Runoff-recharge processes under a strong semi-arid climatic gradient

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HYDROLOGY

1 Introduction

Hydrological processes in semi-arid environments are highly dynamic and variabel. In the eastern slopes of the West Bank these dynamics are even intensified due to:

- predominant karst morphology
- strong climatic gradient (150-700 mm mean annual precipitation)
- small-scale variability of land use, topography, soil cover and vegetation

The region is characterized by a scarcity in water resources and a high population growth. Therefore detailed information about the temporal and spatial distribution, amount and variability of available water resources is required. Providing this information by hydrological models, as intended by this study, is challenging because available data is extremely limited.

2 Study area and methods

The study area is situated in the western escarpment of the Jordan Rift Valley north of the Dead Sea.

A dense monitoring network was installed for rainfall, meteorological parameters, spring discharge and water chemistry, runoff in ephemeral streams, soil moisture and groundwater levels (Figure 1). The network design considered an adequate representation of the accentuated climatic gradient from West to East.

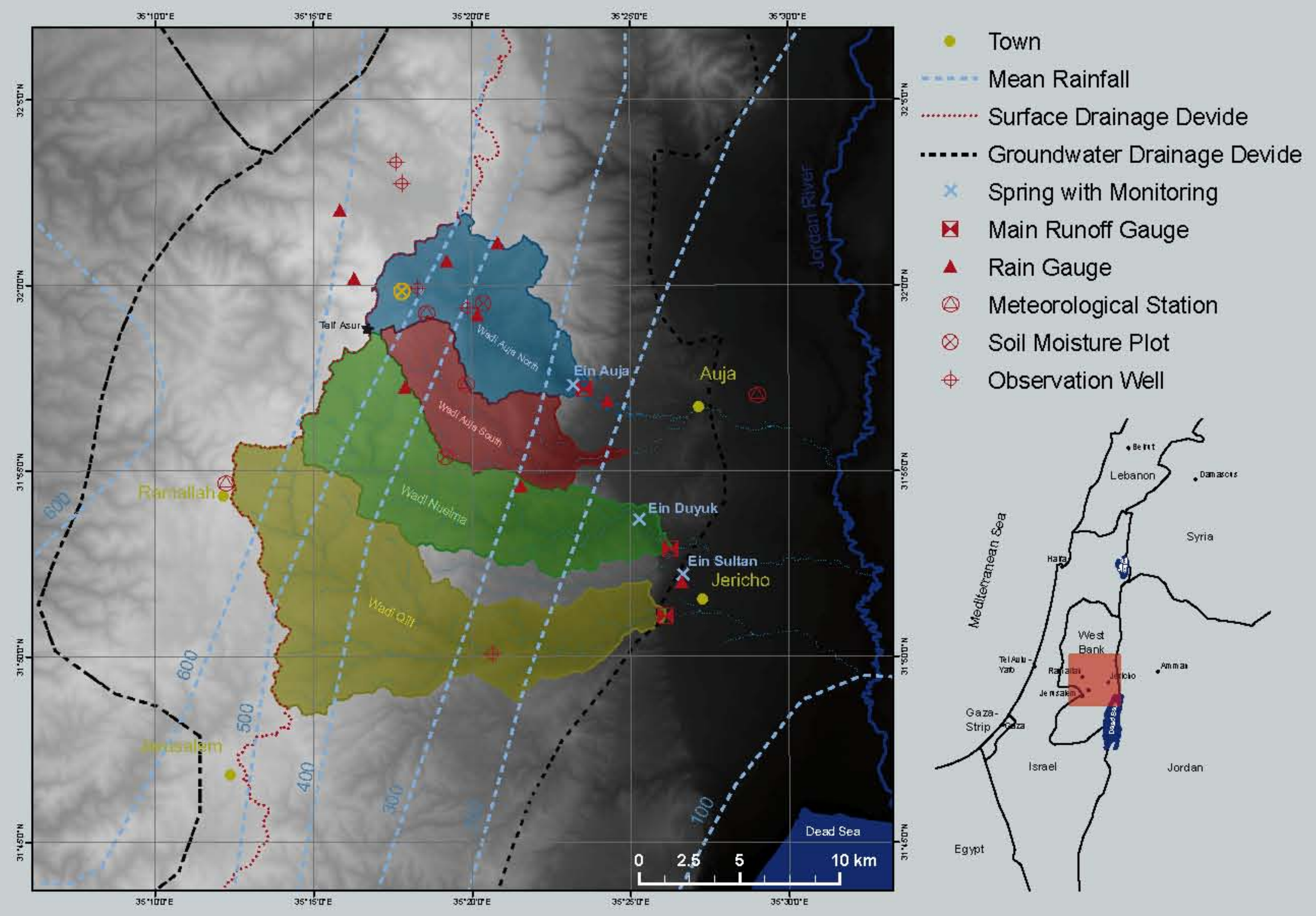

Figure 1: Hydrometeorological network in the study area (topographical gradient varies from 1016 m.a.s.l. at Tell' Asur to 422 m.b.s.l. at the Dead Sea)

3 General processes

The study area is strongly heterogeneous (Figure 2-4) in terms of hydrometeorology, vegetation and morphology with effects on runoff generation and recharge processes.

Runoff generation: Infiltration excess overland flow is often reported to be the dominant runoff process in (semi-)arid environments. In the mediterranean areas, permeable soils of variable depth are saturated only by major storm events leading to a spill-over of soil pockets. High percentage of rock outcrops result in a redistribution of rainfall and lead to a additional saturation of the soil layer.

Recharge processes: Depending on the fundamental processes direct, localized (e.g. in depressions) and indirect recharge can be distinguished. In the mediterranean areas direct and localized recharge are assumed to be dominant while the proportion of indirect recharge (transmission losses of storm runoff in ephemeral streams) increases with increasing aridity.

Figure 2: Landscape in the headwaters of Wadi Auja

Figure 3: Landscape in the central part of Wadi Auja

Figure 4: Landscape in the chalk-dominated low lying areas of Wadi Auja

4 Soil saturation and spring response

Processes within the unsaturated soil zone are a key for the understanding, modelling and quantification of runoff and recharge. A set of soil moisture plots at diffent hydroclimatic conditions were installed in the study area.

Measurements in a terra rossa soil on Cenomanian Limestone show (⊗ in Figure 1):

a) Continous drying out in the entire soil profile in summer (10 to 26 vol% at end of dry season)

↓

b) Sucessive wetting up with two month time delay at 80 cm depth (after 180 mm of cumulative rainfall)

↓

c) Complete saturation in 80 cm depth following a strong rainfall event mid of January

↓

d) Increasing duration of saturated conditions from one hour to two days within four intensive rainfall events

↓

Inition of karstic spring discharge (Ein Auja) two days after second rainfall event causing soil saturation

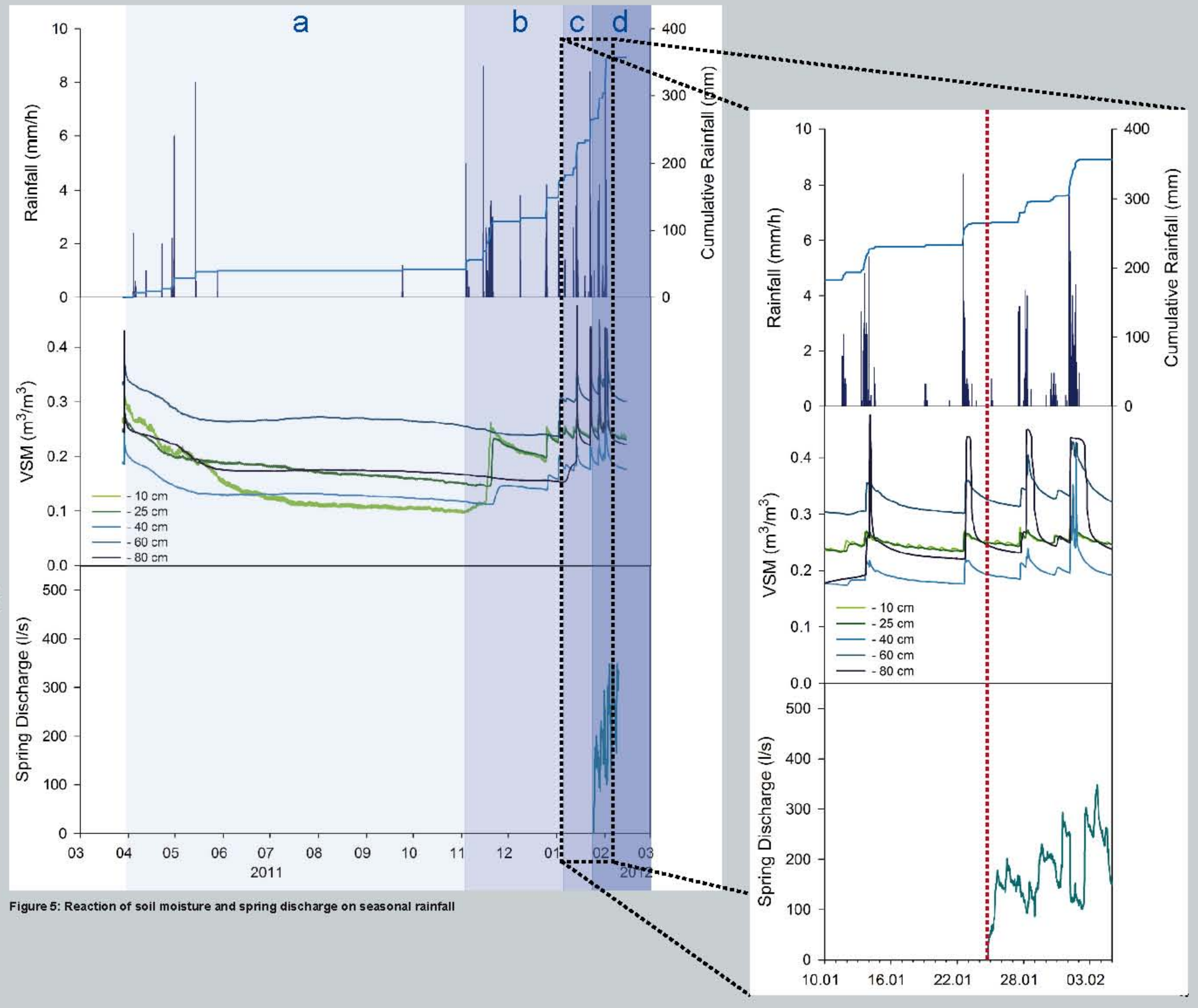

Figure 5: Reaction of soil moisture and spring discharge on seasonal rainfall

5 Modelling

Groundwater recharge and runoff in ephemeral streams will be simulated with the coupled physically-based and spatially distributed model TRAIN-ZIN which consists of two main compartments (Figure 6):

- **TRAIN** - a soil-vegetation-atmosphere model focusing on soilwater balance and vertical water fluxes
- **ZIN** - a rainfall-runoff model developed for representing runoff generation processes and transmission losses in (semi-)arid environments

The soil moisture routine acts as an interface between both models.

For the modelling, processes in the unsaturated zone are of special importance. Therefore the soil water movement at the plot-scale will be modelled and compared with measured information from the soil moisture plots. This can improve the determination of realistic parameters and model results.

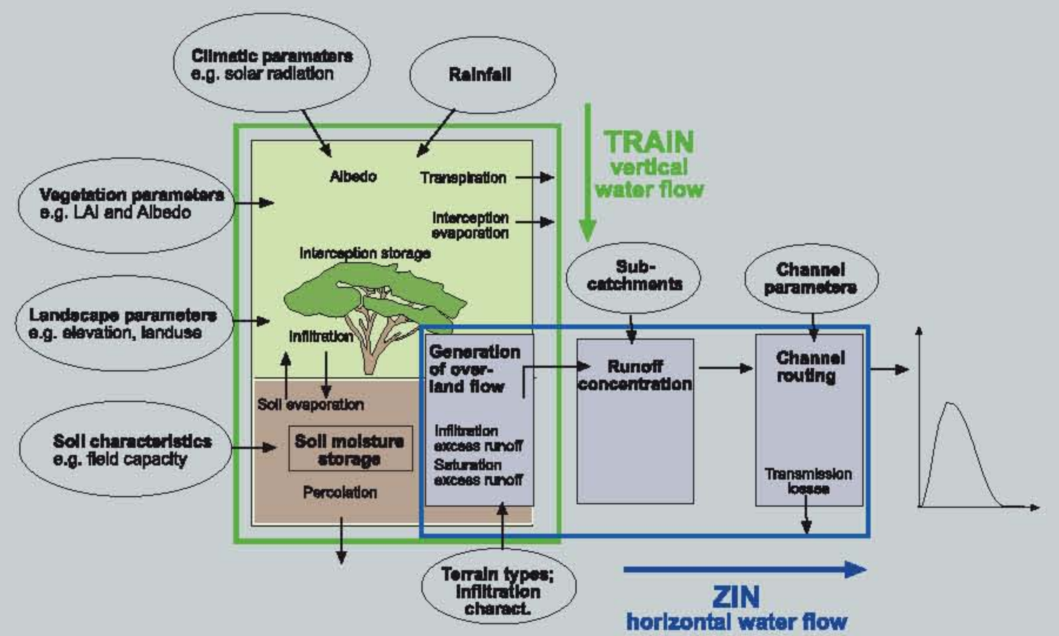

Figure 6: Shematic structure of the TRAIN-ZIN model (Gunkel & Lange, 2011)

6 Outlook

Further intensive field investigations are planned in order to get better insights into soil physical properties of the study area:

- Sprinkling experiments with dye tracer Brillian Blue for detecting infiltration patterns and preferential flow paths (Figure 7)
- Taking high resolution aerial images for the analysis of soil surface patterns (Figure 8)
- Determination of soil hydraulic parameters
- Collection of TRAIN-ZIN modell parameters

These data will be used for the understanding of dominant processes and the parametrisation and verification of the model work.

Figure 7: Infiltration experiments with Billian Blue FCF showing preferential flow paths along the rock outcrop

Figure 8: Patchiness of soil cover in the headwaters of Wadi Auja

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SMART

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