

In-situ WH functionality and soil water process monitoring

Training of trainers / workshop
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Nov 16, 2021 (online)

Training of trainers on in-situ WH functionality and soil water process monitoring

November 16, 2021

TIME	TOPIC	TRAINER
10:00 – 10:15	Welcome and Introduction	Stefan Strohmeier & Mira Haddad
10:15 – 11:00	Surface and soil water dynamics in drylands	Stefan
11:00 – 11:15	Coffee break	
11:15 – 12:00	In-situ WH soil water dynamics monitoring and data interpretation	Stefan
12:00 – 12:15	Discussion; Q&A	Stefan (& group)
12:15 – 13:00	Lunch break	
13:00 – 13:45	Surface runoff processes modeling (practical part I)	Mira (& group)
13:45 – 14:00	Coffee break	
14:00 – 14:45	Surface runoff processes modeling (practical part II)	Mira (& group)
14:45 – 15:00	Discussion; Q&A	Mira & Stefan (& group)

November 17, 2021

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09:00 - 09:15	Welcome and Introduction	Stefan Strohmeier & Mira
		Haddad
09:15 - 09:30	General discussion of the	Stefan & Mira (& group)
	ecosystem services concept	
09:30 - 10:45	Assessment of selected	Mira
	ecosystem services using	
	tools/models	
10:45 – 11:00	Discussion; Q&A	Stefan & Mira (& group)
11:00 – 11:15	Coffee break	
11:15 – 12:15	Advanced ecosystem services	Stefan
	assessment case studies	
12:15 – 13:00	Lunch break	
13:00 – 13:45	Robust soil-water-ecosystem	Stefan
	processes experiments and	
	monitoring methods in	
	drylands	
13:45 – 14:00	Coffee break	
14:00 – 15:00	Designing soil-water-	Group work
	ecosystem processes	
	experiments and monitoring	
	campaign	

November 17, 2021

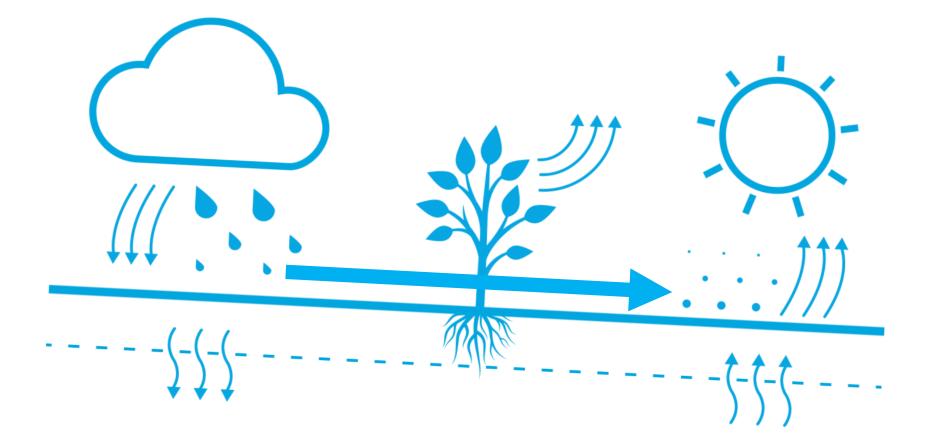
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Surface and soil water dynamics in drylands

$$P = SR + ET + GW + \Delta S$$

P Precipitation
SR Surface Runoff
ET Evapotranspiration

GWGroundwater RechargeΔSSoil Water Storage Change



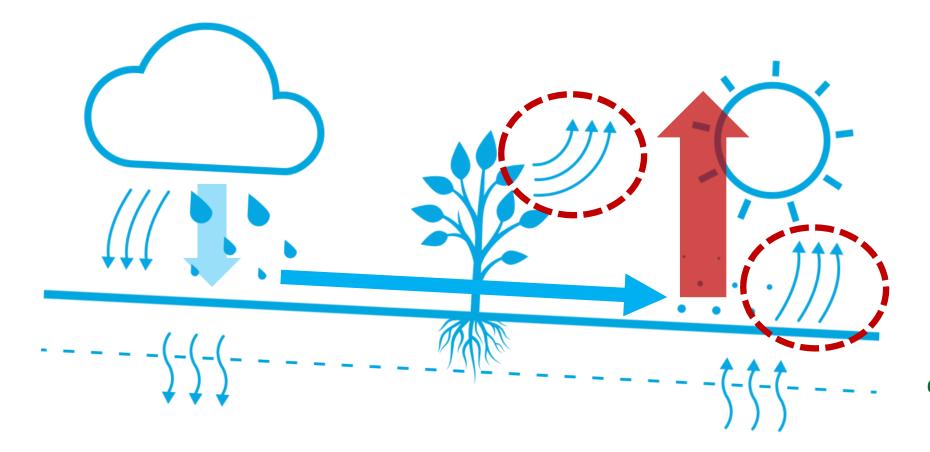
Surface and soil water dynamics in drylands

$$P = SR + ET + GW + \Delta S$$

Precipitation Surface Runoff SR ET

Evapotranspiration

Groundwater Recharge GW ΔS Soil Water Storage Change



Surface and soil water dynamics in drylands





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... is there (excess) water at all?



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Torrential rain, snow storms and flooding hit the Middle East $\,$



People drive past vehicles stranded on flooded streets in the Jordanian capital Amman

Picture: KHALIL MAZRAAWI/AFP/Getty Images

... where does the excess come from..?

... rainfall across the Mediterranean is erratic...

'The Mediterranean climate is also influenced by both sub-tropical and mid-latitude climate dynamics and is therefore very sensitive to global climate change. Extreme weather events, including heavy precipitation and flash-flooding during the fall season, severe cyclogenesis associated with strong winds and large sea waves during winter, and heat waves and droughts accompanied by forest fires during summer, regularly affect the Mediterranean region causing heavy damages and human loss...'

HyMeX – Hydrological cycle in the Mediterranean Experiment 2010-2020 (https://www.hymex.org/)

Harvest the excess!



Source: Gagnon, B. 1986 (Wikipedia)



Palestine. NARC, ARIJ, ICARDA

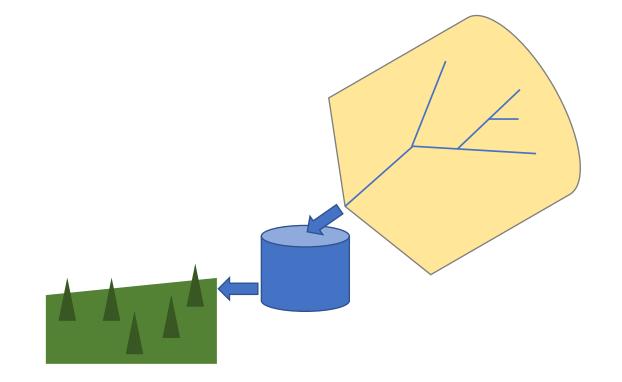
The water harvesting concept

..... the ancient concept is simple and facilitates the concentration and storage of excess rainwater in defined locations for targeted utilization (Oweis, 2017).

..... the ancient concept is simple and facilitates the concentration and storage of excess rainwater in defined locations for targeted utilization (Oweis, 2017).

Concept

- Catchment (excess water)
- Collection & concentration zone
- Facilitation of water (use)





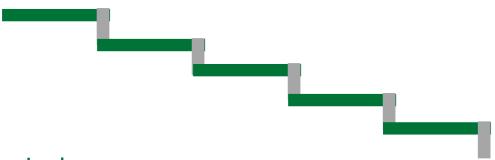
Source: Gagnon, B. 1986 (Wikipedia)



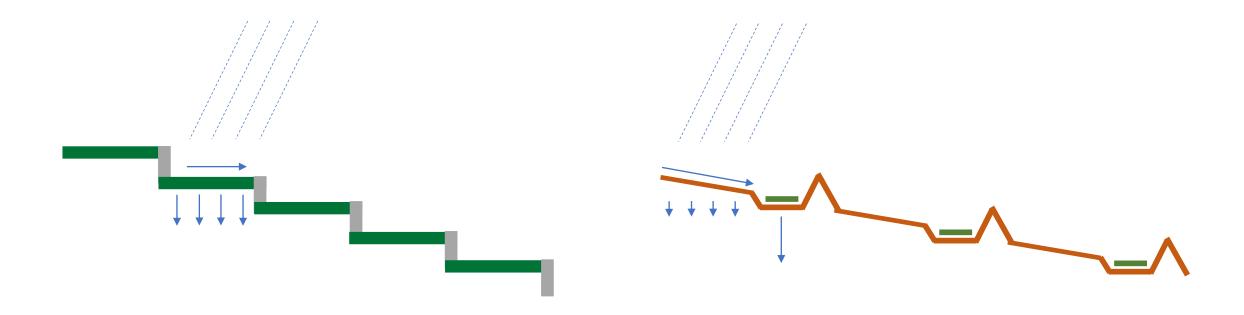
Palestine. NARC, ARIJ, ICARDA

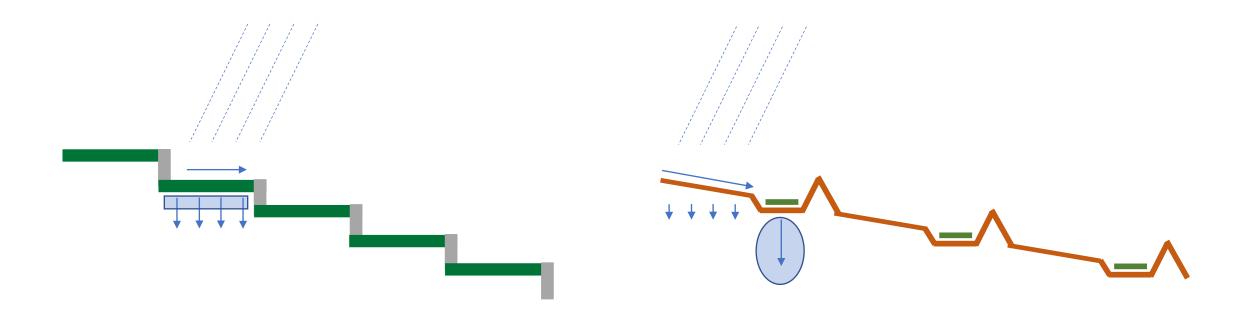


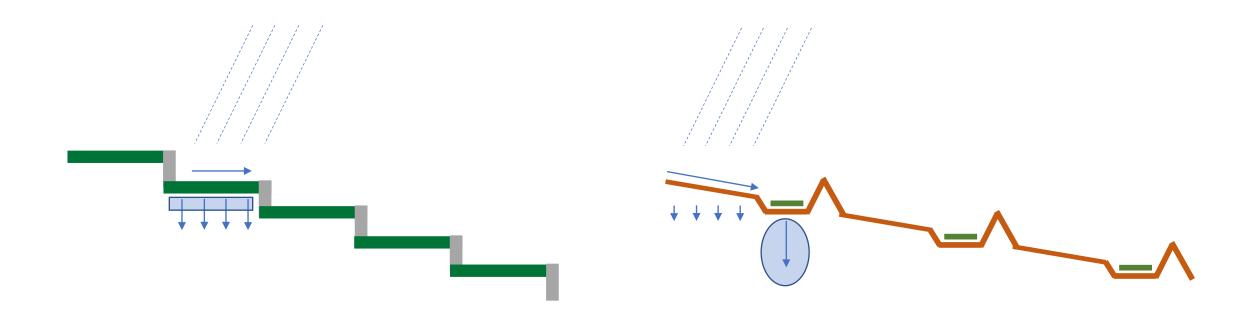












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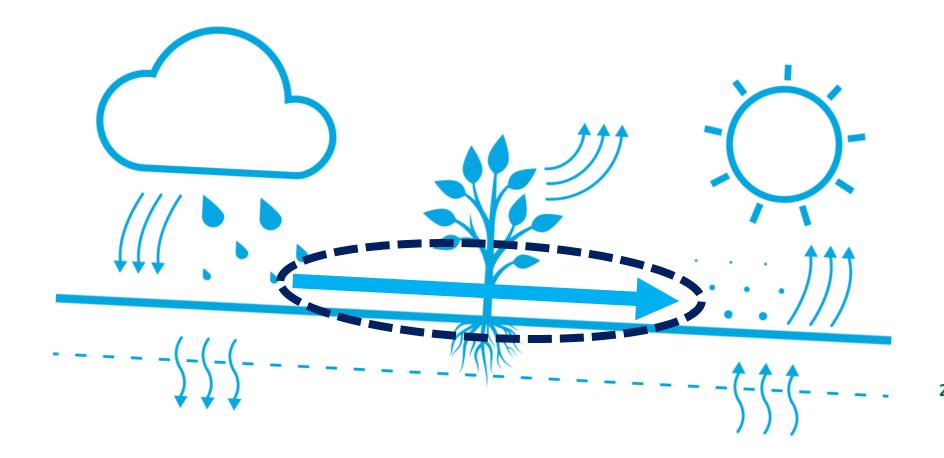


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Palestine. NARC, ARIJ, ICARDA

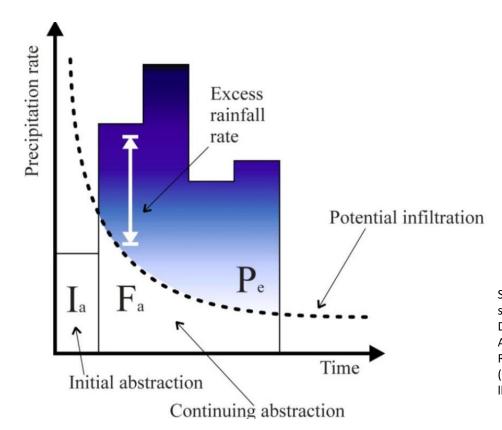
How can we determine the excess in a changing environment?



When does surface runoff occur...?

Basically, when...

Rainfall intensity exceeds initial abstraction and infiltration into the soil...

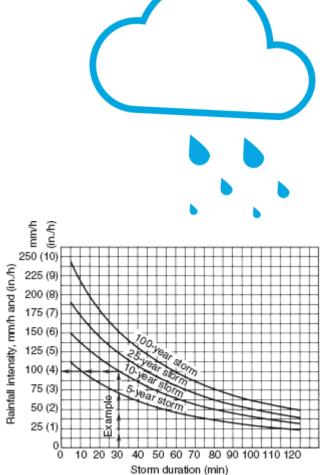


Source: Modeling catchment scale infiltration. Serena Ceola, DICAM, University of Bologna Advanced Hydrology & Water Resources (https://distart119.ing.unibo.it/a lbertold/files/infiltration1.pdf)

When does surface runoff occur...?

... heavily depends on the rainfall amount and even more on its intensity

# Storm file for scenario: Zaragoza								
#	Date bu	ilt:	April 2	20, 202	1, 3:15	am (Ve	rsion 2	2.3)
# State: CA								
#	Climate	Stat	ion: 04	4647				
7	783 # Th	e num	ber of	rain e	vents			
0	7783 # The number of rain events 0 # Breakpoint data? (0 for no, 1 for yes)							
#		day			Rain	Dur	Tp	Ip
#		aaj	111011011	Jour	(mm)	(h)	-12	-12
"	1	28	1	1	7.7	6.70	0.73	7.97
	2	1	2	1	2.2	3.67	0.07	2.62
	3			1				
		16	2		1.9	6.51	0.02	4.23
	4	17	2	1	2.0	4.77	0.30	7.65
	5	21	2	1	22.6		0.08	5.85
	6	24	2	1	8.6	3.62	0.02	3.87
	7	25	2	1	42.7	4.98	0.02	4.37
	8	28	2	1	4.9	12.17	0.00	7.21
	9	6	3	1	27.2	4.42	0.08	1.97
	10	8	3	1	4.8	18.56	0.03	5.52
	11	9	3	1	2.6	9.54	0.01	5.16
	12	10	3	1	23.6	4.54	0.02	2.29
	13	14	3	1	2.3	4.47	0.04	3.35
	14	19	3	1	2.2	6.77	0.14	3.49
	15	13	4	1	10.1		0.04	4.62
			4	1				
	16	24			2.2	3.88	0.06	8.26
	17	2	5	1	1.3	0.70	0.92	1.73



Initial abstraction (interception)

• Surface cover (foliar)

'Intercepted rainfall is the water captured by plant canopies or litter before it hits the soil surface...'

Direct surface cover and unsteadiness



Initial abstraction (interception)

• Surface cover (foliar)

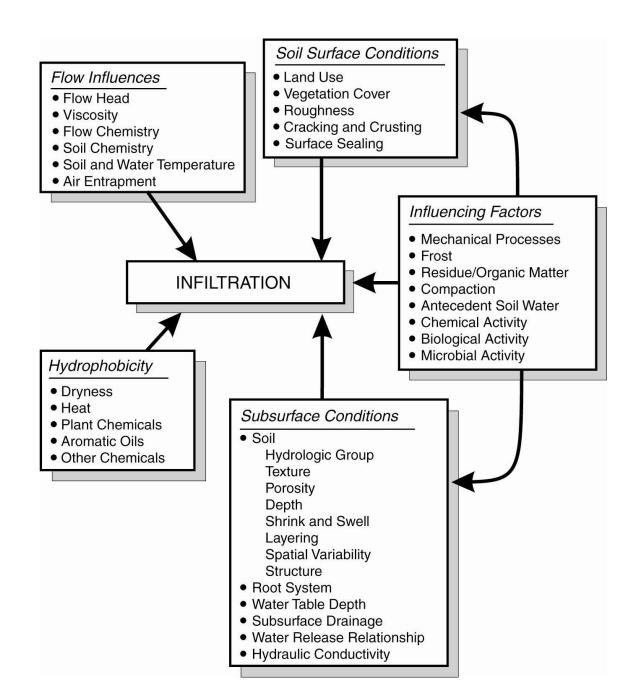
'Intercepted rainfall is the water captured by plant canopies or litter before it hits the soil surface...'

Direct surface cover and unsteadiness

Surface cover in drylands is low



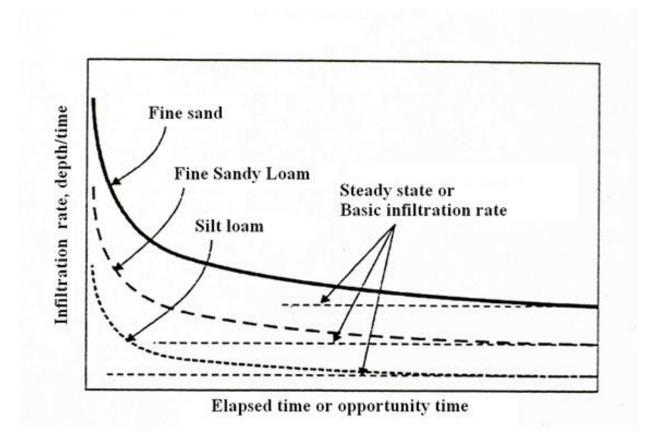
Rainwater infiltration into the soil





Infiltration







Rainfall



Cover



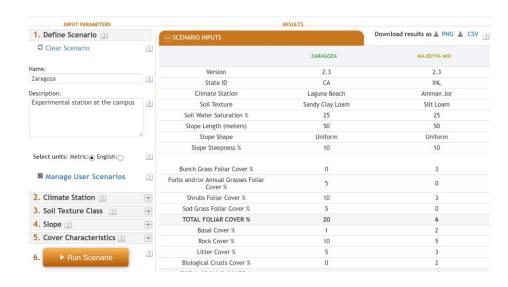




Scenarios: surface runoff modeling

Rangeland Hydrology and Erosion Model (RHEM)

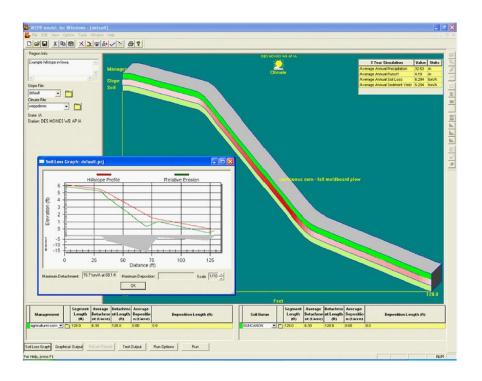
- Rangelands
- Unmanaged soils (mostly)
- Natural vegetation cover



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Water Erosion Prediction Project (WEPP)

- Agricultural areas
- Managed soils
- Agricultural vegetation cover



Scenarios: surface runoff modeling

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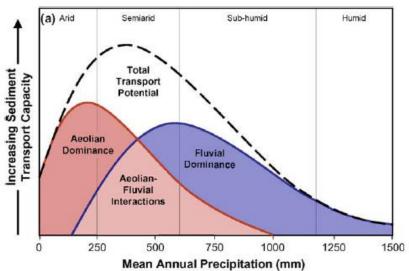
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Land degradation: erosion through water (ecosystem services consideration)

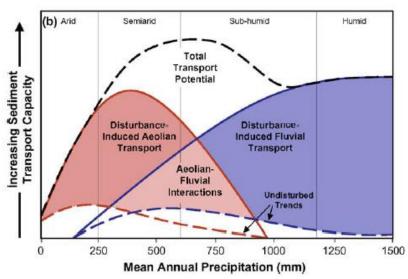


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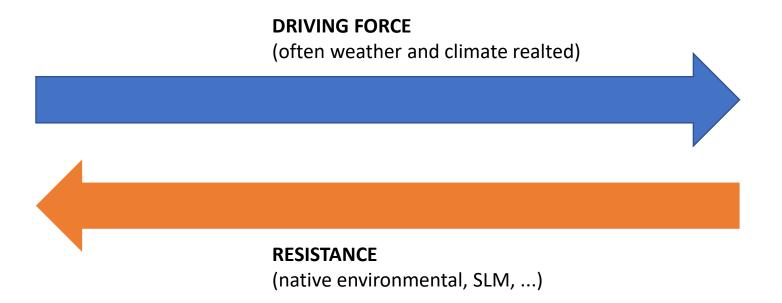


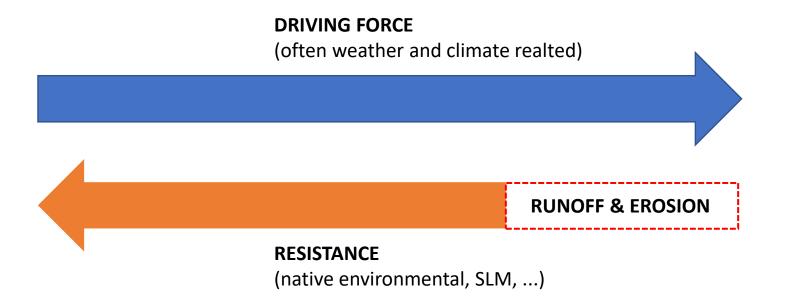






Source: Hannah et al. (2004)







DRIVING FORCE

(often weather and climate realted)

RESISTANCE

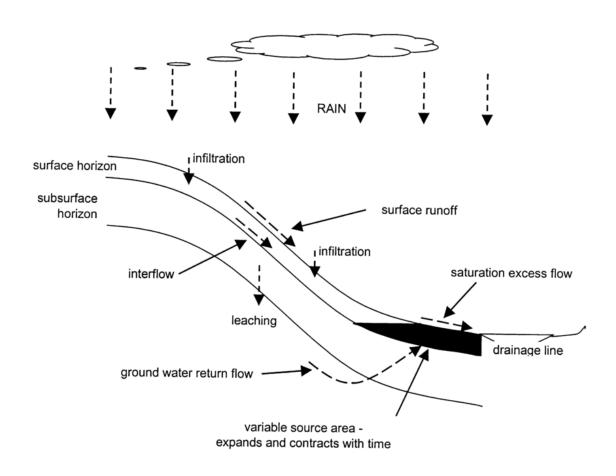
(native environmental, SLM, ...)

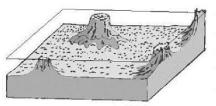






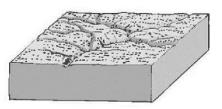
Runoff and erosion: a question of scale





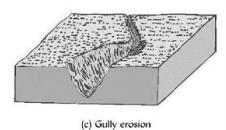
(a) Sheet erosion





(b) Rill erosion







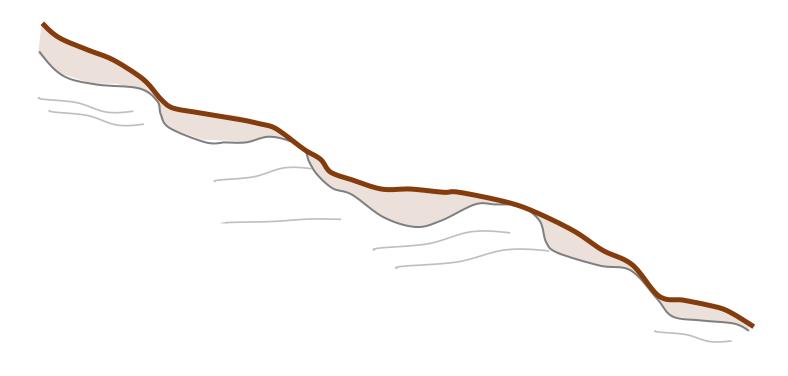
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Warwick et al. (2004) (https://www.researchgate.net/figure/Basic-components-of-hillslope-hydrology_fig3_51369131)

Influence connectivity: shorten the hillslope



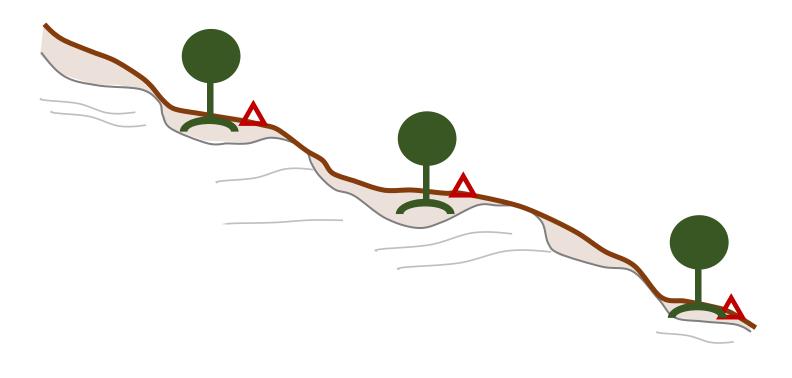




Influence connectivity: shorten the hillslope



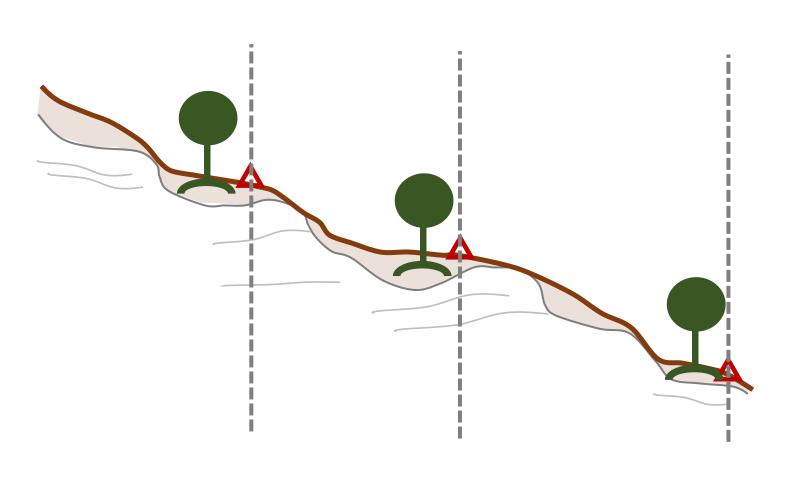




Influence connectivity: shorten the hillslope

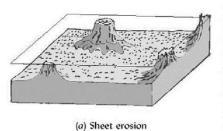




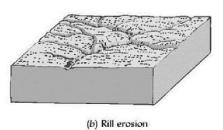


Runoff and erosion: a question of scale

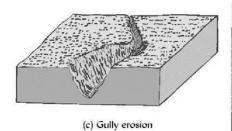
40







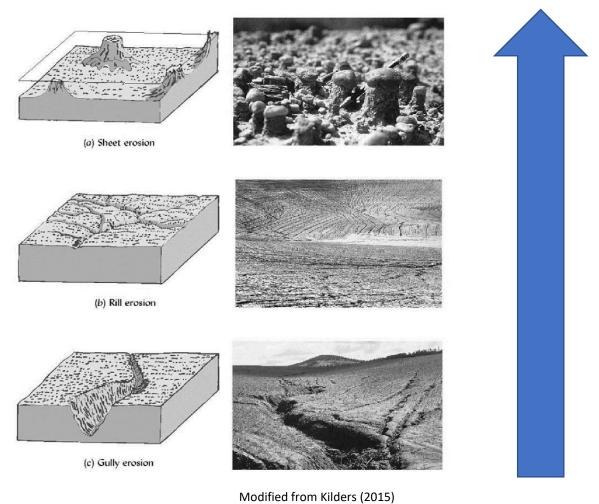






Modified from Kilders (2015)

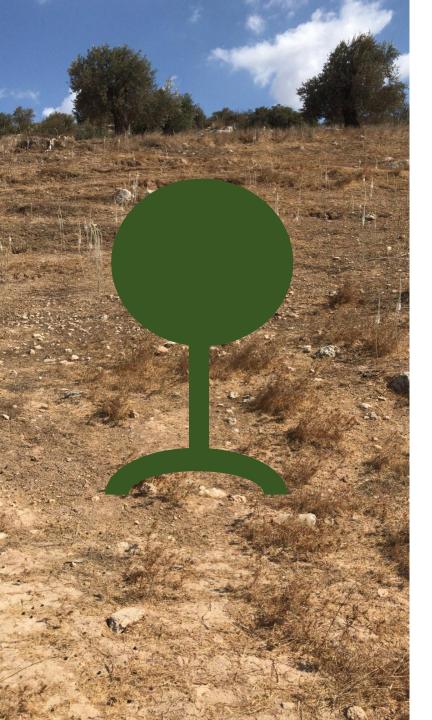
Runoff and erosion: a question of scale



icarda.org Modified from Kilders (2015)



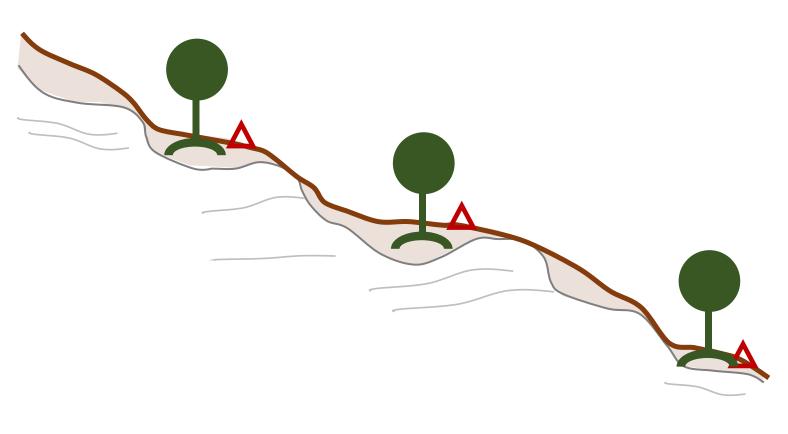
Soil is key



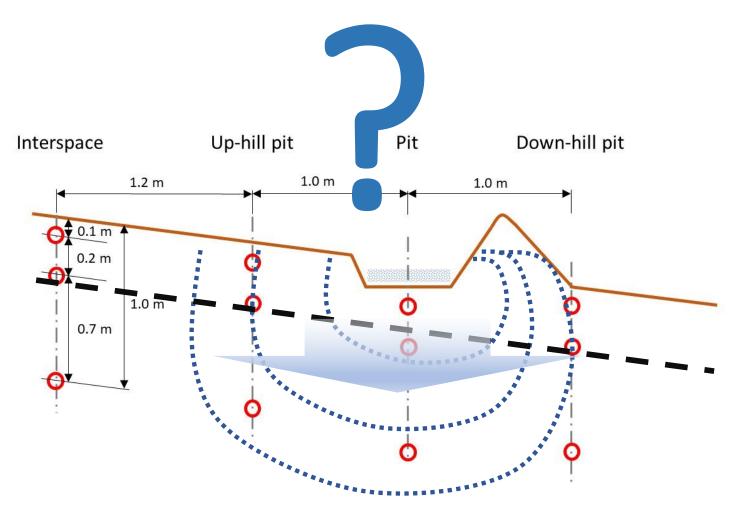


Soil is key





What happens with water in the soil?



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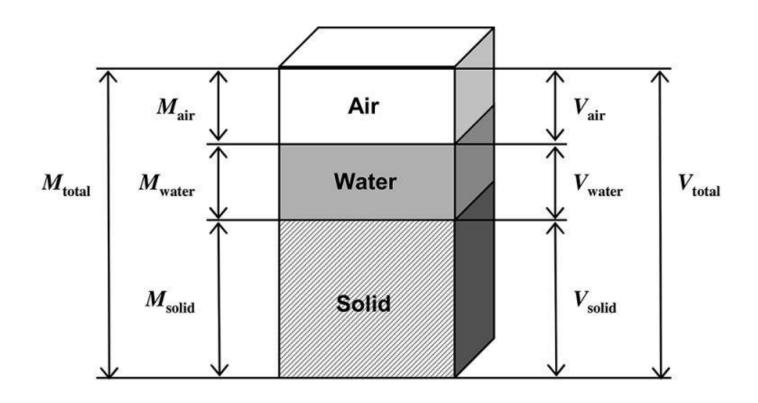
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Soil physical properties: soil water implications

Soil physics deals with the dynamics of physical soil components and their phases as solid, liquids, and gases. Lal and Shukla (2004)



Soil physical properties: Texture

Texture

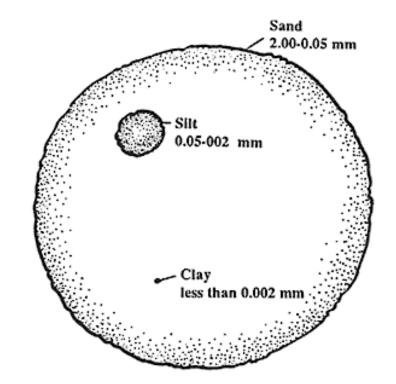
Relative proportions of various sizes of individual soil particles

USDA classification

Sand: 0.05 – 2.0 mm

Silt: 0.002 - 0.05 mm

Clay: <0.002 mm





Soil texture analysis

State of Palestine Ministry of Agriculture National Agricultural Research Center (NARC)



دولة فلسطين وزارة الزراعة المركز الوطني الفلسطيني للبحوث الزراعية

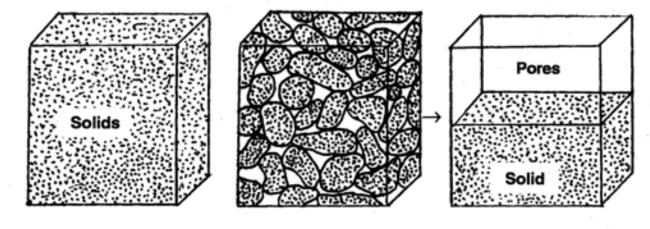
التاريخ: 2021/10/12

الرقم: م.ب.ز:

Om %	%Н	Clay %	Silt %	Sand%	NO
2.2	7	56.4	26.8	16.72	1
4.2	3	36	36	28	2
5.5	3	30.9	33.4	35.6	3
2.2	5	28.9	31.5	39.5	4

تم احتساب الرمل على اساس 100-طين -سلت اي ان OMوالمعادن من ضمنه

Soil physical properties: Structure



Particle Density

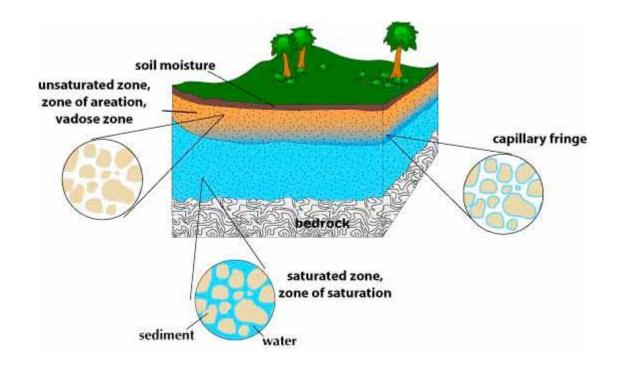
100% solid Weight = 2.66 g Volume = 1 cm³

Bulk Density

50% solid, 50% pore space Weight = 1.33 g Volume = 1 cm³



Soil moisture and saturation



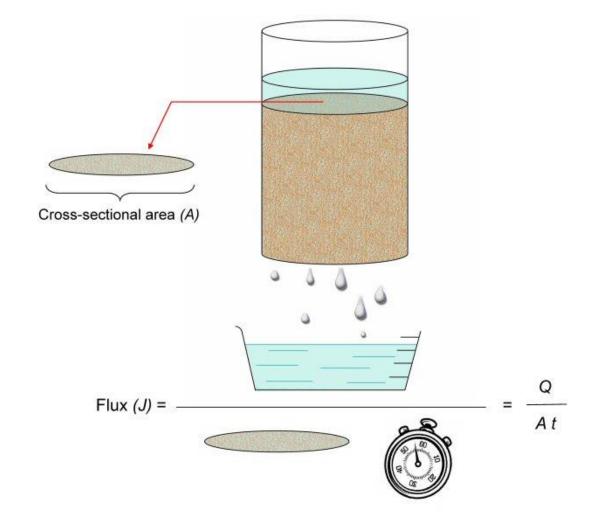


Water movement through (saturated) soils

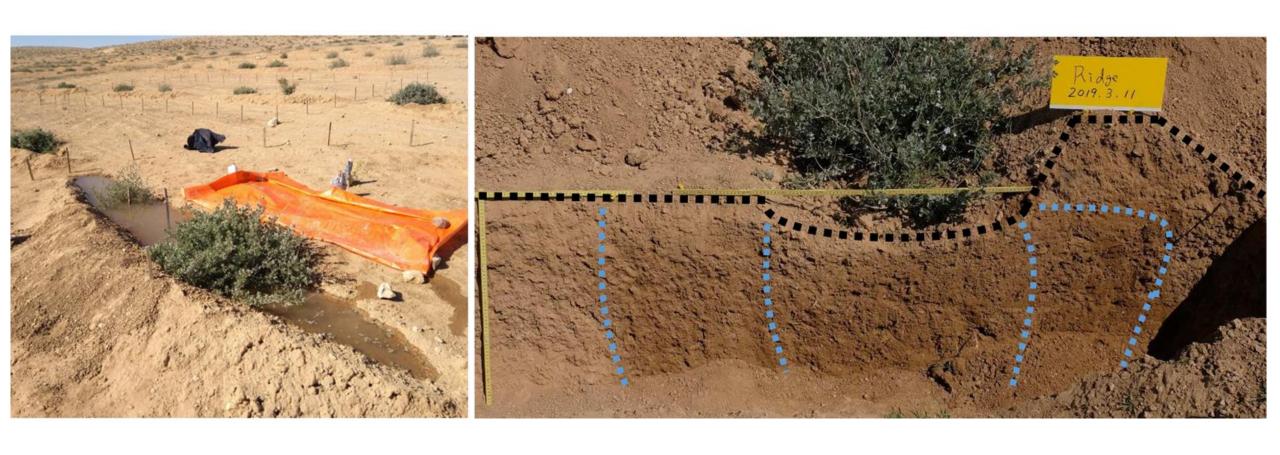
Infiltration and conductivity

Saturated hydraulic conductivity (m s⁻¹)

$$q = K \nabla H$$



Soil water movement in unsaturated soils



Soil water movement in unsaturated soils: Soil water potential

$$\psi_t = \psi_m + \psi_p + \psi_g + \psi_o$$

 ψ_t = Total soil water potential

 ψ_m = Matric potential (capillary)

 ψ_p = Pressure potential

 ψ_g = Gravity potential

 ψ_o = Osmatic potential

Soil water movement in unsaturated soils: Soil water potential

$$\psi_t = \psi_m + \psi_p + \psi_g + \psi_o$$

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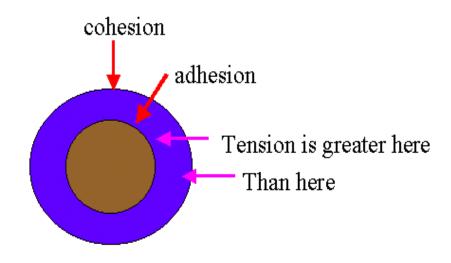
 ψ_p = Pressure potential

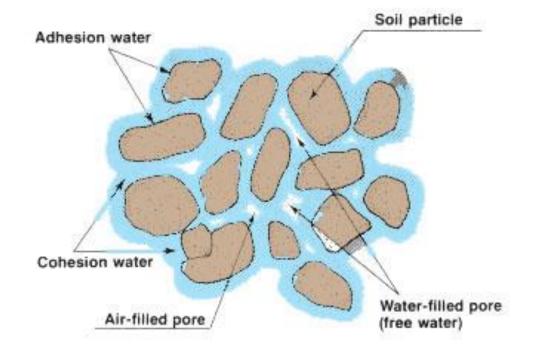
 ψ_g = Gravity potential

 ψ_o = Osmatic potential

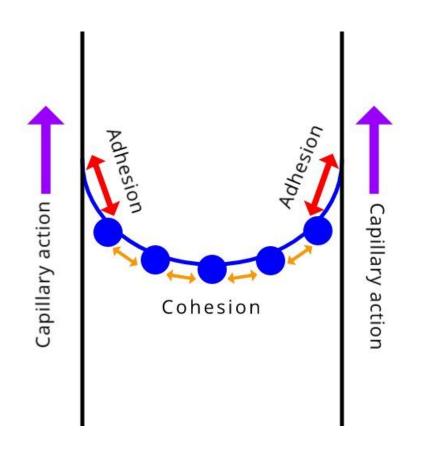
 ψ_m commonly, has the greatest effect

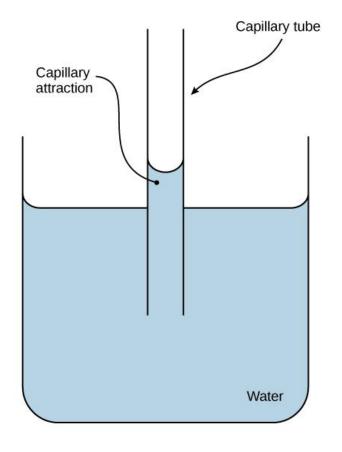
Soil water (matric) potential



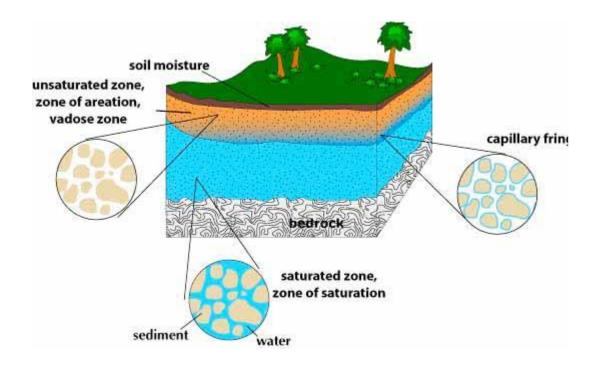


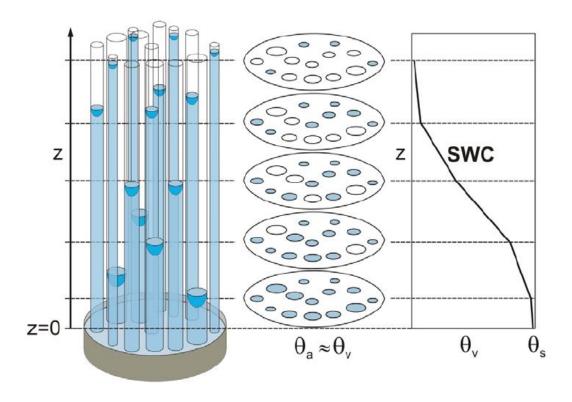
Soil matric potential – capillary rise





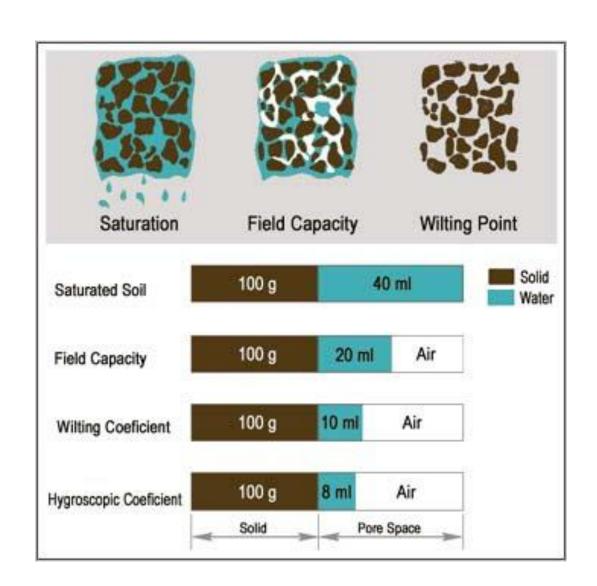
Soil matric potential – capillary rise





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Soil matric potential – soil water status



Soil matric potential – soil water status

Field Capacity (FC or θ_{fc})

- Soil water content where gravity drainage becomes negligible
- Soil is not saturated but still in a wet condition
- Traditionally defined as the water content corresponding to a soil water potential of -1/10 to -1/3 bar
- As a rule of thumb: evolves in full saturated soil profile after 2-5 days

Permanent Wilting Point (WP or θ_{wp})

- Soil water content beyond which plants cannot recover from water stress (d)
- Still some water in the soil but not enough to be of use to plants
- Traditionally defined as the water content corresponding to -15 bars of SWP

Soil water status – plant water availability

Plant Available Water Content

Field Capacity (FC) - Permanent Wilting Point (PWP)

Soil Solids (Particles	s) ca. 50%	
	Very Small Pores: 15% (Fixed/Unavailable Water)	
Total Pore Space ca. 50%	Medium-sized Pores: 20% (Plant Available Water)	
	Very Large Pores: 15% (Gravitational Water Loss)	

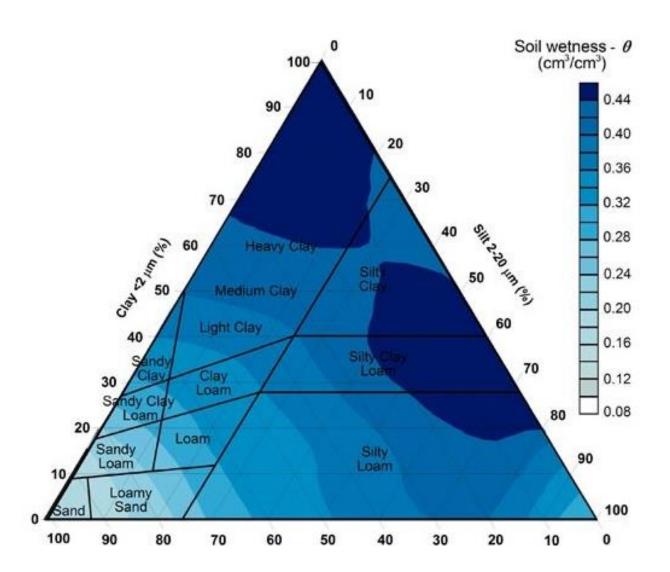
Soil water status – plant water availability

Plant Available Water Content

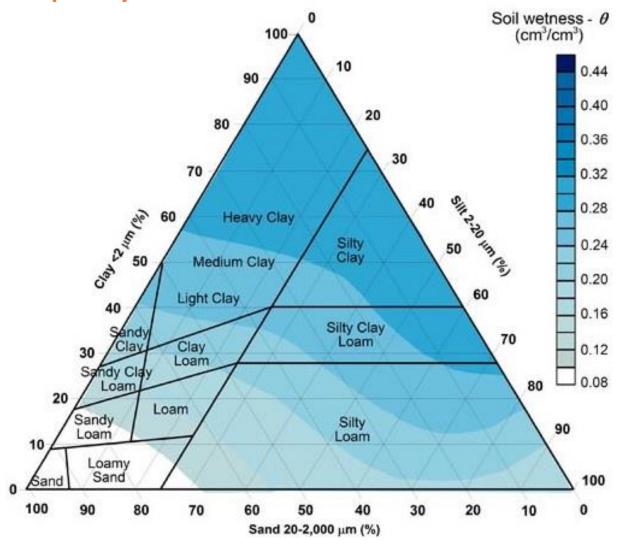
Field Capacity (FC) - Permanent Wilting Point (PWP)

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Field Capacity (FC)



Permanent Wilting Point (PWP)

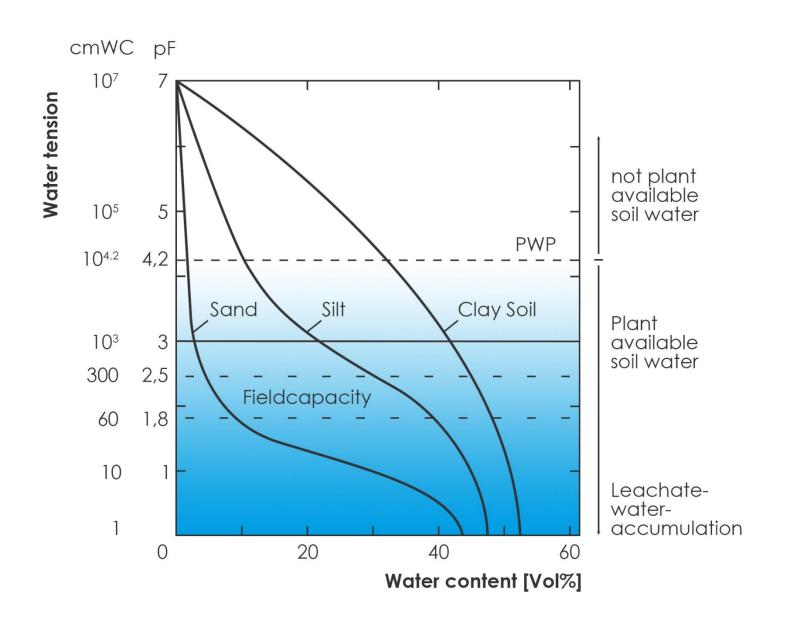


Soil water availability: link with texture

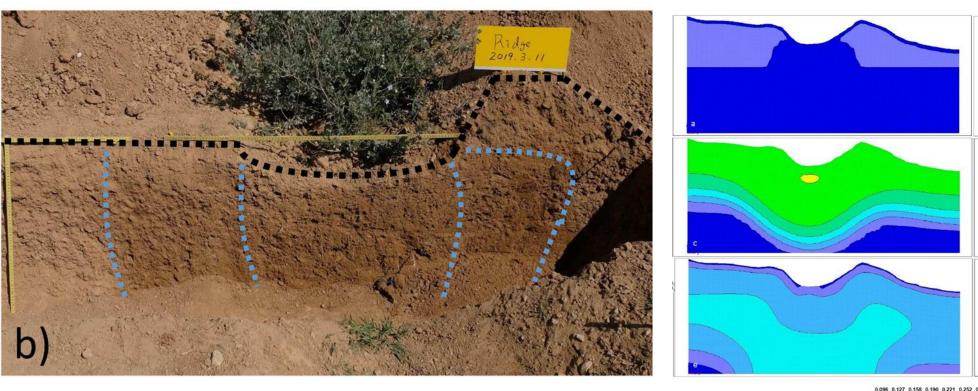
Plant Available Water Content

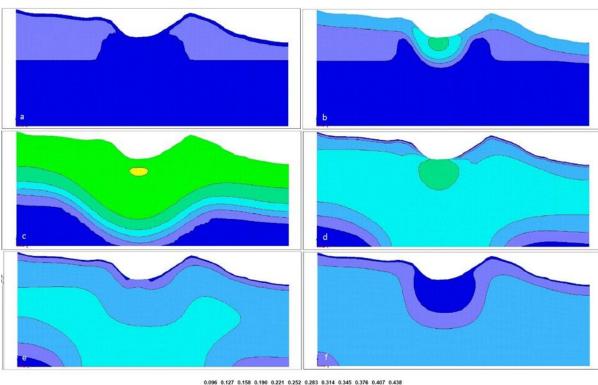
Soil Texture	θ_{fc}	$ heta_{\sf wp}$	AWC
Coarse Sand	0.10	0.05	0.05
Sand	0.15	0.07	0.08
Loamy Sand	0.18	0.07	0.11
Sandy Loam	0.20	0.08	0.12
Loam	0.25	0.10	0.15
Silt Loam	0.30	0.12	0.18
Silt Clay Loam	0.38	0.22	0.16
Clay Loam	0.40	0.25	0.15
Silt Clay	0.40	0.27	0.13
Clay	0.40	0.28	0.12

Soil water retention

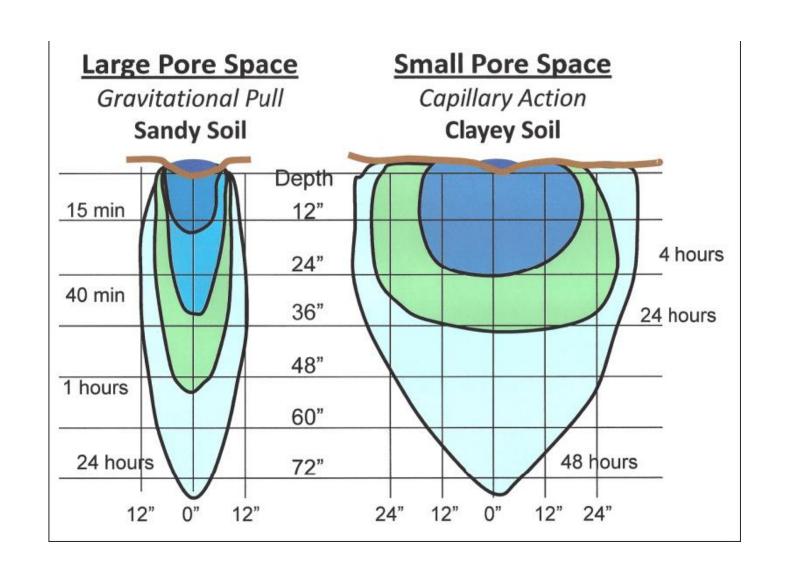


Soil water infiltration



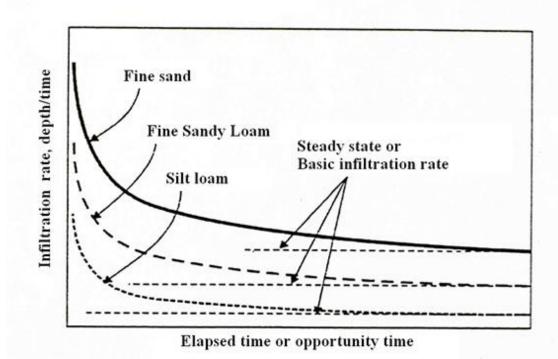


Water Content - th[-], Min=0.096, Max=0.438





Soil water infiltration



Soil water infiltration

State of Palestine Ministry of Agriculture National Agricultural Research Center (NARC)



دولة فلسطين وزارة الزراعة المركز الوطني الفلسطيني للبحوث الزراعية

التاريخ: 2021/10/12

الرقم: م.ب.ز:

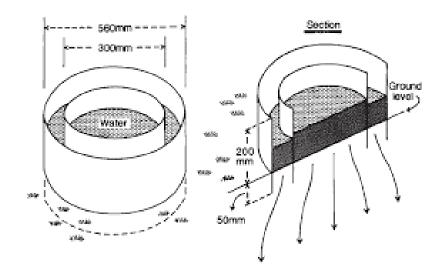
Om %	%Н	Clay %	Silt %	Sand%	NO
2.2	7	56.4	26.8	16.72	1
4.2	3	36	36	28	2
5.5	3	30.9	33.4	35.6	3
2.2	5	28.9	31.5	39.5	4
	Om % 2.2 4.2 5.5 2.2	Om % %H 2.2 7 4.2 3 5.5 3 2.2 5	2.2 7 56.4 4.2 3 36	2.2 7 56.4 26.8 4.2 3 36 36	2.2 7 56.4 26.8 16.72 4.2 3 36 36 28

تم احتساب الرمل على اساس 100-طين -سلت اي ان OMوالمعادن من ضمنه

Monitoring soil water dynamics

.... what kind of field tests and devices help?

Infiltration (fully saturated)





Infiltration (fully saturated)



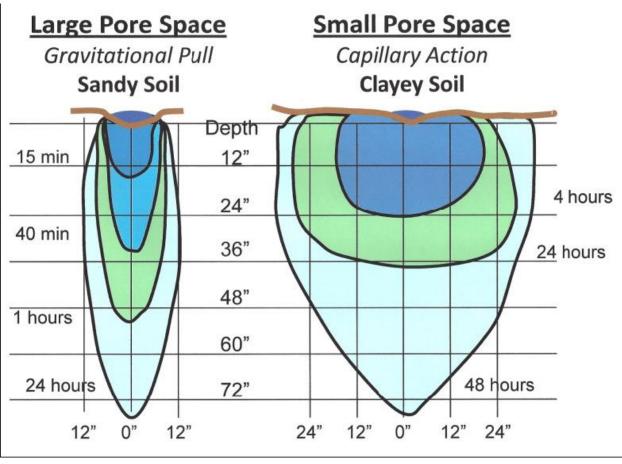
e location:	EXAM <i>P</i>	LE.	Sail ty		⊃∂m MS<	Test da	te: .5D E S	19.8.7.
l ding on the clock	2 Time difference	3 Cumulative time	re before	adings after	5 Infiltration	6 Infiltration rate	7 Infiltration rate	8 Cumulative infiltration
min sec	oin	min		-	1000	ma/min	mm/hour	_ con
05 0	start = 0	start = 0		100	, , ,	101 .		start = 0
Λ ΓΛ	1 2	(0+2) 2	a 2	100	(100-92) 8	(%2) 4·00	240	(6+8) 8
	3	- 			(100-93) 7	(7/3) 2.33	140	· · · · · · · · · · · · · · · · · · ·
10 0	5	(2+3) 5	93	99		(10/5) 2.00	120	(8+3) 15
15 0		(5+S) 10	89	101	<u> </u>	. 1-1	:	(15HO) 25
25 0	10	(10+10) 20	8u	100	(101-84) 17	C-710) - 1		(25+17)42
***	10		· · · · ·		(100-89) 11	(11/10) 1.10	66	7
	10				(102-95) 7	(7/10)0.70	42	(42+11) 53
	20	(3040) 40	95_	101	(101-92)9	(9/20) 0.45	27*	(53+7) 60
05 0		(40+20) 60	92	100				(60+G) 69
25 0	10	(60+20) 80	91		(100-91)9	(3/20)0:42	27 /	(ba+9)78
	1	(== 1,==)	·· · · · · · · · · · · ·			·		V-5 3/15
<u> </u>	1					ļ		
<u> </u>					<u> </u>			
]	i			1		
	1 ding on the clock min sec 05 0 07 0 10 0 15 0 25 0 45 0 05 0	1 ding on the clock	ding on the clock	1	1	1	1	1

* basic infiltration rate

Infiltration

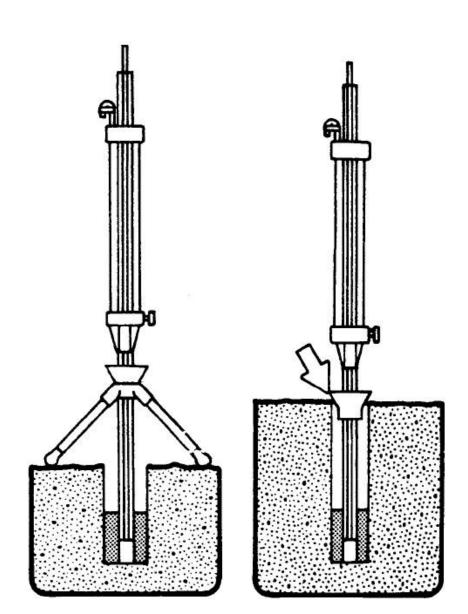
Infiltration (fully saturated)





Infiltration (fully saturated) + lateral matrix flux

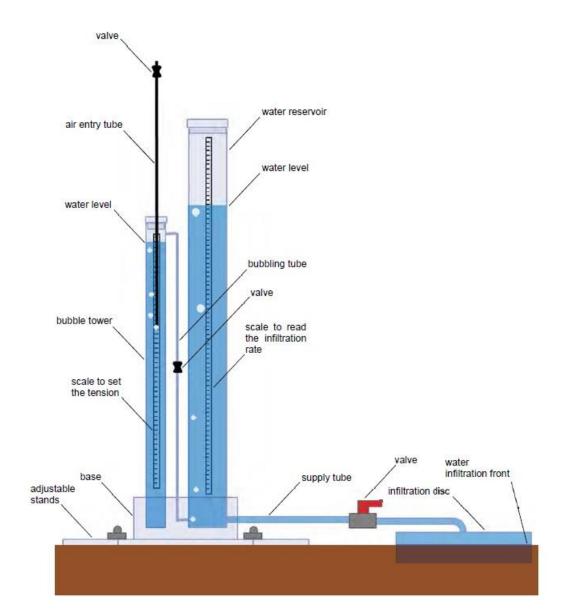




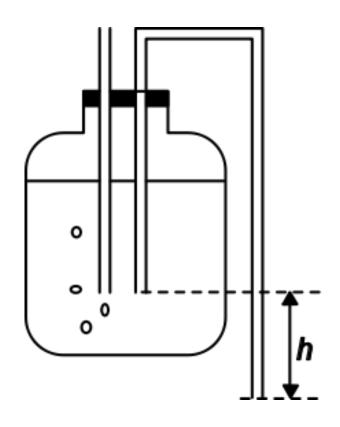
Infiltration <u>unsaturated</u>

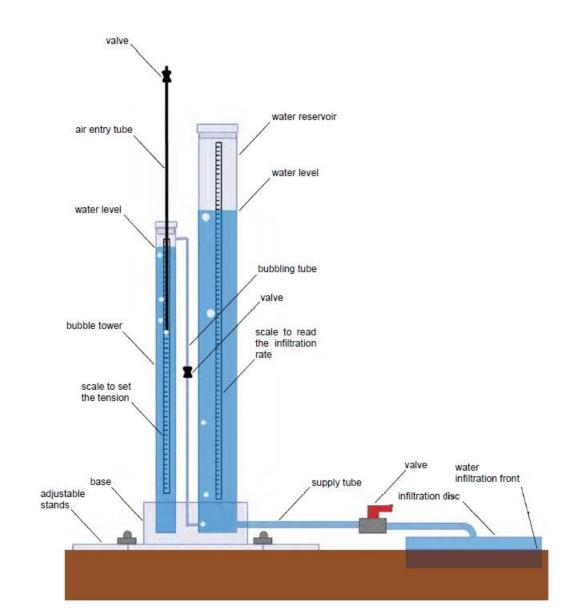




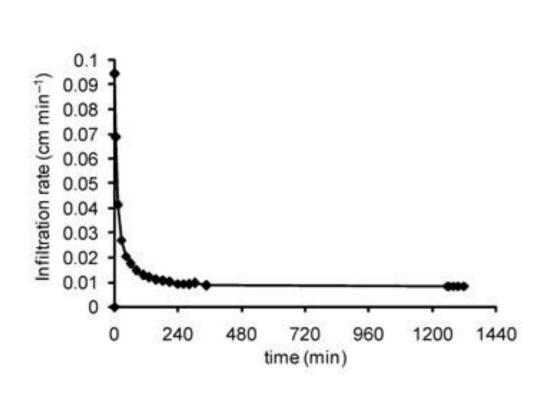


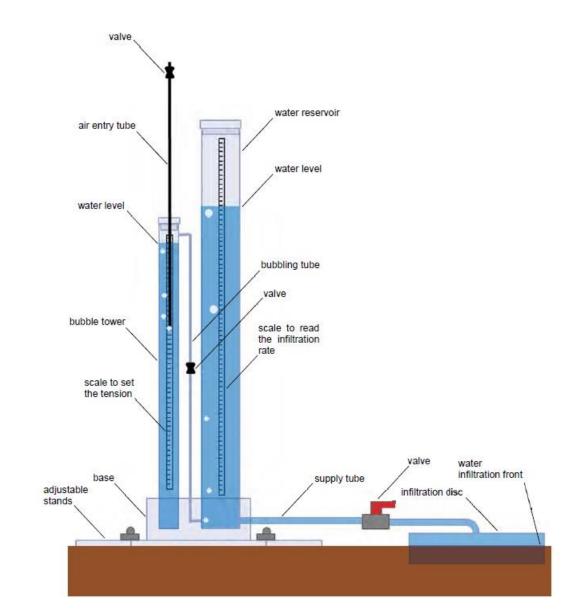
Infiltration <u>unsaturated</u>





Infiltration <u>unsaturated</u>









Indirect water quantity

Indirect - electric signal (EM wave) / neutrons

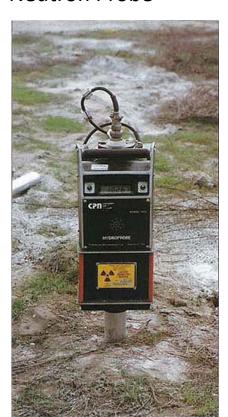
TDR



FDR

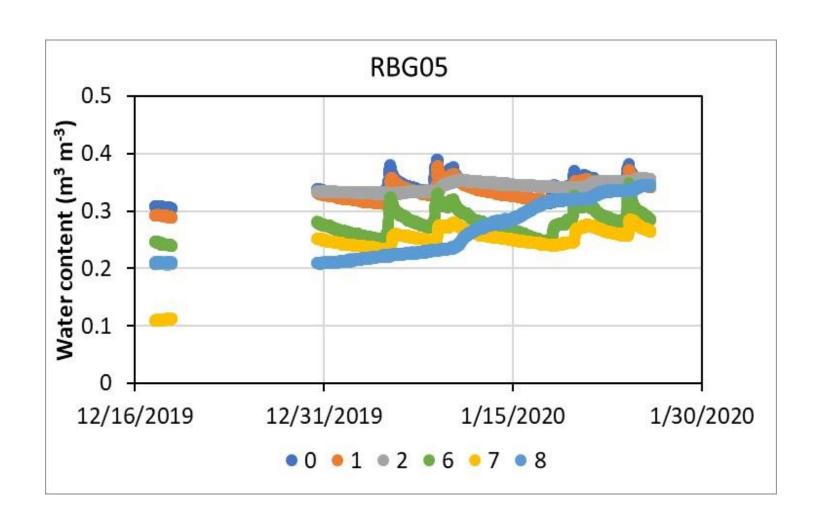


Neutron Probe









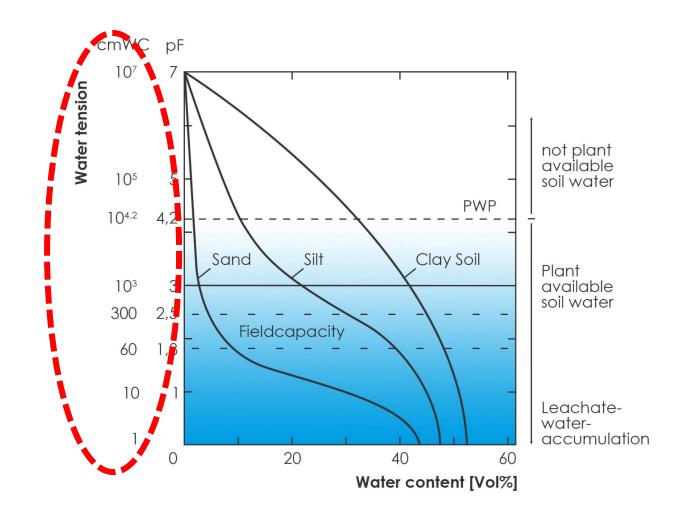
... but how to link between soil moisture and availability and movement..?



icarda.org

Soil moisture & matric potential

Matric potential



Soil water potential

Matric potential

Tensiometer



Up to 1 bar (practically appr. 0.7 bar)

Soil water potential

Matric potential

Gypsum block



Indirect measurement!

Ceramic block

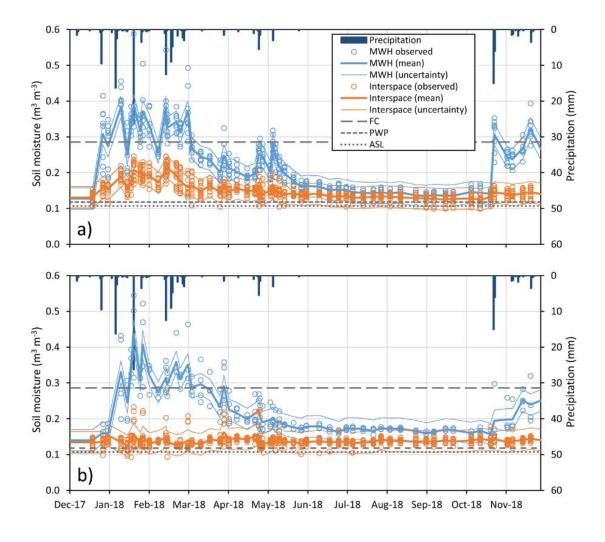


If we only have soil moisture?





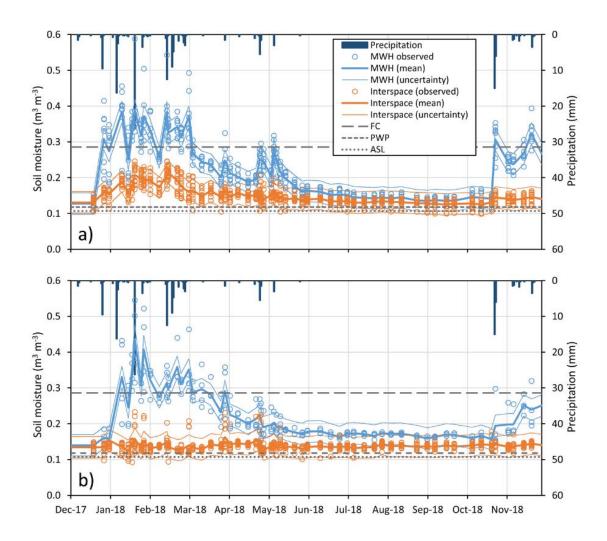
Soil moisture only? Modeling!



$$\theta_{(\psi)} = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + (\alpha|\psi|)^n\right]^{1 - 1/n}}$$

θ_r	θς	α	n	K _s
L ³ L ⁻³	L ³ L ⁻³	cm ⁻¹	-	cm day ⁻¹
0.0865	0.452	0.0089	1.4962	10.53

Soil moisture only? Modeling!



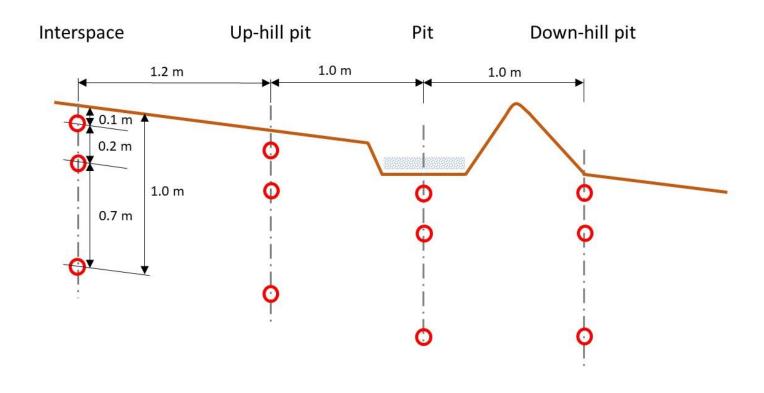
$$\theta_{(\psi)} = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + (\alpha|\psi|)^n\right]^{1 - 1/n}}$$

θ,	θς	α	n	K _s
L ³ L ⁻³	L ³ L ⁻³	cm ⁻¹	-	cm day ⁻¹
0.0865	0.452	0.0089	1.4962	10.53

... but you need to know soil (physical) properties and processes...

Designing soil moisture monitoring...





Afternoon: assessment of surface runoff...

TIME	TOPIC	TRAINER
10:00 – 10:15	Welcome and Introduction	Stefan Strohmeier & Mira Haddad
10:15 – 11:00	Surface and soil water dynamics in drylands	Stefan
11:00 – 11:15	Coffee break	
11:15 – 12:00	In-situ WH soil water dynamics monitoring and data interpretation	Stefan
12:00 – 12:15	Discussion; Q&A	Stefan (& group)
12:15 – 13:00	Lunch break	
13:00 – 13:45	Surface runoff processes modeling (practical part I)	Mira (& group)
13:45 – 14:00	Coffee break	
14:00 – 14:45	Surface runoff processes modeling (practical part II)	Mira (& group)
14:45 – 15:00	Discussion; Q&A	Mira & Stefan (& group)