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Sabine Kraushaar

Soil Erosion and Sediment Flux in Northern Jordan

Analysis, Quantification and the Respective Qualitative Impacts on a Reservoir Using a Multiple Response Approach

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Analysis, Quantification and the Respective Qualitative Impacts on a Reservoir Using a Multiple Response Approach

Doctoral Thesis accepted by
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To those who inspired, payed, critized,
supported and will read it. Thank you!

Supervisor's Foreword

The present study focuses on erosion and sediment transport within a catchment Wadi Al-Arab in Northern Jordan—a country ranked as the fourth water-scarce in the world. Besides the loss of soil, erosion leads to an increased sedimentation and pollution of the Wadi Al-Arab water reservoir. The aim of an integrated water management is therefore to improve water infiltration at the soil surface to increase recharge of groundwater resources, and, in turn, to decrease run-off and the transport of sediment loads to surface waters. A fundamental prerequisite to reach these goals is to better understand the mechanisms and local conditions responsible for erosion. This work provides substantial new insight based on a thorough geomorphological study and will be in the position to enhance water availability and quality in a water- and data-scarce country.

The work comprises the identification of the relevant sediment sources throughout the Wadi Al-Arab, the quantification of the erosion processes and an estimation of sediment transport and connectivity to the final sink—the Wadi Al-Arab reservoir. Geochemical analyses of the soil materials in the source regions together with those in the sediments of the reservoir were used in a multiple sediment fingerprinting to calculate the contribution of the various sources. This also provided a substantial understanding of many natural abundant heavy metals and sediment-bound anthropogenic pollutants, such as hexazinone, trifluralin and tNP fertilizer. The results were used to calibrate and validate the SedNet model to obtain a spatial understanding of the processes and to identify hot spot areas. In combination with detailed geomorphological analysis a multiple response approach of different complementary methods was established internalizing the potential of one method validating or falsifying results from another. This led to a consistent interpretation of the ongoing processes.

Overall, this work met the exceptional challenge to identify sediment sources and quantify hydro-morphological processes in a relatively big catchment area of heterogeneous geology, topography and land use. All this was done in the limited time frame of a research project and without support of any pre-existing data. The skillful collection of erosion values in different time- and spatial scales,

geochemical properties, and the analysis of sediment connectivity and spatial modelling resulted in an extensive field data set that allowed a thorough understanding of the relevant sediment transport processes. This provides valuable information for policy-makers and resource authorities to prioritize areas suitable for mitigation strategies with respect to erosion and to select possible locations for in-channel constructions to support ground water recharge. I hope this work will stimulate more creative research within regions that are not only scarce in water but also scarce in available data.

Halle, Germany
February 2016

Prof. Hans-Jörg Vogel

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Contents

Abbreviations

AD	Anno Domini
a.s.l.	Above Sea Level
ASL/AHP	Amman silicified Limestone/Al-Hisa Phosphorites
Aster	Advanced Spaceborne Thermal Emission and Reflection Radiometer
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
BMBF	German Federal Ministry of Education and Research
BP	Before Present (1950)
BPA	Bisphenol A
BSh-Csa	Steppe-Mediterranean Climate
CF	Correction Factor
CIA	Central Intelligence Agency
(G)DEM	(Global) Digital Elevation Model
dGPS	Differential Global Positioning System
EC	Electrical Conductivity
EDXRF	Energy Dispersive X-ray Fluorescence
EP	Erosion Pin
FAO	Food and Agriculture Organization
GC MSD	Gas Chromatography coupled with a Mass Spectrometry Detector
GIS	Geographic Information System
GLASOD	Global Assessment of Human-Induced Soil Degradation
GTZ today GIZ	German Society for International Cooperation
HDPE bottles	High-Density Polyethylene bottles
HIGRADE	Helmlholtz Interdisciplinary Graduate School for Environmental Research
HP-5MS	Low bleed column for gas chromatography

HSDR	Hill slope Sediment Delivery Ratio
IAEA	International Atomic Energy Agency
ICP AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
IOC	International Oil Council
IP	Influencing Parameters
IPSWAT	International Postgraduate Studies in Water Technologies
ISRIC	International Soil Reference and Information Centre
IUSS Working Group WRB	International Union of Soil Sciences working group for World Reference Base for Soil Resources
IWRM	Integrated Water Resource Management
JDA	Jordan Dam Authority
JICA	Japan International Cooperation Agency
Landsat ETM+ GLS 2010 scenes	Landsat Enhanced Thematic Mapper (Landsat 7) Global Land Survey 2010 scenes
LAWA	Working Group on water issues of the Federal States and the Federal Government
MAD	Median Absolute Deviation
MAR	Managed Aquifer Recharge
MCM	Muwaqqar Chalk Marl
METI	Ministry of Economy, Trade, and Industry (METI) of Japan
MoA	Jordan Ministry of Agriculture
MWI	Jordan Ministry of Water and Irrigation
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NICE-office	Implementation research office in Jordan
OSL dating	Optically Stimulated Luminescence dating
P	Precipitation
PAHs	Polycyclic Aromatic Hydrocarbons
PET	Potential Evapotranspiration
PPCPs	Pharmaceuticals and Personal care products
RUSLE	Revised Universal Soil Loss Equation
SMART-Project	Sustainable Management of Available Water Resources with Innovative Technologies
SMRAM	Stepwise Multiple Regression Analysis Model
SSA	Specific Surface Area
TAC	Technical Advisory Committee
TIC	Total Inorganic Carbonate

TIN	Triangular Irregular Networks
TOC	Total Organic Carbonate
TrinkwV	German Drinking Water Ordinance
T-value	Soil-loss tolerance value
UN	United Nations
UNEP	United Nation Environment Programme
UNHCR	The UN's refugee agency
URC	Umm Rijam Chert
USEPA	Unites States Environmental Protection Agency
WC-coated	Tungsten Carbide coated
WD	Wadi Deposits
WDXRF	Sequential Wavelength Dispersive X-ray Fluorescence
WHO	World Health Organization

Chapter 1
Introduction

1.1 Background and Framework of the Thesis: The Smart—Project

Jordan is one of the water scarcest countries in the world with the Lower Jordan River Basin constituting an overexploited closed river basin (MWI and GTZ 2004; Venot et al. 2006; Wolf et al. 2007; Hötzl 2004; Hötzl et al. 2009). The physical water scarcity is prompted by an increasing water demand, due to the constantly growing population (3.86 % estimated for 2014, CIA 2014; UNEP 2005). Over the past 20 years the population has doubled, mainly due to refugees from Iraq, Palestine, and Syria which currently make up 34 % of Jordan's population (CIA 2014). The lack of water-related infrastructure and water management has led to an additional qualitative water problem due to leaking septic tanks, lack of waste water treatment facilities, effluents from industry, and diffusive agricultural-related inputs (Abu-Sharar 2006; Ghrefrat and Yusuf 2006), as well as contaminated leachate from landfills (Abu-Rukah and Kofahi 2001) or geologically driven through the dissolution of evaporites (Salameh 2001).

In regard to the worsening situation on site and the millennium development goals (UN resolution 58/217, 2000), Jordan aspires to achieve an Integrated Water Resources Management (IWRM). IWRM describes a process which promotes "the coordinated development and management of water, land, and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems." (Global Water Partnership 2000).

This implies that suitable strategies, concepts, measures, and technologies are developed especially for a Mediterranean to arid region that result in the optimization of sustainable usage of water resources, despite conceivable climate and land use changes (Geyer and Möller 2011). A consortium of scientists, companies, and authorities of all neighbouring countries to the Jordan River—namely Palestine, Israel, and Jordan plus Germany—set up a research project to deal with this question.

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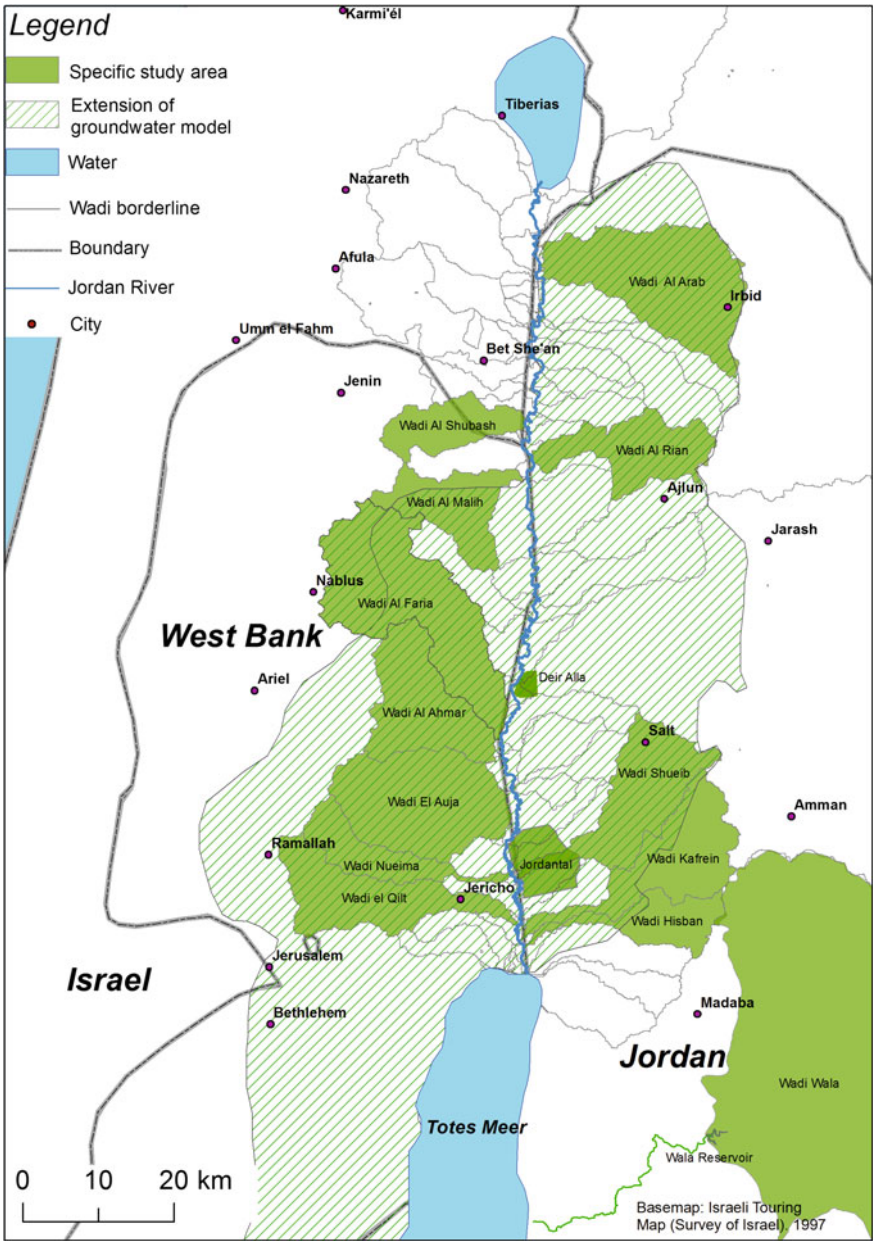

Fig. 1.1 SMART project area—the lower Jordan valley (www.iwrm-smart2.org)

This SMART II Project (= Sustainable Management of Available Water Resources with Innovative Technologies) aims to develop a transferable approach for IWRM in regions of water shortage. The SMART project has been sponsored since 2006 by