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Closing the urban water loop – A Modelling Framework to assess Benefits of Rainwater Harvesting to the Urban Water System


ifak Magdeburg (June 2013)


Kfar Saba main street (October 2015)

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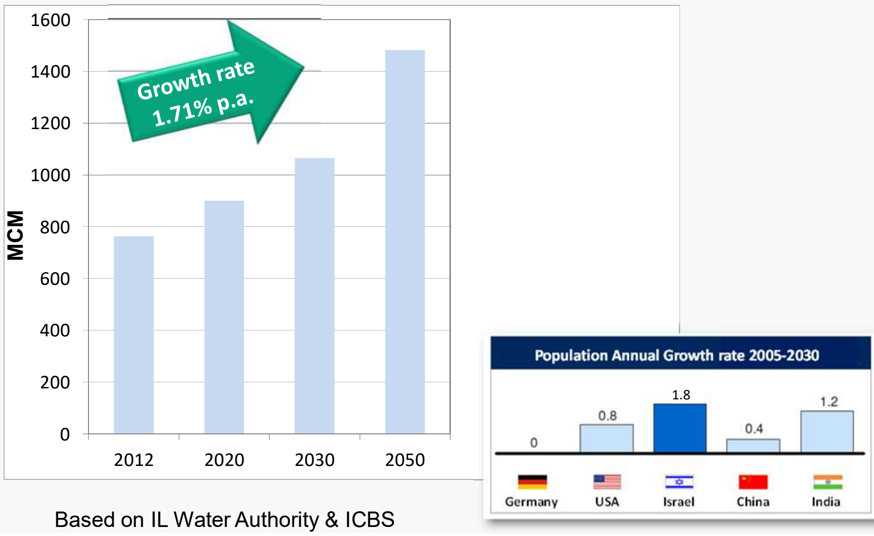
Context of Rain Water Harvesting
Objectives of the work presented here

- Water scarcity, use of rainwater as a resource
- Components of the urban water system, interactions
- Life-cycle of the water system, including the RWH system

- Evaluation of measures in the urban water system
- Modelling framework, suitable for practice
  - Particular focus on RWH, SWH, groundwater, roofs (**g**/**g**)
  - Stochastic demand and rainfall patterns
  - Balancing of availability and demand
- Interlinkage modelling with LCA-components
- Assisting in decisions and planning related to
  - System setup (design)
  - Operation

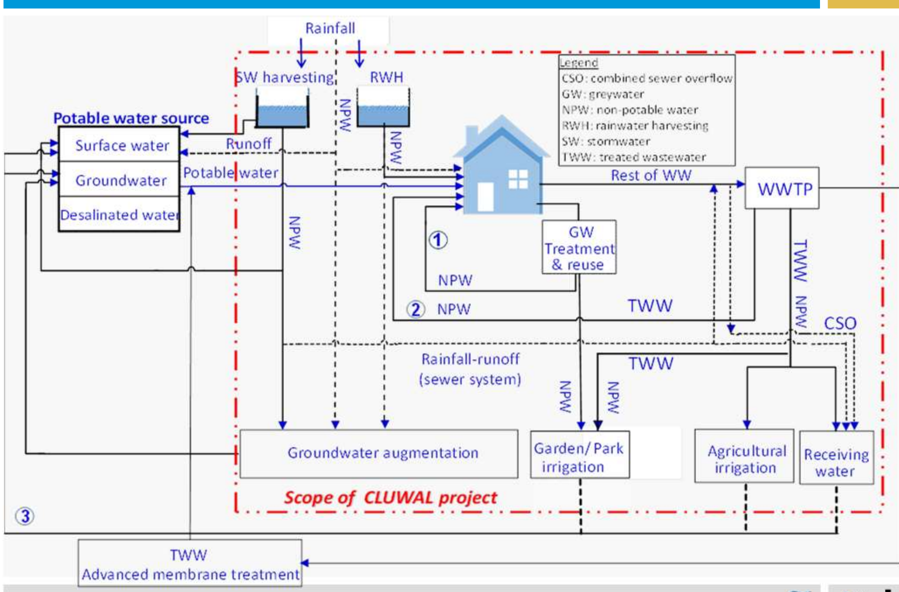
Growth rate of urban water demand in Israel



Based on IL Water Authority & ICBS

3

Scope of modelling work of CLUWAL project



4

Overall objective of modelling work

Set up of a modelling library

„Building blocks“ for water system modelling (in a simplified way), combined with

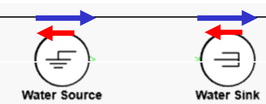
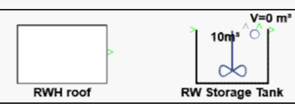
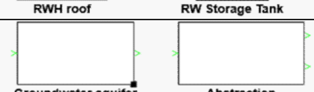
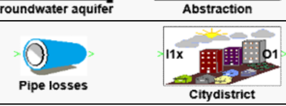
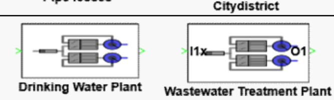
- systems analysis routines
- LCA and assessment elements

- to be applied for optioneering and sustainability assessment,
- Application demonstrated for several case cities

Ensuring user-friendliness by

- using well-established and user-friendly simulation system as a base (Simba#)

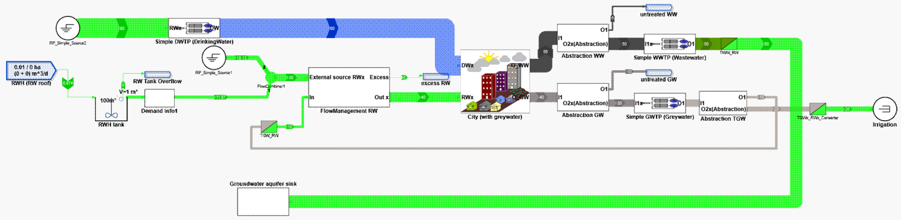
Modelling block library (present draft version)

	Water sources and sinks supply- and demand-driven
	Rainfall and evaporation processing time series
	Rainwater collection roof Rainwater storage tank
	Groundwater, Abstraction Abstraction from various water sources
	Pipe network; City district
	Treatment plants: Converting between streams

Theoretical modelling examples of the Urban Water Cycle

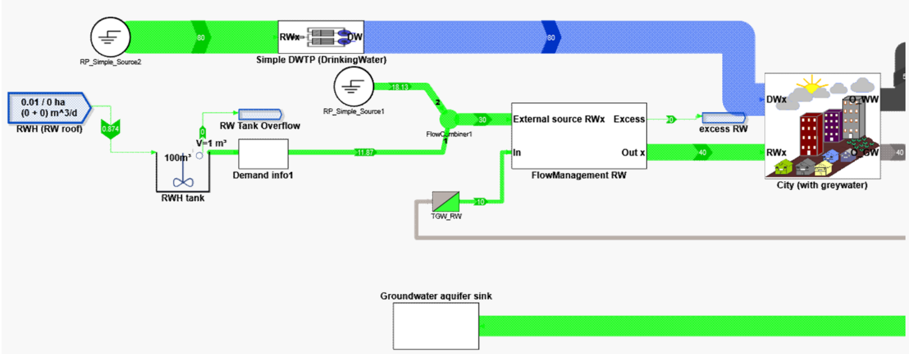
- Example water system as described by Chauvet *et al.* (2016)
  (Benchmark modelling example from the literature)

- Urban Water Cycle including reuse loops
  (cf. Figure shown earlieron)



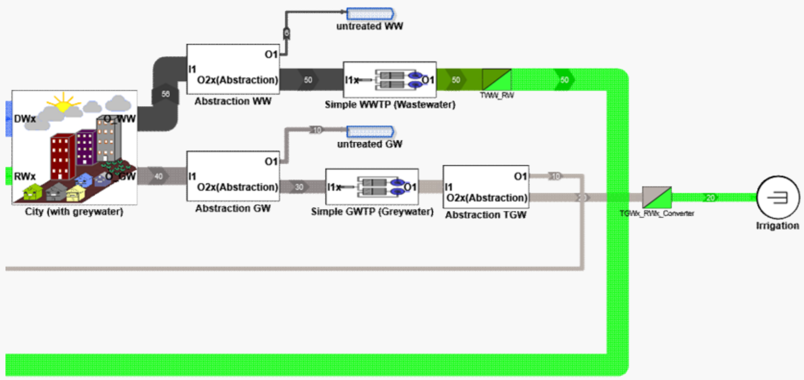
Theoretical Modelling examples Urban Water Cycle

- Urban Water Cycle including reuse loops
  Part I: Water supply part



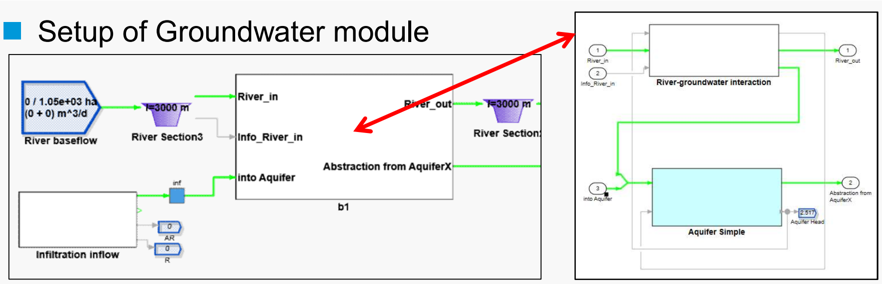
Theoretical Modelling examples
Urban Water Cycle

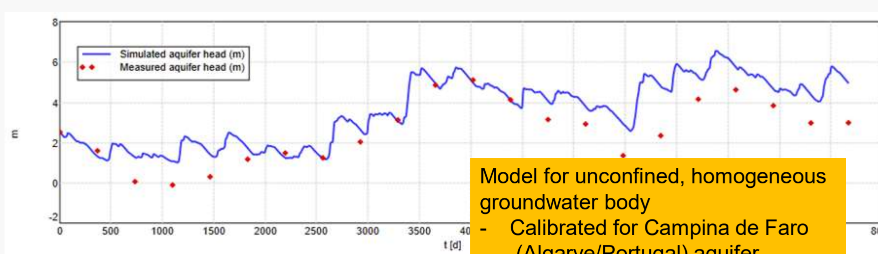
- Urban Water Cycle including reuse loops
  Part II: Wastewater part



Component models:
Simple Groundwater module by Rojas (2018)

- Setup of Groundwater module

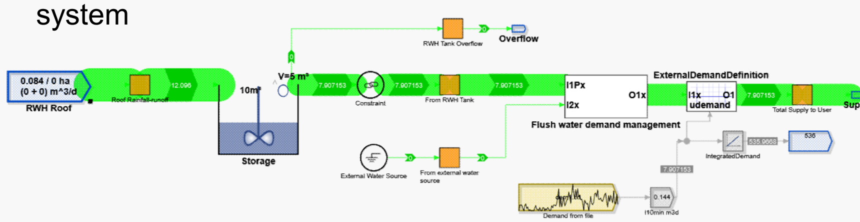




Model for unconfined, homogeneous groundwater body
- Calibrated for Campina de Faro (Algarve/Portugal) aquifer

Component models: Rainwater harvesting

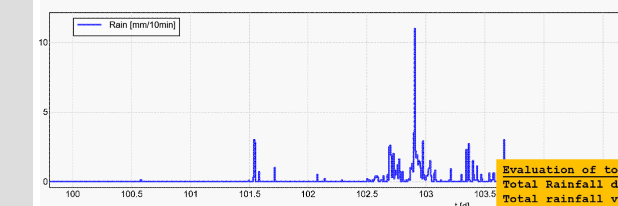
- Use of rainwater as a resource:
  - Analysis of RWH: sizing of RWH storage tanks
- Existing tools (e.g. www.samsamwater.com/rain/) use coarse resolution of rain data
- RWH potential depends strongly on rainfall and demand patterns
- Our work: Detailed analyis & Integration in overall water system



CLUWAL – Modelling examples Urban Water Cycle

Example application of this model: Analysis of RWH efficiency

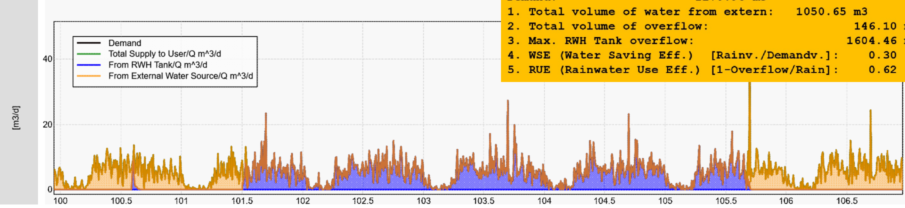
- Rainfall data (excerpt: Days 100 – 107)



Another example:
Quibdó (Colombia)
7815 mm rainfall p.a.
RW can cover 92 % of demand

Evaluation of total time series (here: 1 year)
Total Rainfall depth: 453.64 mm
Total rainfall volume:381.06 m3
RWH Roof runoff: 366.32 m3
RWH Tank Outflow: 220.33 m3
Flow to sink (user): 1270.98 m3
Demand: 1270.98 m3
1. Total volume of water from extern: 1050.65 m3
2. Total volume of overflow: 146.10 m3
3. Max. RWH Tank overflow: 1604.46 m3/d
4. WSE (Water Saving Eff.) [Rainv./Demandv.]: 0.30
5. RUE (Rainwater Use Eff.) [1-Overflow/Rain]: 0.62

- Water usage (excerpt)



Component models:

- RWH modeling: mass-balance on the RW tank:

$$\frac{dV}{dt} = rain - usage - overflow$$

increase decrease

- CLUWAL modeling: potable-water savings **and** drainage effects

- Urban drainage is designed to cope with peak flows → Drainage models in sub-hourly resolution (Campisano&Modica 2014)

Stochastic model

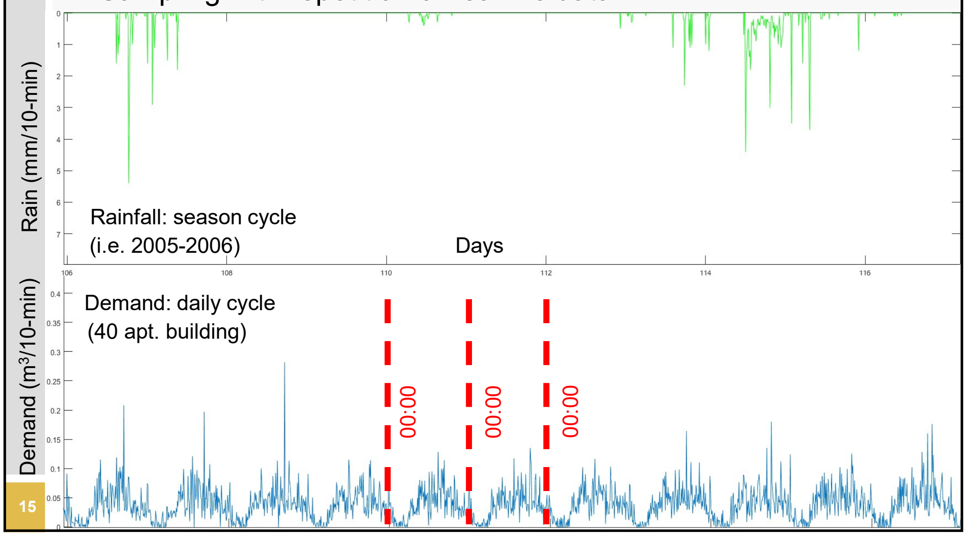
- Rainfall is a stochastic variable, with flexible dependencies between time-steps (rainstorms or rain events) – sampling with repetition of entire rain seasons (IMS data)

- Demand (toilet flushing) follows a daily pattern, but demands are hard to predict in small systems and short time-steps

- Demand data – Steynberg 2015 – analyzing water demands on the single appliance level in 1-second resolution – sampling with repetition of entire days for each household

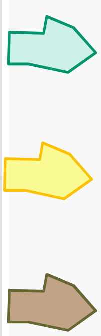
Stochastic model

- Rainfall, water demand: Erratic patterns in small time-steps
- Sampling with repetition of real-life data:



Effects on urban drainage

- Urban clusters:



Harvested area

Impervious unharvested area

Pervious unharvested area

Kaplan neighborhood, Kfar Saba

Effects on urban drainage

- Urban clusters
- Different runoff characteristics for each area type
- Runoff from harvested area: calculated from RW tank overflow

Kaplan neighborhood, Kfar Saba

17

Future work

- Smart-Storage controls (Gee, 2016, Burns, 2018) – auto discharge of RW tank when a storm is forecasted
- Incorporating A/C water harvesting in summer– yearly model

18

Conclusions

- RWH potential depends strongly on rainfall and demand patterns
- A simulation framework for demand estimation and assessment of RWH system has been set up
- Currently, this is integrated in a system-wide urban water modelling framework
- Integration of LCA criteria (cf. Friedler *et al.,* 2018) envisaged
- This will also allow LCA and sustainability assessment

- Our work: Detailed analyis & Integration in overall water system
- Envisaged benefit: Allowing overall strategic pre-planning of water saving and reuse measures, including LCA aspects

Thank you for your attention

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