models, with different regional boundary conditions and assumed trends in global emissions.

#### Tasks

- Run the MM5 regional climate model up to 2050 using boundary conditions from the HADCM3 global climate model under radiative forcing assumptions of the IPCC A2 and B2 emission scenarios. (Grid resolution, 54 and 18 km).
- Run the RegCM3 regional climate model up to 2050 using the ECHAM5 global climate model under radiative forcing assumptions of the IPCC A2 and B2 emission scenarios. (Grid resolution, 50 and 12 km).
- Evaluation of frequencies and intensities of extreme climate events for future simulated climates including heavy rainfall, hot events, drought events, very strong winds etc.

#### Output/Deliverables

Future climate data computed by the regional climate models will provide a major input to the process-oriented calculations of regional water balances (Project 4.2) (See Section 8.3).

### 8.3 Simulating the impact of changes in climate and land use on future water balances in the region (Projects 4.2 and 4.4)

#### Main Question

How will climatic extremes (in particular, extended droughts) and average climate change affect regional water balances under the different GLOWA-JR regional development scenarios?

#### Approach

The approach to this analysis is shown in Box 4. The impact of climate impacts on water resources will be analyzed using hydrologic models. The analysis will have two main parts:

(i) For the entire region: we will analyze the impact of climate on the *vertical water balance* of the region (precipitation minus evapotranspiration and other losses) which will produce an estimate of the impact of climate on *average water availability* over the region. For these computations we will use the TRAIN model fed by information from the land use models (WADISCAPE & LandSHIFT, P3.1 & P3.3).

(ii) For the Lower Jordan River region: we will analyze the combined vertical water balance *and horizontal water balance*. This analysis will produce an estimate of the impact of climate on both *average water availability*, and *surface runoff* of the Lower Jordan River and other intermittent streams that feed it. For these computations we will apply the coupled models TRAIN-ZIN. We only apply them to the Lower Jordan River because their functioning together as a coupled model is only meaningful in the hydrological regime of this sub-region.

(iii) For the Upper Jordan River catchment: we will make use of the detailed hydrological models produced in phase II (HYMKE, WASIM, Hula Valley model) for improving the WEAP water balance.

Vertical and horizontal water balances will be computed for all climate scenarios from Section 8.2 (P4.1) and for all land use scenarios from Section 7.2 (P3.1; P3.3). Water balances will be computed for both long-term average trends in climate as well as for the future meteorological drought conditions identified in Project 4.1.

To improve estimates of the vertical water balance, special studies will be carried out on evapotranspiration from semi-arid forests and shrubland in the region. Ecohydrological models (P3.1.1) will yield information of water fluxes for all representative ecoregions.

**Tasks**

- Using inputs of future climate from Project 4.1, ecohydrological models and WADISCAPE (P3.1) and land use inputs from Project 3.3, the TRAIN model is used to compute vertical water balances for the entire region (P4.2). These water balances will be computed for long-term average trends in climate as well as for future meteorological drought conditions
- The coupled TRAIN-ZIN model is tested and verified for the Lower Jordan River region using in part remote sensing data (P4.4)
- Using inputs of future climate from Project 4.1, ecohydrological models and WADISCAPE (P3.1), and future land use from Project 3.3, the coupled TRAIN-ZIN model is used to compute vertical and horizontal water balances for the Lower Jordan River region. (Project 4.2) These water balances will be computed for long-term average trends in climate as well as for future meteorological drought conditions.
- Data from Phase II on evapotranspiration from forests and shrubland in the region are consolidated and used for the vertical water balance calculations of TRAIN (P4.2)
- Soft coupling of the project's hydrological models with WEAP will be established for making direct use of them in the WEAP calculations
- Input from the models simulating climate extreme effect on ecosystem properties (P3.1) will further improve the water balance estimates.

**Output/Deliverables**

Computed water balances will provide input to the more comprehensive but less detailed regional water balances of WEAP (P1.2; the WEAP water balances are "more comprehensive" because they will take into account all of the future water sources described in Project 2, but will be "less detailed" in that they do not explicitly take into account the hydrologic processes described in TRAIN-ZIN outside the lower catchment. However, model results from phase II will be used for the Upper Catchment water balances). This information will provide insight into the impact of climate change on the future water situation in the region. The WEAP regional water balances will then be used in the scenario exercise (Project 1.1) to develop new ideas on future water management under average climate change trends and future climate extremes (questions 1 and 2). The water balances from the TRAIN-ZIN and WADISCAPE analysis will also provide direct input to the scenario exercise (P1.1).

## 8.4 Simulating the impact of changes in climate extremes and land use on future water balances in open space (Project 3.1)

**Main Question**

How will climatic extremes (in particular, extended droughts) and average climate change affect regional water balances and water productivity in open space under the different GLOWA-JR regional development scenarios?

### Approach

The approach can be found under the Land use question (P3.1), only that a focus will be put on investigating climatic extremes.

### Tasks

- Analyzing in detail climate extreme effects on shrublands and forests under different land use scenarios (from P3.3)
- Extrapolating phase II results to the entire basin using ecohydrological models / WADISCAPE.

### Output/Deliverables

Detailed data based on unique field data sets (P3.1.2, P4.3) and subsequent modeling (water balances) on important parameters (e.g. LAI, WUE) will serve to parameterize TRAIN

## 8.5 Support for Identifying strategies for coping with droughts (coupling Questions 1-3)

### Main Question

What strategies can be used for coping with future droughts? (In cooperation with Project 1, scenario analysis and WEAP analysis).

### Approach

The question of drought management is obviously intertwined with the question of providing new water sources for the region (see Section 6) and with the question of how land management can get the most value out of water in the region (see Section 7). But it is given special attention here to droughts and dry spells because they have a severe impact on water-dependent activities when they occur, even if they are relatively infrequent. Special studies are conducted here to support the analyses of strategies under the New Water Question (Section 6) and Land Use Question (Section 7).

The approach to this analysis is shown in Box 4. The identification and evaluation of strategies will be carried out on two scales: for specific "focus areas" (P4.2) and for the entire region (P1; 2; 3). Water balances under past and future drought conditions will be computed under Section 8.3 and will be used in cooperation with the WEAP analysis to identify the effectiveness of different management strategies to minimize water losses, to make more water available, and to make the best use out of scarce water. These strategies include, e.g. production of drought-resistant crops, utilization of rainwater harvesting, conducting managed aquifer recharge, and building more conventional water storage schemes.

### Tasks

- Using the TRAIN-ZIN coupled model, we investigate the major sources of water loss under historical drought conditions (1998-9) in two focus-areas in the region (P4.2). This information will feed into region-wide analyses carried out by WEAP (P1.2) and will provide further input to the scenario analysis (P1.1).
- Using the TRAIN-ZIN model, we evaluate the effectiveness of rainwater harvesting, managed aquifer recharge and other strategies for making more water available for human use under past and future drought conditions. Evaluations are carried out on two scales—in the focus-areas and in the entire Lower Jordan River region (P4.3). This information feeds into region-wide analyses done by WEAP (P1.2) and provides input to the scenario analysis (P1.1).

- Other tasks to evaluate drought management options will be carried out in Projects 2 and 3.

#### Output/Deliverables

The output of these tasks in conjunction with Projects 1, 2 and 3 will be information about the effectiveness of different strategies (rainwater harvesting and others) in coping with drought conditions.

# 9 Dissemination and Capacity building

## 9.1 Introduction and Goals

The goal here is to ensure application of tools and use of scientific findings in the region beyond the duration of the project by communicating results and tools to a broader public, as well as presenting scientific results to the scientific community in a more comprehensive manner. A major way to ensure that the knowledge and tools developed will not be lost to stakeholders and the local scientific community is via **capacity building**. The goal here is to continue our approach from the previous phases of giving young scientists and experts from the region the competence to use the scientific approaches taken in the GLOWA-JR project. This activity cuts across all subprojects. Transboundary knowledge transfer has been and will be given special attention.

## 9.2 Approaches

Various approaches will be used for dissemination such as distribution of WEAP and a scenario viewer, various workshops, a wrap-up conference and varied scientific products.
Capacity building includes on-the-job training of scenario specialists, special workshops for training in the use of the WEAP model and other models (continued from phase II), and co-supervision of undergraduate (B.Sc. and M.Sc.) and doctoral students. Phase III expands this successful activity to capacity building in the scenario exercise (Table 1)

## 9.3 Tasks

- WEAP training workshops, similar to Phase 2 for stakeholders and young scientists in the region, in collaboration with development agencies (P1.2)
- Jordan Valley workshop with local stakeholders for distribution of main results (P1.1)
- Continuous meetings between scientists and stakeholders beyond GLOWA JR (P1-4)
- Coordination of a wrap-up conference and follow-up meetings (P1.3)
- Special journal issues and special sessions in international conferences (P1.3)
- Consolidating spatial data (maps) generated in and outside GLOWA JR (P1.3)
- A young scientist from Israel and a young scientist from the PA and from Jordan will work with the scenario team in Project 1.1 to learn about scenario analysis techniques. The topic of the two internships will be:
    - PA - Integration of quantitative and qualitative information in comprehensive water scenarios for the Jordan River region. (Methods for developing scenarios that incorporate socio-economic, climatological and other driving forces, and that are useful for water management planning)
    - Coupling the scenarios with the WEAP analyses in Jordan.

- Training a number of graduate and undergraduate students (Table 1), for example 3 M.Sc. students and 2 PhD students in WEAP and conduct their own independent water balance analyses

### 9.4 Output/Deliverables

The output of this activity will be:

- Trained stakeholders using WEAP for supporting water management decisions
- Scenario Viewer
- Special journal issues and special sessions in international conferences (P1.3)
- Geodatabase including maps generated in GLOWA JR (land use maps, maps of ecosystem properties, climate scenarios, etc.)
- Multi-lingual fact sheets as outreach to general public and to local stakeholders
- Website with information and support beyond the project duration
- Established dialogue between GLOWA scientists and stakeholders in the region
- A young scientist from Israel and a young scientist from the PA and from Jordan will
- Fact sheets and other popular products facilitating the outreach to stakeholders and local development agencies
- Press releases
- Trained young scientists from the region in new scientific approaches to the analysis of global change and water resources. These young researchers will provide an important source of expertise for follow-up to the GLOWA-JR project and continuing research and management in the region.

## 10 Project management

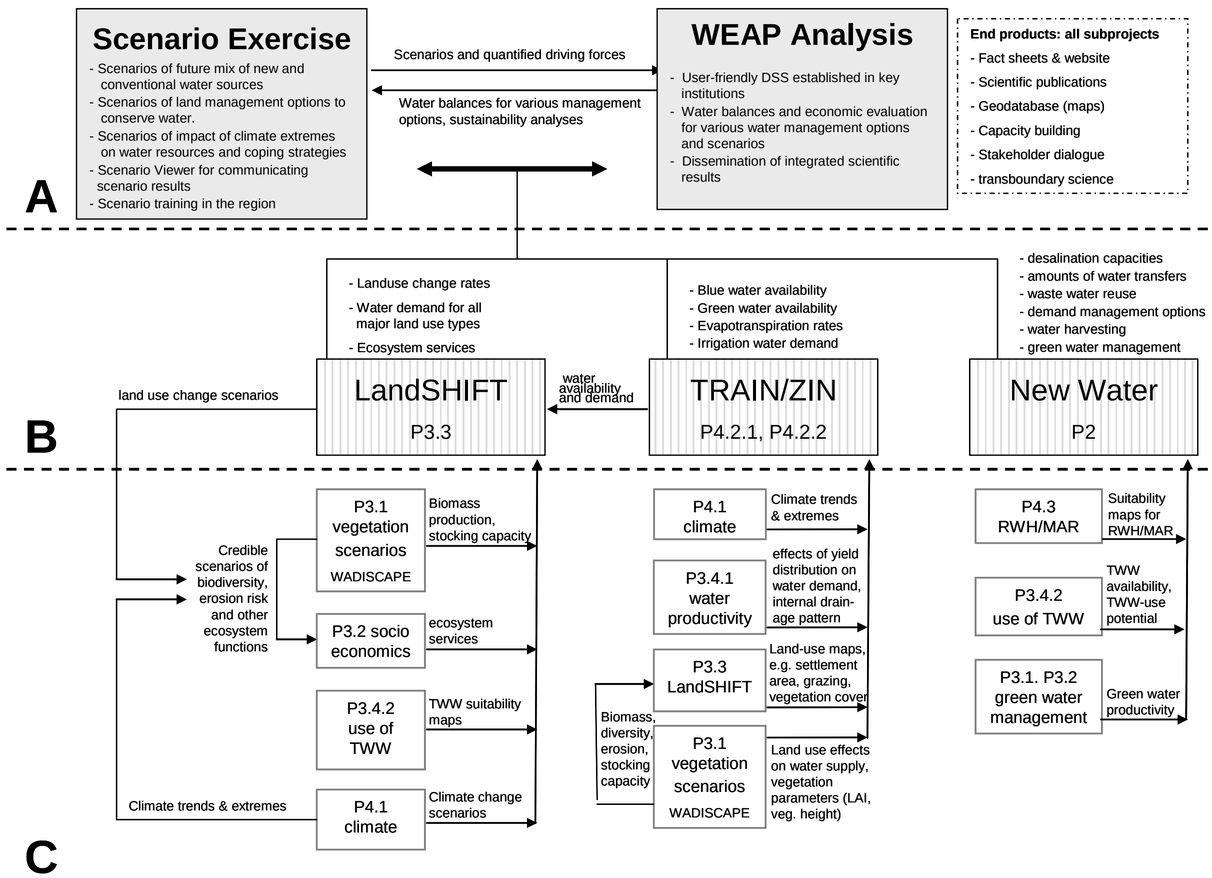
a) Scientific Committee consists of Katja Tielbörger, Joseph Alcamo and Pinhas Alpert.

b) Technical Coordination is done at Tübingen University. K. Tielbörger is also the sole main contact for internal and external issues, for the project management agency, and the JAC.

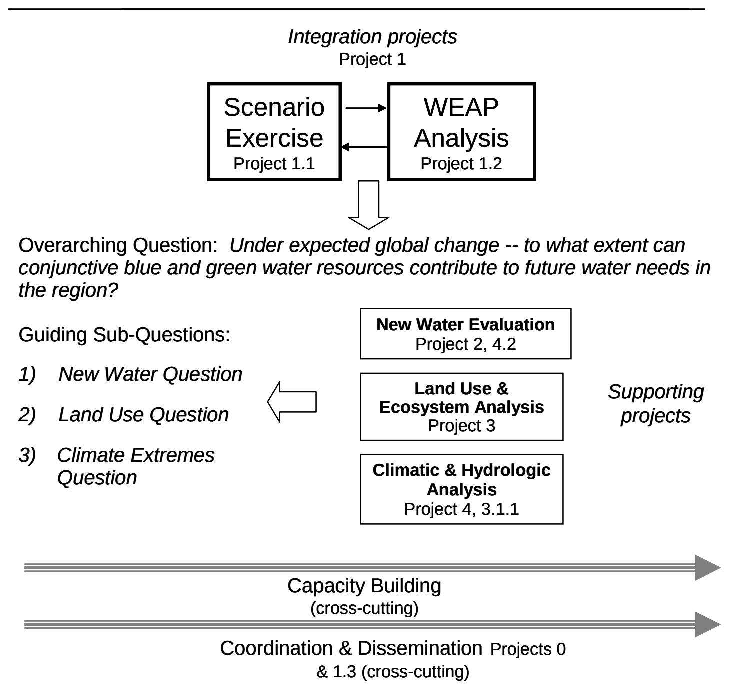
c) The steering committee consists of the three scientific coordinators and representatives from all countries and disciplines: K. Tielbörger, J. Alcamo, P. Alpert, A. Salman, A. Jayyousi, T. Dayan, M. Shechter, E. Karablieh, J. Lange, H. Hoff, R. Twite. It is complemented by stakeholders participating in the scenario development.

# 11 Annex

**Box 1a: Hierarchical (top-down) approach of phase III of the GLOWA Jordan River project.**
Area A includes the final products of all GLOWA JR project phases. Area B includes information and model outputs needed to produce the final products. Area C includes outputs needed for producing the information in area B. Due to feedback loops, several projects occur in more than one hierarchical level. More detailed information and specific examples about how the subprojects feed into each other for realizing the end-products can be found in the description of the sub-questions




**Box 1b. Project Organization & Key Questions**



### Box 2. Analysis of the "New Water" Question

**Guiding question:** Under expected global change, how can "new water" sources be combined with conventional water resources and green water resources (question 2) and provide adequate water for society and nature in the region?

**Sub-questions**
- What are the future needs for water in the region?
- How much can "new sources" versus other sources of water cover future water needs?
- How can ecosystems be restored in the Jordan River?

**Scenario Exercise** Project 1.1

**WEAP Analysis** Project 1.2

**Evaluation of new water sources**
- Water conservation (Project 2)
- Desalination (Project 2)
- Water transfers including Red Sea-Dead Sea Canal (Project 2)
- Increased water productivity of crops
- Wastewater reuse (Project 3.4)
- Rainwater harvesting (Project 4.3)
- Managed aquifer recharge (Project 4.3)
- Green water (P3, question 2)

Evaluated against 4 scenarios

**4 scenarios of regional development under global change (2005-2050)**
"Poverty & Peace"
"Willingness & Ability"
"Modest Hopes"
"Suffering of the Weak & Environment"

**Tasks**
- Identify future water needs of society & nature
- Assemble and evaluate new water sources
- Compute water balances with WEAP model
- Present water balances to stakeholders in scenario exercise

**Output**
- New regional water balances
- New scenarios depicting use of new water sources for coping with water scarcity due to global change

### Box 3. Analysis of the "Land Use" Question

**Guiding question:** Under expected global change- to what extent should can land use planning, i.e. green water management, become an integral part of water management under different scenarios?

**Questions**
- Land use change, climate change & water availability
- Agricultural water productivity under change
- Water productivity in open space, incl. ecosystem services

**Scenario Exercise** Project 1.1

**WEAP Analysis** Project 1.2

**Evaluation of ecosystem services** Project 3.1 & 3.2

**Modeling of land use (LandSHIFT)** Project 3.3

Evaluated against 4 scenarios

**4 scenarios of regional development under global change (2005-2050)**
"Poverty & Peace"
"Willingness & Ability"
"Modest Hopes"
"Suffering of the Weak & Environment"

**Reliable estimates of future ecosystem properties**

**Crop yield modeling & water productivity** Project 3.2.

**Open space modeling Ecohydrologi cal models feed into**

**Evaluation wastewater irrigation sustainability** Project 3.4 &

**Tasks**
- Produce land use scenarios with LandSHIFT
- Determine water productivity of crops and open space with Wadiscape and economic models
- Evaluate potential for wastewater irrigation
- Estimate economic value of different land uses

**Output**
- Land use scenarios as input to regional water balances and ecological models
- Economic value of different land uses: comparing economic value and water requirements
- New scenarios depicting land use management as strategy for conserving water

### Box 4. Analysis of the "Climate Extreme" Question

**Guiding question:** What will be the effect of climatic extremes on the regional water balance and sustainable management of water resources in the region?

**Sub-topics**
- Computing future changes in regional climate
- Simulating the impact of changes in climate and land use on future water balances in the region
- Identifying strategies for coping with droughts

**Scenario Exercise** Project 1.1

**WEAP Analysis** Project 1.2

**Evaluation of drought strategies**
Project 4.3
- Evaluation of blue/new water sources with TRAIN-ZIN (question 1, P4.2, P4.3, P2)
- Evaluation of land-use strategies with LandShift

**4 scenarios of regional development under global change (2005-2050)**
"Poverty & Peace"
"Willingness & Ability"
"Modest Hopes"
"Suffering of the Weak & Environment"

Evaluated against 4 scenarios

**Computation of climate extreme impact**
Project 4.2, Project 3.1
- TRAIN and TRAIN-ZIN modeling of water balance
- WADISCAPE modeling of landscape structure

**Computation regional climate scenarios**
Project 4.1
- Future droughts & long term average trends
- MM5 regional climate model (with HadCM3)
- RegCM3 regional climate model (with ECHAM5)

**Tasks**
- Compute future climate extremes and average trends with regional climate models
- Compute water balances with hydrologic models
- Evaluate hydrologic effectiveness of conjunctive green-blue water mgmt for coping with drought
- Compute climatic extremes effects on water productivity in ecosystems

**Output**
- Scenarios of future climate in region, as input to other models
- Hydrologic water balances → input to WEAP analyses
- New scenarios depicting impact of drought & strategies for coping with drought

**Table 1. Capacity building within GLOWA JR: Number of PhD, MSc., and BSc. students, as well as of capacity building workshops.**

| | **Phase I + II** | | | | **Phase III** | | | |
|---|---|---|---|---|---|---|---|---|
| Country | **PhD** | **MSc** | **BSc** | **Workshops** | **PhD** | **MSc** | **BSc** | **Workshops** |
| **German** | 14 | 13 | 4 | 3 | 2 | 5 | 3 | 4 |
| **Jordanian** | 1 | 8 | 0 | 1 | 4 | 10 | 3 | 3 |
| **Palestinian** | 5 | 8 | 0 | 2 | 3 | 4 | 0 | 3 |
| **Israeli** | 26 | 41 | 4 | 10 | 10 | 9 | 3 | 3 |
| **Total** | **46** | **70** | **8** | **16** | **19** | **28** | **9** | **13** |

Note that many PhD Students educated in Phase 2 will work as Post Docs within Phase 3 incorporating their valuable existent know how.