A Hydroecological Technique to Improve Infiltration of Clogged Bed of Recharge Dam in Oman

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Overview

- Introduction
- Methodology
- Results
- Conclusions and Recommendations

Dams in Oman: Types and Storage Capacities

Total Storage Capacity of 174 dams is: 423 Mm^3

56

Recharge dams

Storage capacity: 102 Mm^3

115

Surface storage dams

Storage capacity: 100 Mm^3

Wadi Dayqah large dam

Storage capacity: 100 Mm^3

3

Protection dams

Storage capacity: 121.2 Mm^3

+ 11 small scale protection dams in Muscat

Impact of Recharge Dams

Through scientific research it has been proven that recharge dams:

1. Contribute to control of seawater intrusion in coastal aquifers
2. Augment underlying aquifer systems, especially, where groundwater abstraction is controlled
3. Mitigate flood hazards

Kacimov A.R., Obnosov Yu.V. Size and shape of steady sea water intrusion, sharp-interface wedge: the Polubarinova-Kochina analytical solution to the dam problem revisited. ***J. Hydrologic Engineering*****, ASCE, 2016, v. 21 (8), 06016005-1-006016005-6.**


Al-Khoud recharge dam


Recharge dam- Al-Dahirah Governorate

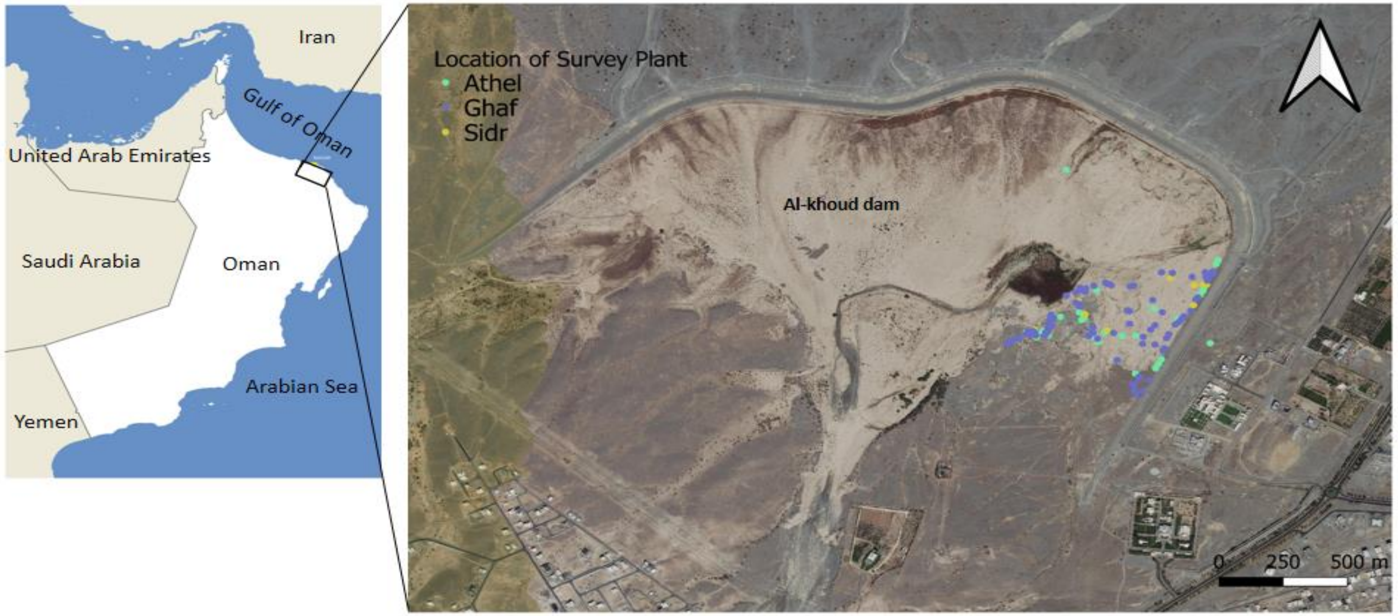
Challenges

- **Sedimentation (siltation problem) that:**
  1. **Degrade reservoirs' storage capacity** – hence overflow and siltation of recharge basin downstream the dam and its stilling basin
  2. **Clogging of** dam's lake topmost soil and clogging of toe drains of the embankment (earth-filled dams)
  3. **Vertical translocation of fine particles** between inside the dam wall – amplified the unwanted vegetation growth on the slopes of the embankment – deep root penetration into the embankment shoulders – long-lasting wetting and hence dramatic increase of permeability of the clay core that threatens the dam safety

Thus, management of dams is a must to sustain its functionality

Faber, S., Al-Maktoumi, A., Kacimov, A., Al-Busaidi, H., Al-Ismaili, S., Al-Belushi, M. Migration and deposition of fine particles in a porous filter and alluvial deposit: Laboratory experiments. *Arabian. J. Geosciences* 2016, v.9 (4), 321-339,

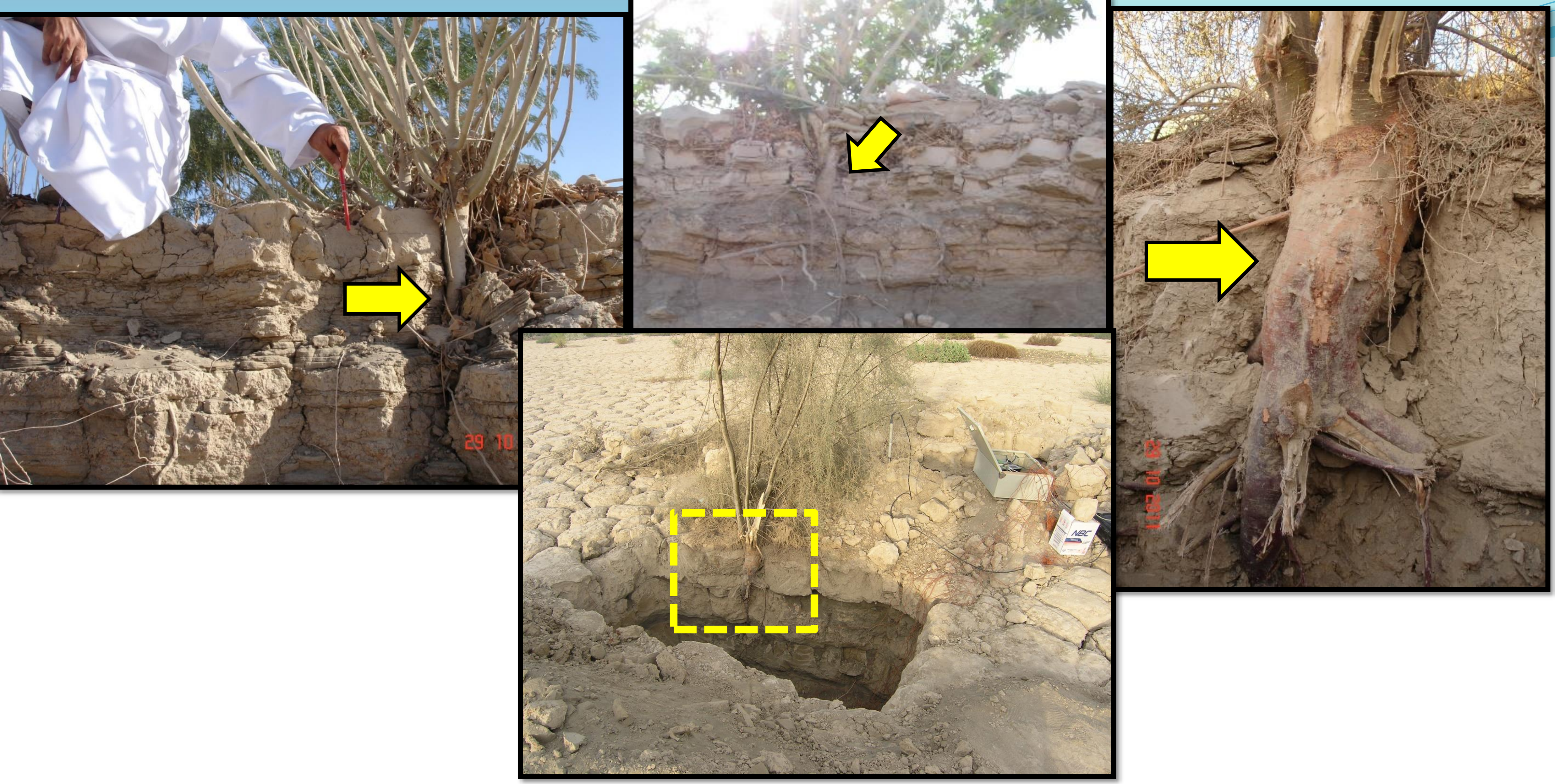
Motivation: Hydro-ecological solution for sedimentation



Photos of some of the surveyed trees: Sidr (Ziziphus spina-christi), Ghaf (Prosopis cineraria), and Athel trees (Tamaric aphylla)

Kacimov A.R., Brown, G. A transient phreatic surface mound, evidenced by a strip of vegetation on an earth dam. *Hydrological Sciences J.* 2015, v. 60, N 2, 361-378.

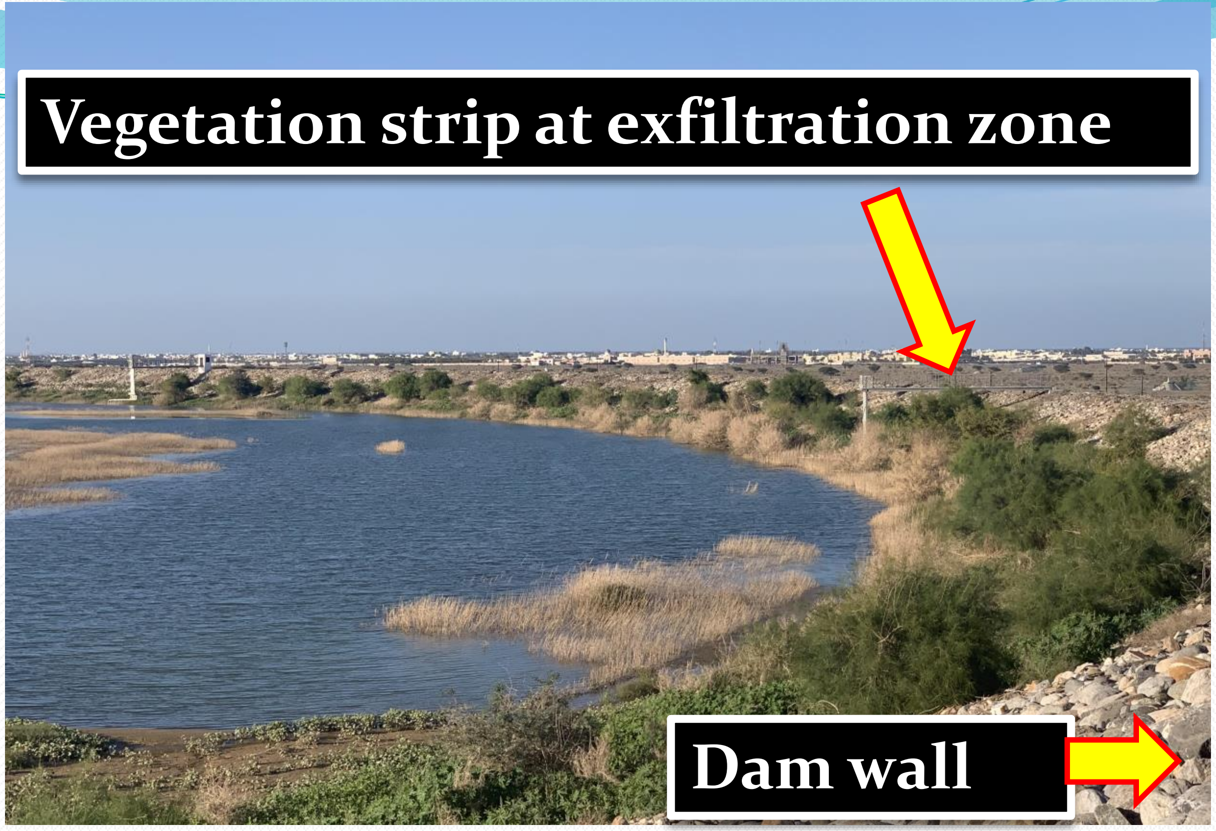
A satellite image of the Al-Khoud dam showing the location of surveyed trees



Al-Maktoumi, A., Kacimov, A., Al-Busaidi, H., Al-Ismaily, S., Al-Mayahi, A., Al-Khanbashi, S., and Al-Sulaimi, A. Enhancement of infiltration rate of clogged porous beds in the vicinity of dams in arid zones by the roots of indigenous *Ziziphus spina-christ* trees. *Hydrological Processes,* 2020, v. 34, 4226–4238

Clogged Embankment

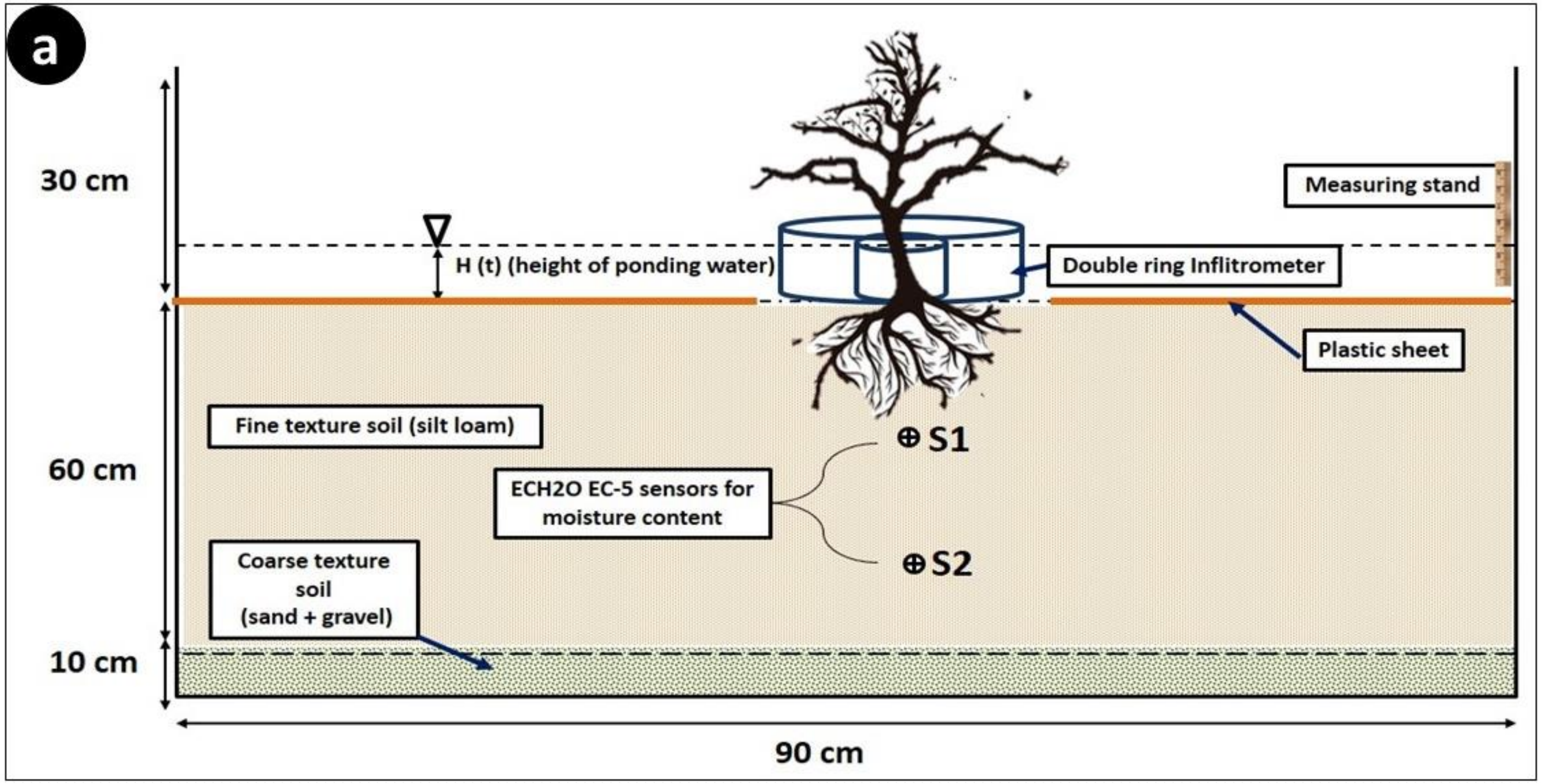
Sediments conveyed by flashflood currents were observed to be translocated (entrained by seepage) into the vadoze zone of the beds (vertically) and into the embankments (horizontally). This resulted in clogging of the toe drain and also filling the pores between the gabion rocks making up the dam walls.

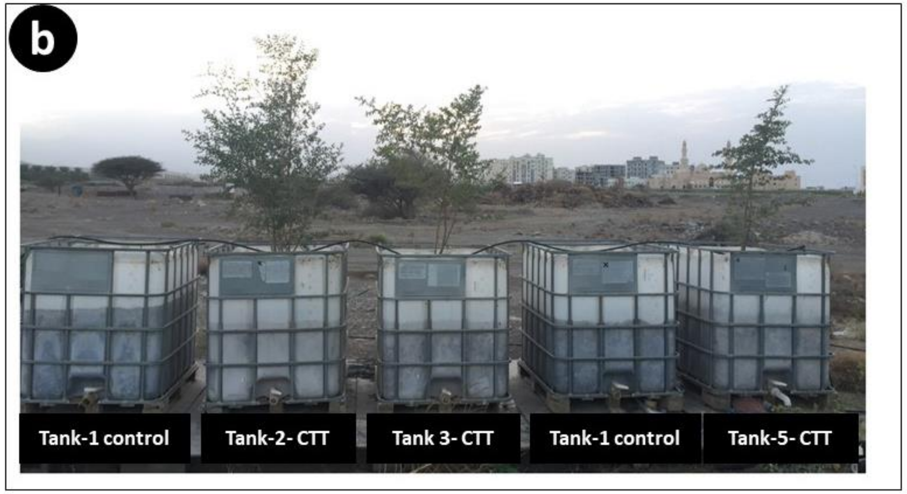


The tapered fine sediments store water that stimulates the growth of vegetation and trees in the dam walls that threaten dam's safety as roots follow the propagating wetting fronts and unwanted long retention of moisture inside the embankments' bodies.

Vegetation can have a dual impact: positive (for enhancing the recharge to underlying aquifers, and negative in threating the dam's core).

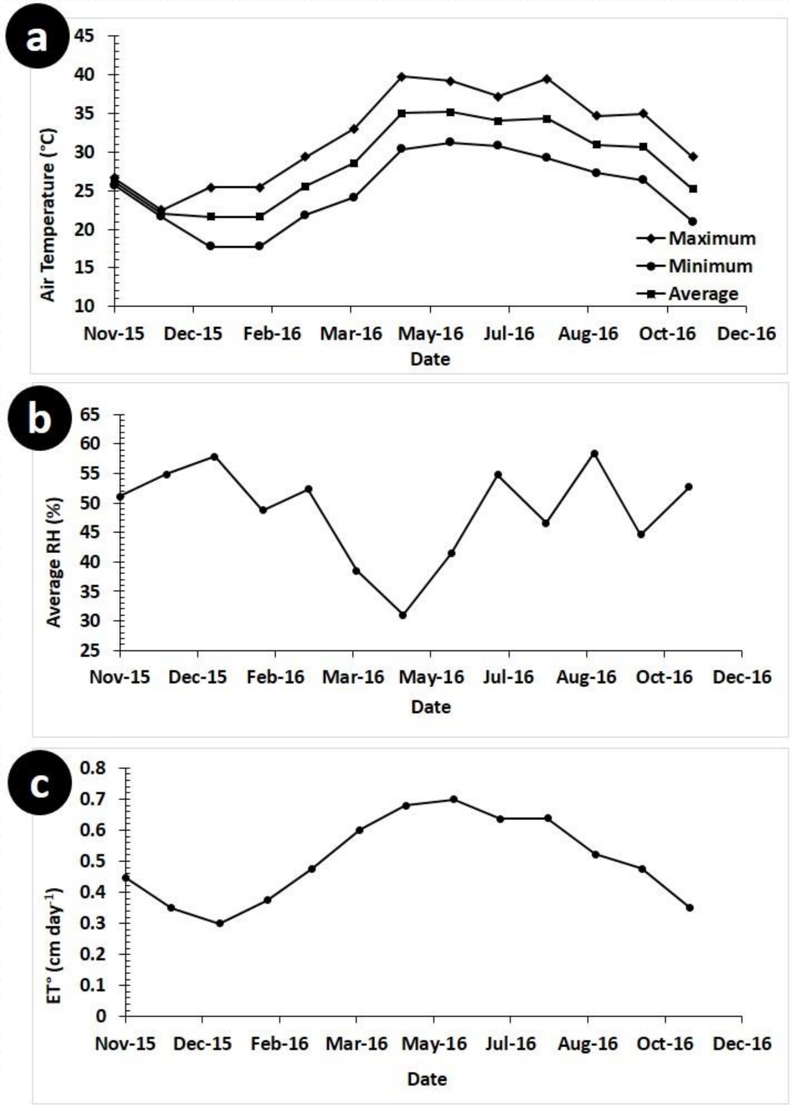
Methodology: Experimental Setup





(a) Schematic drawing for a vertical axial section of the tank, (b) photo of five tanks in the field (CTT indicates Christ's thorn tree), (c) double ring infiltrometer in the control tank during an infiltration test.

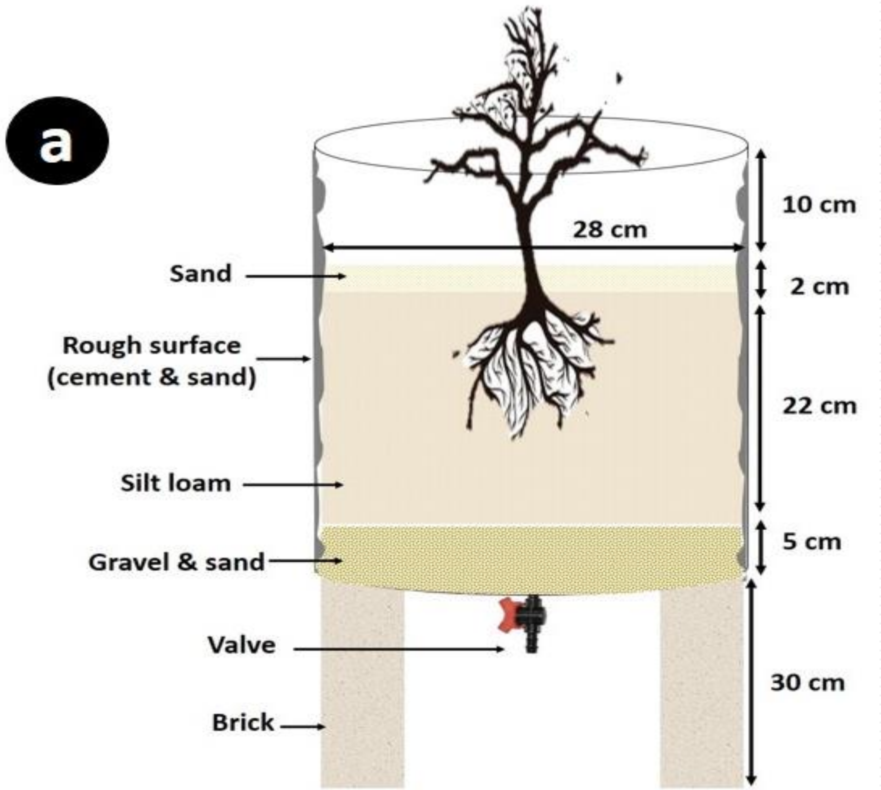
Methodology: Experimental Setup



Soil texture	Soil particles (%)			Bulk density (g cm^{-3})	K_s (cm/day)	EC_e (dS/m)	pH
	Sand	Silt	Clay				
Silt loam	22	56	22	1.44	14.7	1.55	7.8
Applied water	-	-	-	-	-	0.5	8.6

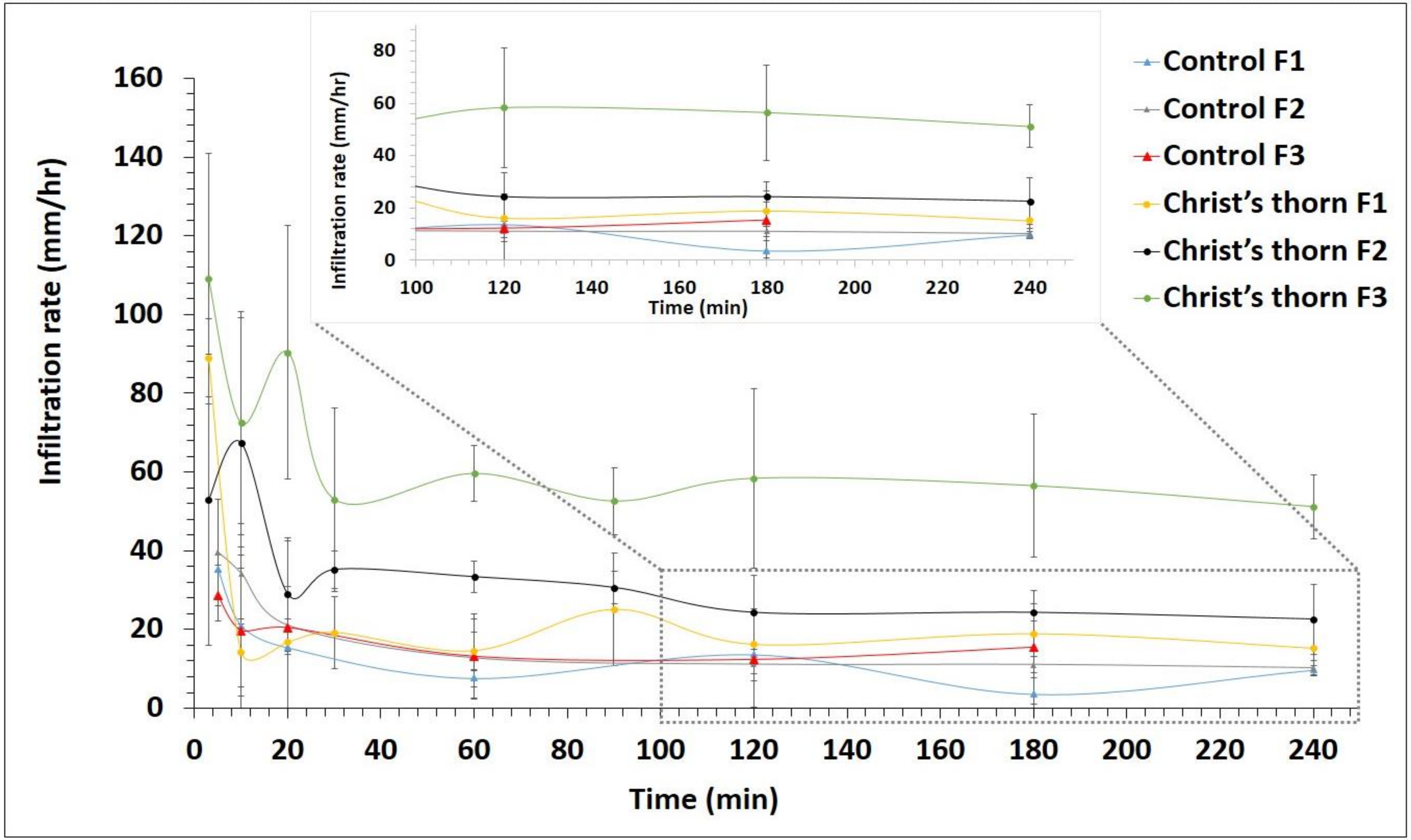
Physico-chemical properties of used soil & irrigation water

Methodology: Small Pot Experiment



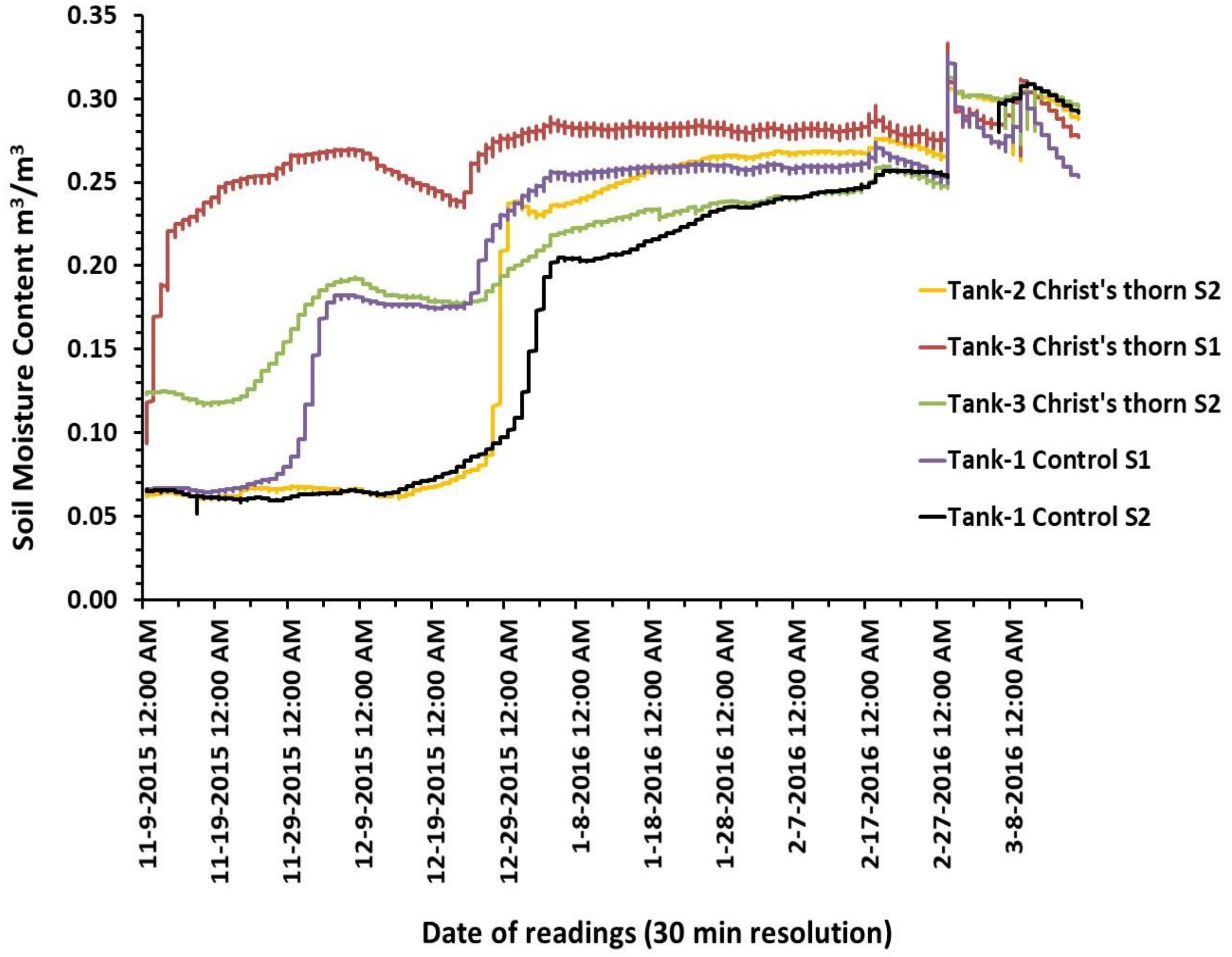
Pot experiments: (a) Schematic diagram of an axial cross-section for the pot experiment, (b) plastering of walls with coarse sand and cement, (c) compacting of soil with a piece of interlock, (d) leveling of the pots, (e) irrigating Christ's thorn CTT seedlings in the PVC pipe, (f) infiltration test, (g) cutting the pots, (h) slicing the soil, (i) extracting roots by flushing the soil.

Results: Infiltration Rates Over 2 Years Experiments

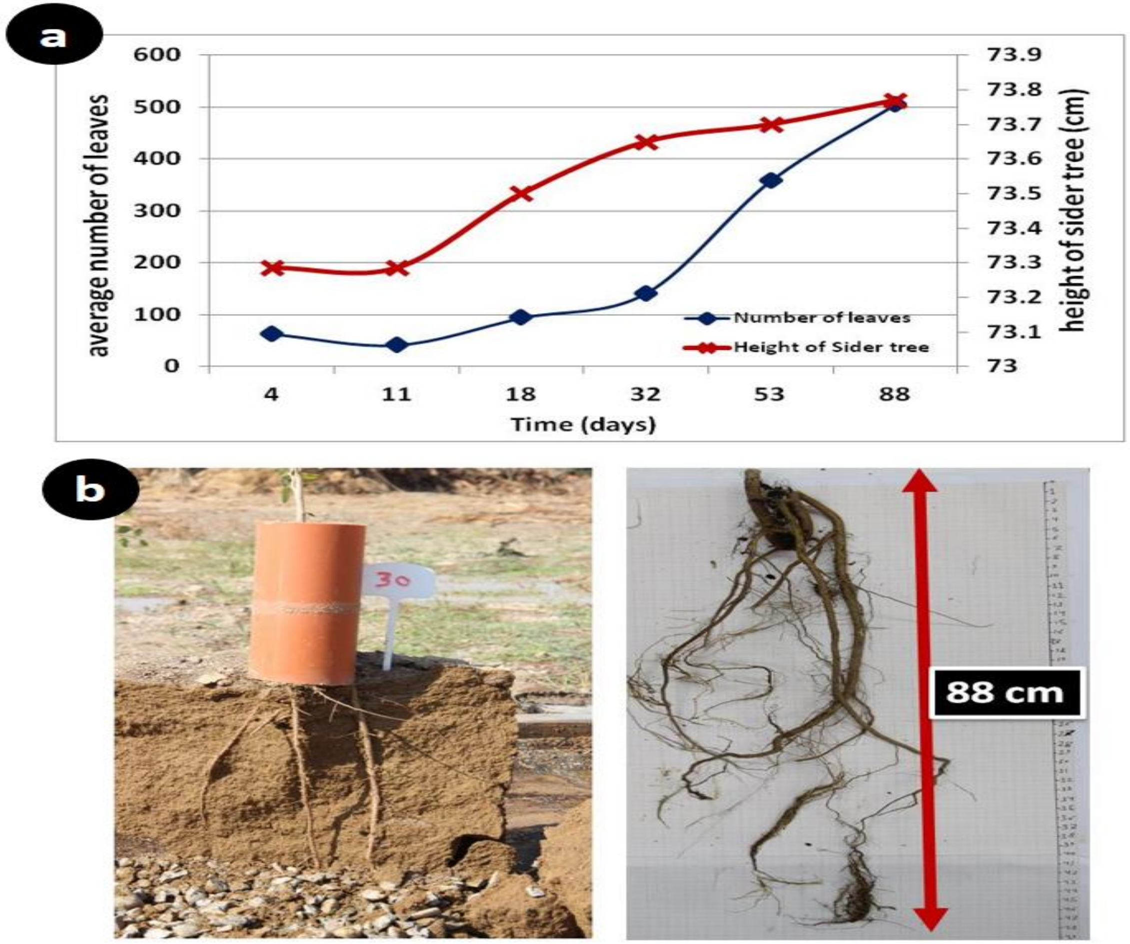


Increased by 6 times 10-14 mm/hr to 75 mm/hr in average

Results: Sensor Data & Plant Growth Parameters

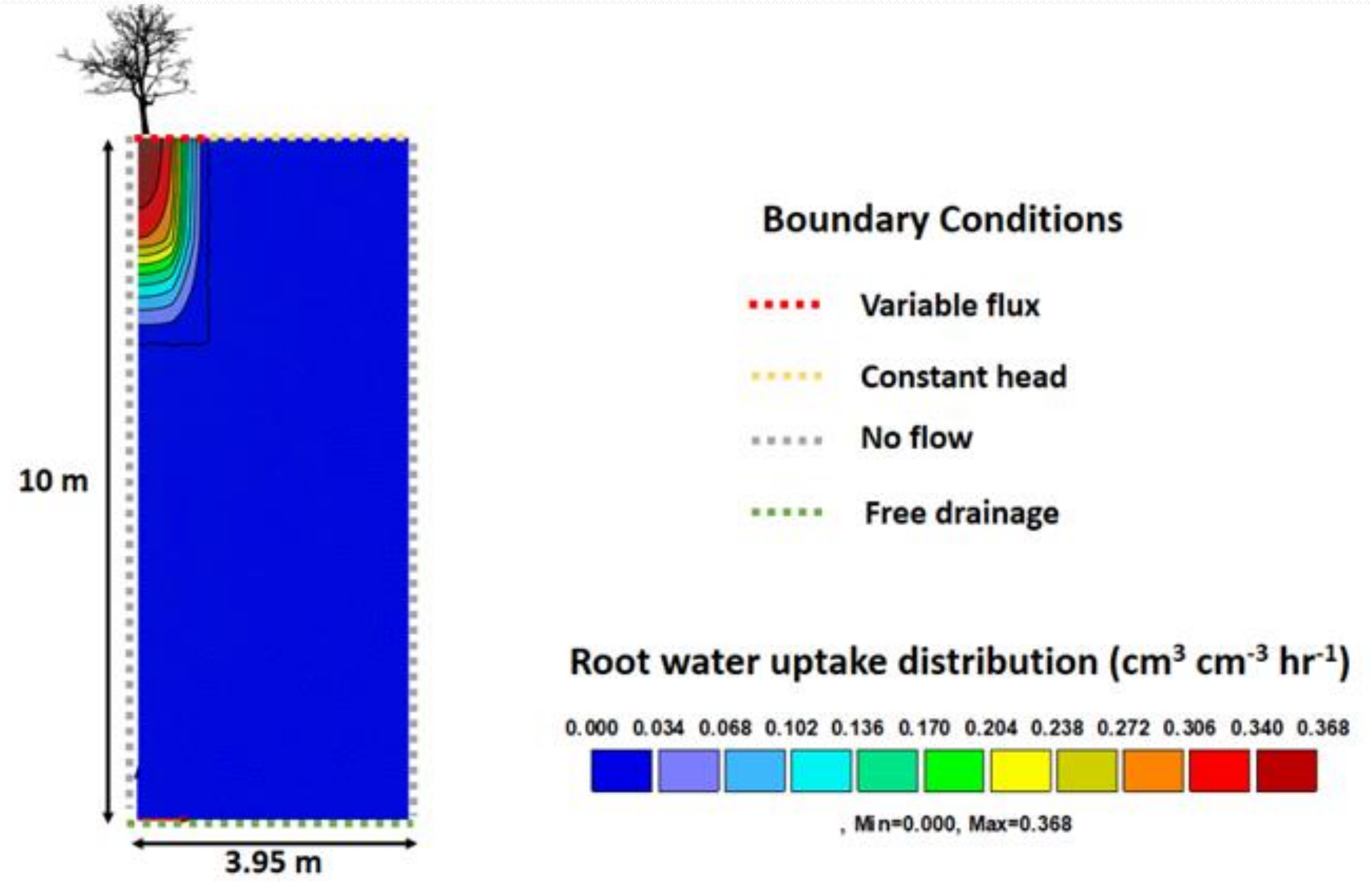


Soil moisture content sensors readings in control (Tank-1) and CTT treatment. S1 and S2 are depths of the sensors at 20 cm and 40 cm, respectively



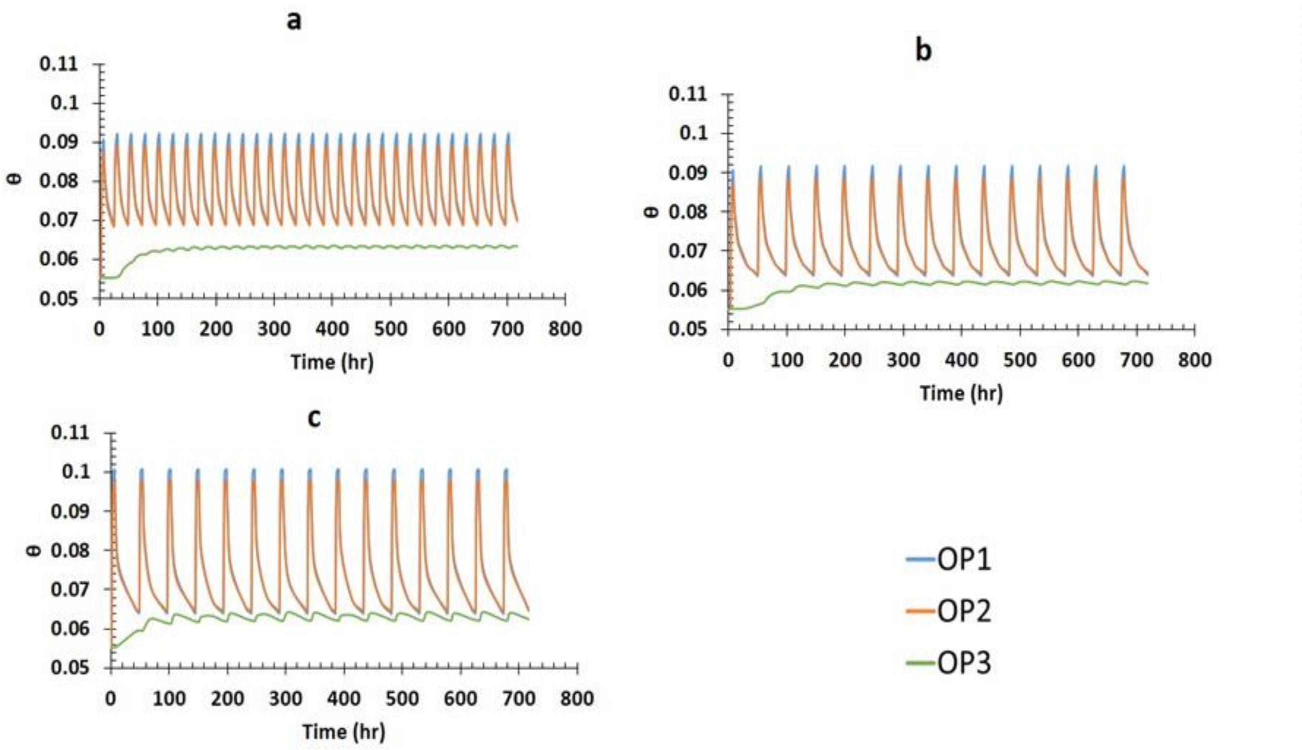
Plant growth parameters: average plant height and average leaf number for Sider trees. (b) main and fibrous roots penetrated the silty loam sediment and washed roots, (adapted from Al-Maktoumi et al., 2020)

Numerical Modeling using HYDRUS-2D

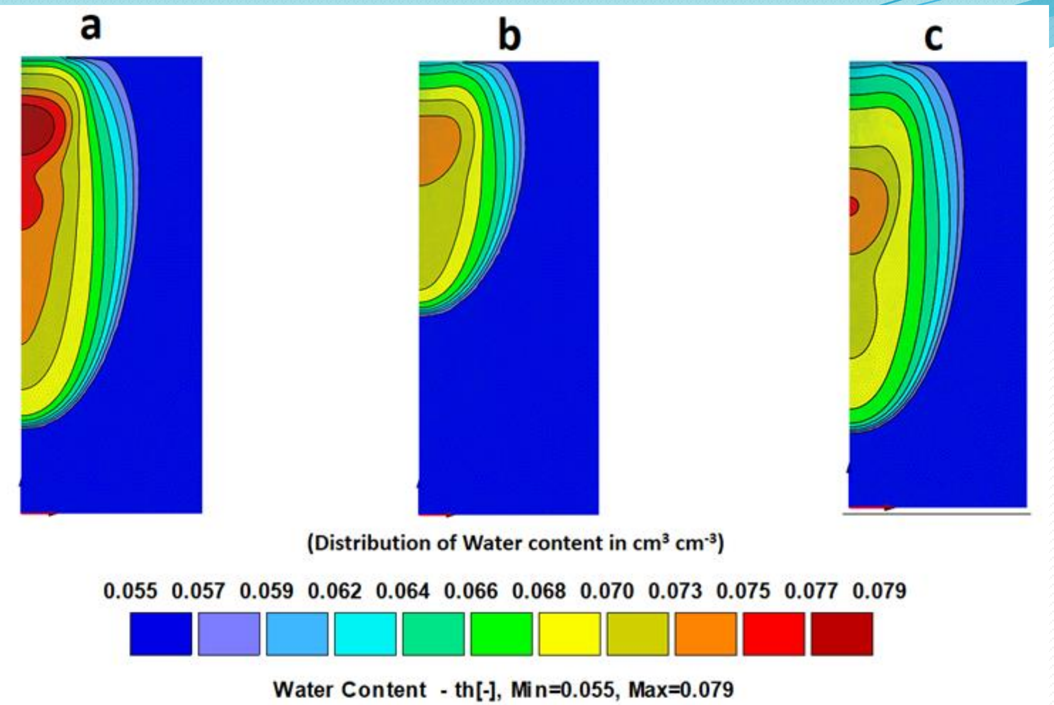


HYDRUS-2D was used to simulate axisymmetric moisture dynamic in a hypothetical soil cylinder with root water uptake (RWU) by a tree (resembling Sider tree) under three different water supply patterns

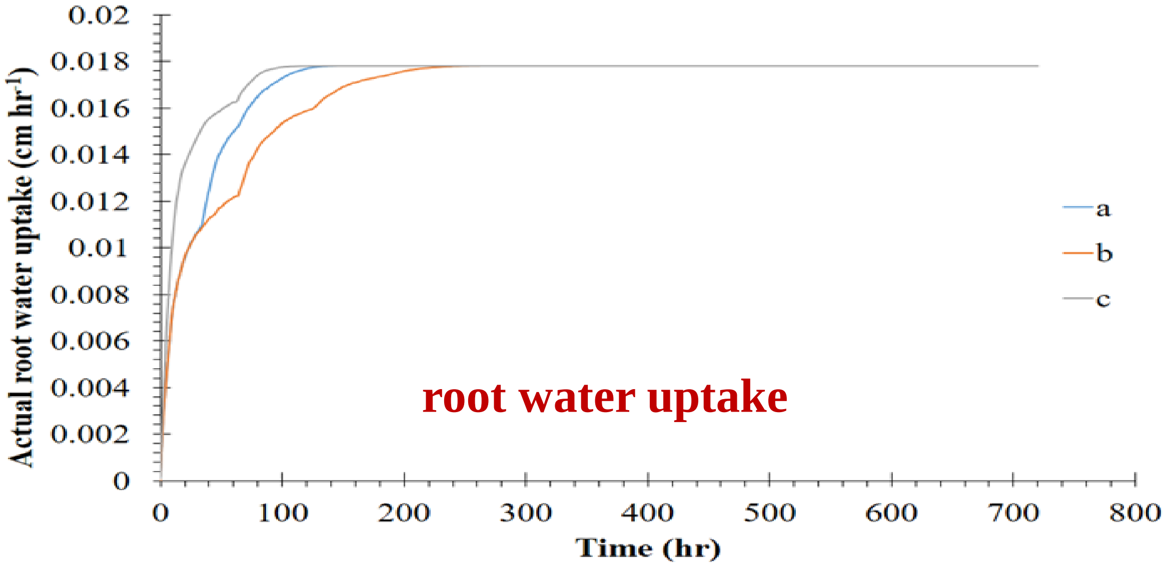
Simulated Moisture Contents



HYDRUS simulated water content curves at the three-set observation points for the three scenarios. a) background regime, b) deficit irrigation, c) irrigation under reduced frequency and increased flux as compared to scenario a.



Distribution of water content in HYDRUS domain after steady state was attained (t=720 hr).



root water uptake

Conclusions and Recommendations

- This study demonstrates the possibility of applying hydro-ecoengineering techniques for improving the infiltration rate and hence the recharge efficiency of recharge dams in arid areas.
- The Christ's thorn trees **significantly increased the steady state infiltration rate of the sediments by 6 times compared to the control (bare soil).**
- Moreover, intensified infiltration from dams' lakes **contributes to decrease of flashfloods to downstream area of the dam**, which is intensely urbanized.
- **To upscale the results to silted recharge dams, a detailed field study to measure the entire water budget for the study area is required.** Moreover, the interactions between surface water and the underneath unconfined aquifer are needed. This will support the optimum design and management of aquifer recharge.

Acknowledgements

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