# Infiltration

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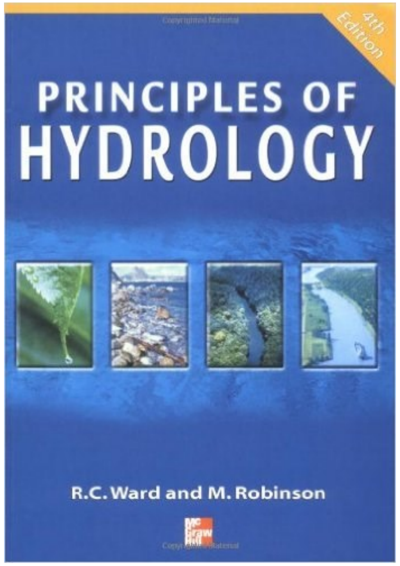
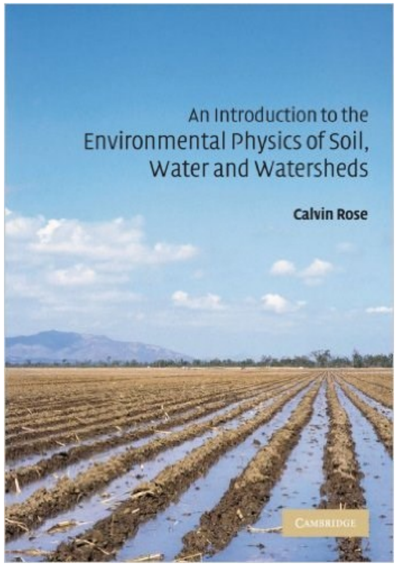
Soil, Water & Atmospheric Processes




Ward & Robinson –
Soil Water chapter




Rose –
Chapter 6

# Rate of soil water flow

## Saturated conditions: Darcy's Law

"The public fountains of the town of Dijon" (1856)

Henry Darcy

http://www.lifeinthefastlane.ca/wp-content/uploads/2008/12/water_fountain_44sfw.jpg

http://biosystems.okstate.edu/Darcy/Darcy.jpg

# Saturated conditions: Darcy's Law

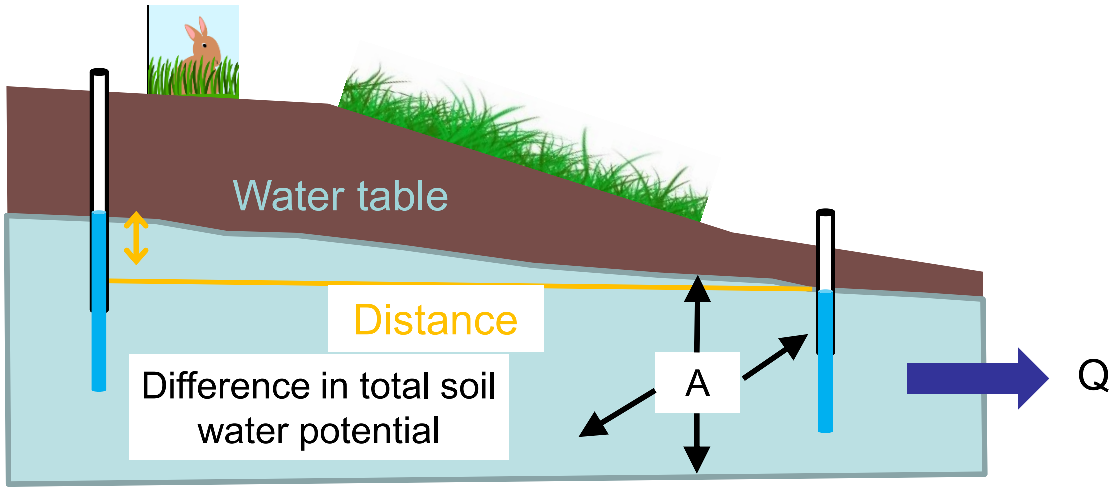
## Q = K x I x A

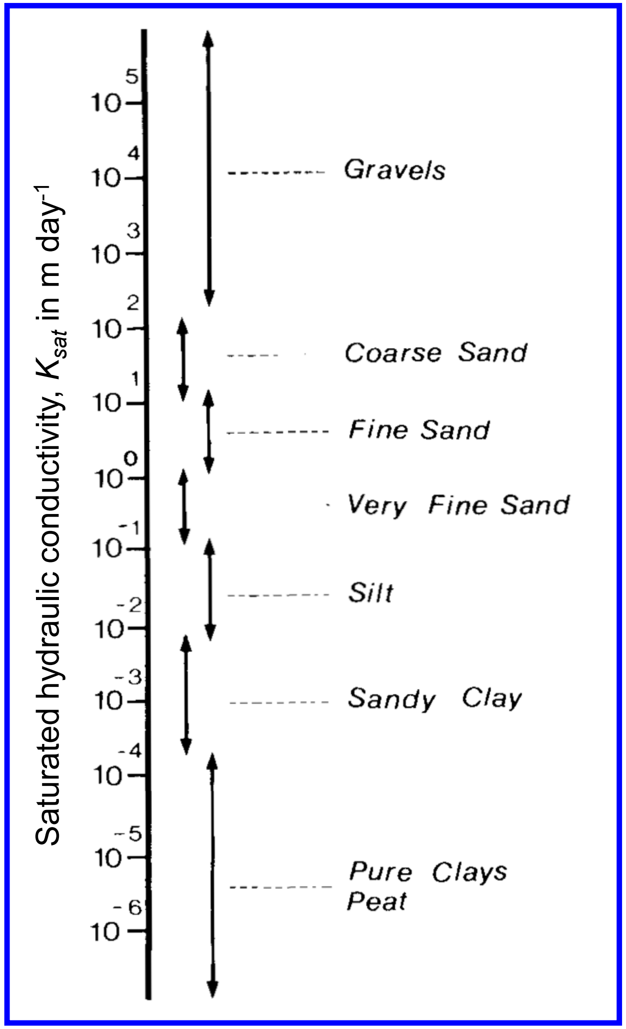
Q = rate of soil water movement ($m^3\ day^{-1}$)

A = cross-sectional area through which flow occurs ($m^2$)

I = hydraulic gradient (gradient of total soil water potential energy) ($m\ m^{-1}$)

K = hydraulic conductivity – rate of water movement through saturated soil ($m\ day^{-1}$)




(Newson, 1994)

# Soil water movement in unsaturated soils

- More complex - value of K varies depending on soil water content, soil matric forces, soil texture
- Richards' equation
  - Non-linear: needs to be solved iteratively
  - Mixed form

$$\frac{\delta\theta}{\delta t}=\frac{\delta}{\delta z}\left[K(\theta)\left(\frac{\delta\varphi}{\delta z}\right)-1\right]$$

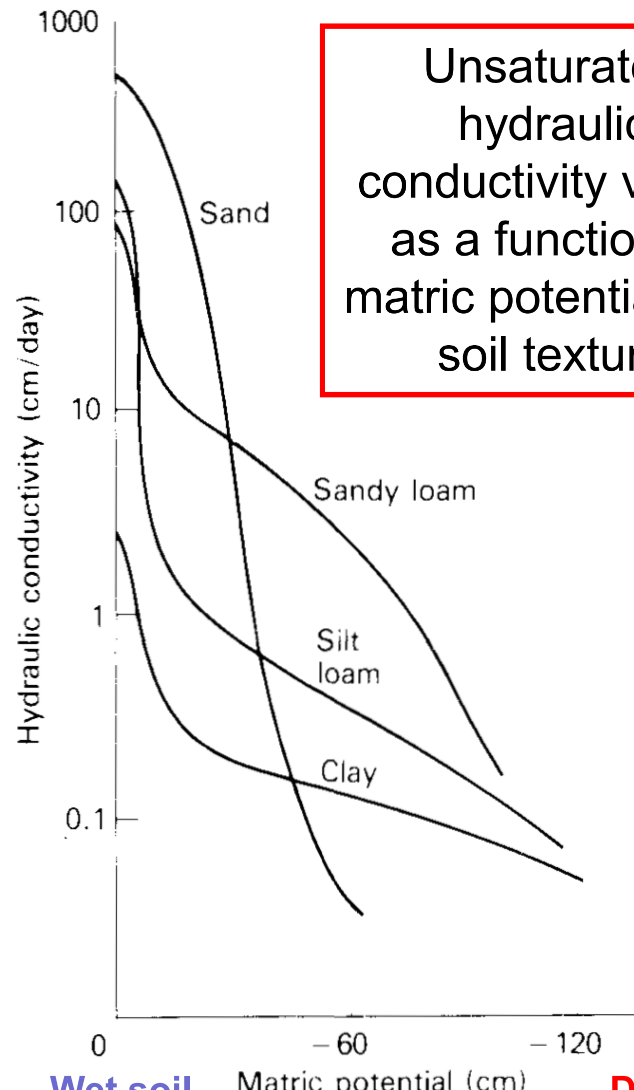
θ= soil water content

z = vertical direction

Ψ = soil water potential

K = hydraulic conductivity

t= time




Wet soil

Dry soil

Unsaturated hydraulic conductivity varies as a function of matric potential and soil texture

(Ward & Robinson, 1999)

# Infiltration

- Infiltration = process of water entry through soil surface
- Depth of water moving into soil over time
- Usual units: mm $hour^{-1}$
- Pivotal process in catchment hydrological system: partitions precipitation that reaches ground surface

# Infiltration rates vary between soil types

| *Soil texture* | *Soil type* | *Infiltration rate (mm hour$^{-1}$)* |
|---|---|---|
| Sands and gravels | Deep. Well-drained | 7.9-9.6 |
| Sandy loams to sandy clay loams | Well-drained brown forest soils | 5.8-7.8 |
| | Acid brown earths | 4.1-5.7 |
| Clay loams to silty clay loams | Gleyed brown forest soils. Podzolic soils | 2.8-4.0 |
| | Gley soils | 1.5-2.7 |
| Clay soils | Saturated peats | 0.8-1.4 |
| Impervious materials | Shallow podzols. Skeletal soils | 0-0.7 |

Soils in England and Wales

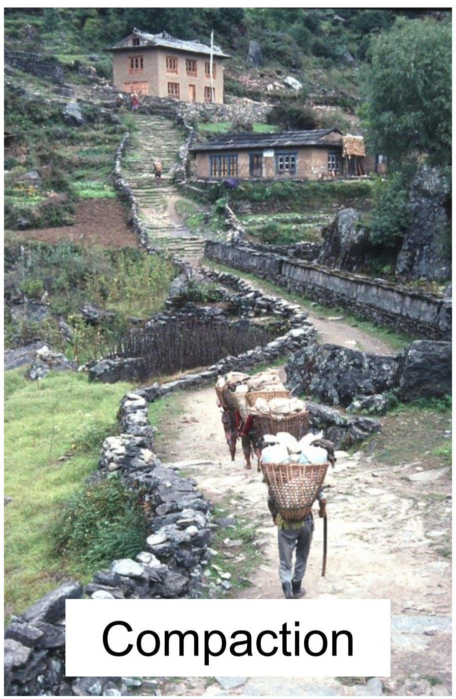
(Rodda et al., 1976)

# Factors affecting infiltration rate: soil surface conditions

Macropores

- Inwashing of fine particles
- Precipitation characteristics

Standing water



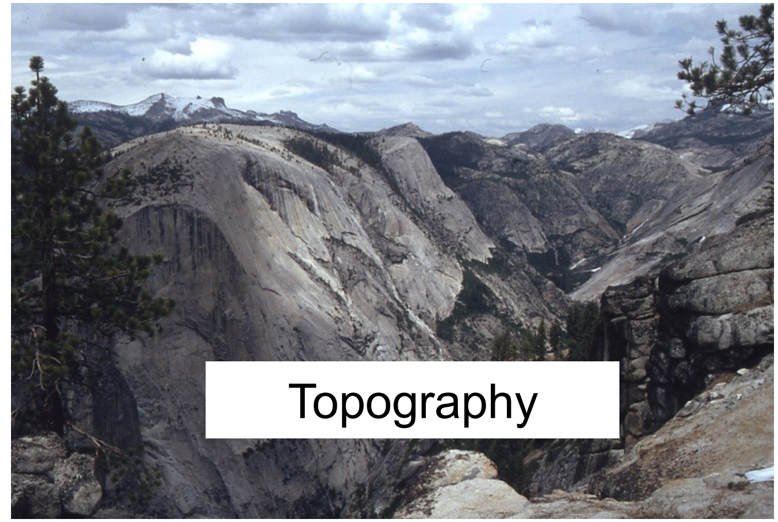
Compaction

Vegetation cover

Frost/frozen ground

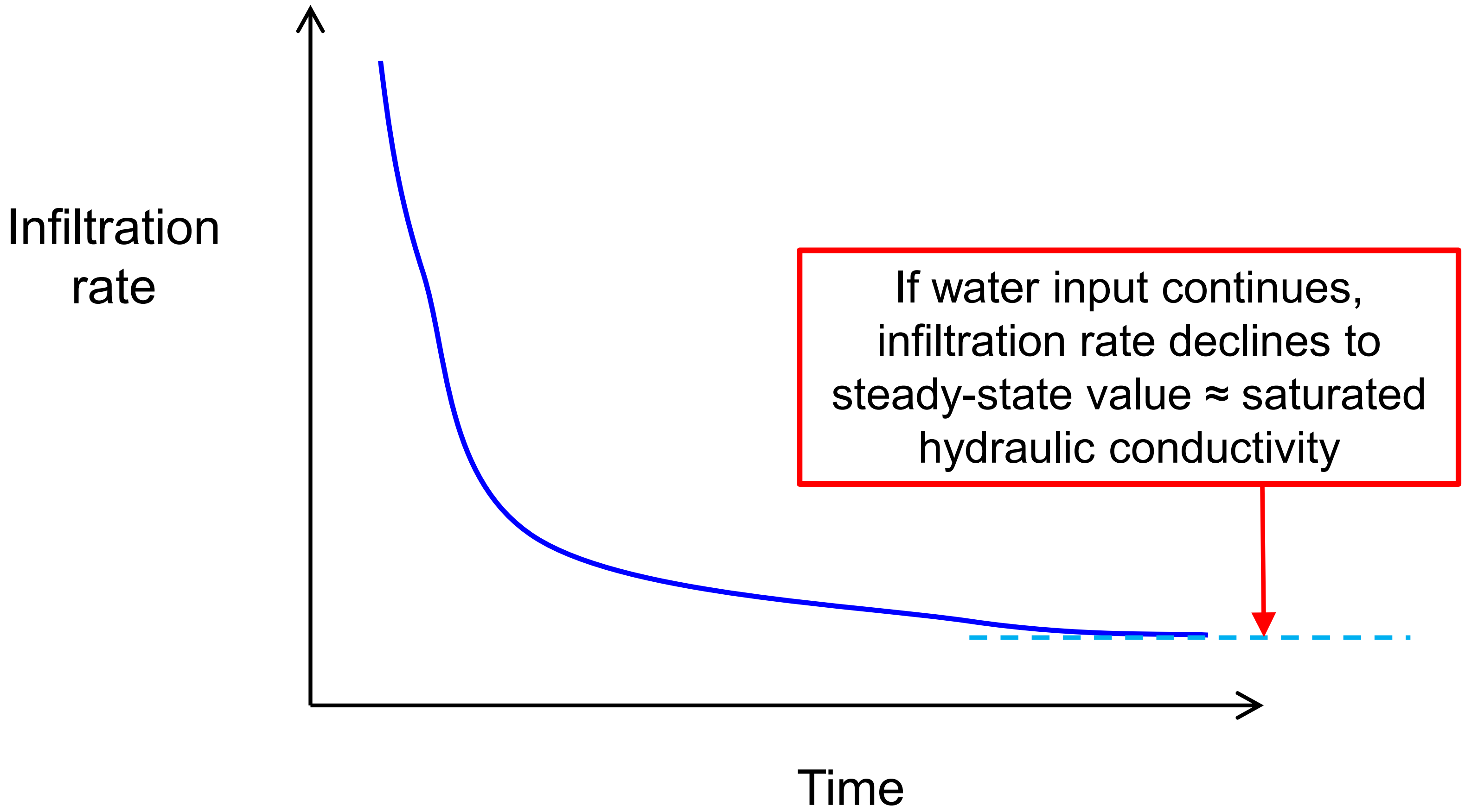
# Factors affecting infiltration rate: processes within the soil profile

- Antecedent moisture content

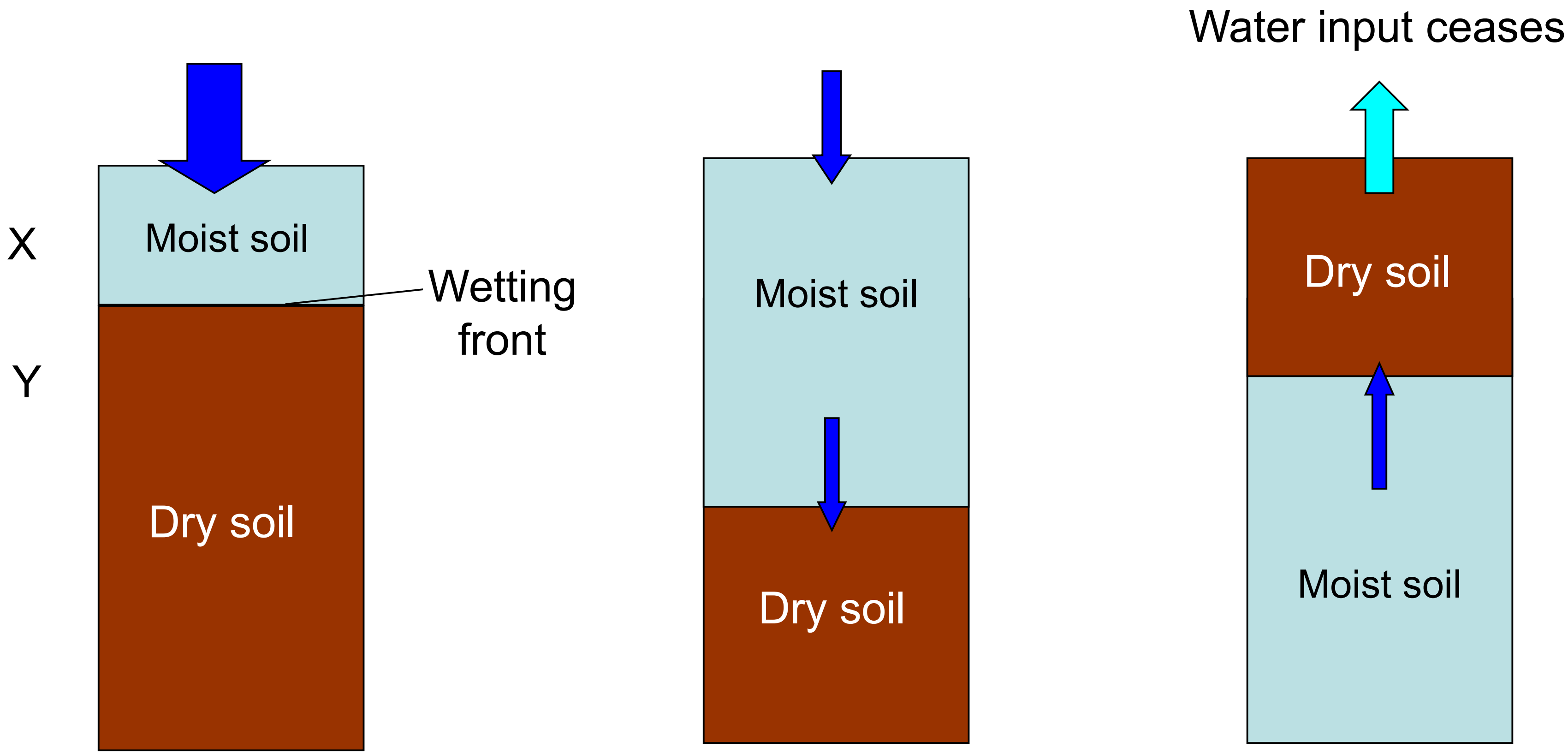





# Change in filtration rate over time



# Why do infiltration rates change over time?




Gravitational potential: X>Y

Matric potential: Y>X

**High initial infiltration rate**

Matric potential gradient decreases

Water movement at gravity-controlled infiltration rate

**Infiltration rate declines**

Gradual decline in infiltration rates until field capacity reached

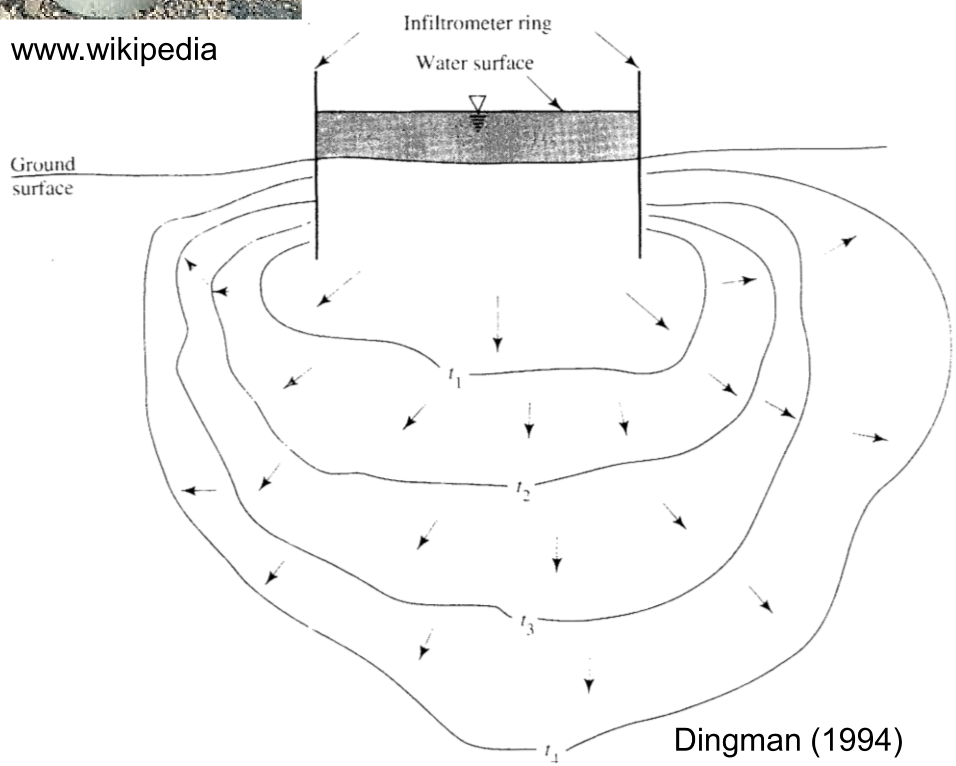
Water lost by evapotranspiration

Soil begins to dry out

# Measurement of infiltration: infiltrometers

www.wikipedia

Single-ring infiltrometer




Dingman (1994)

Problem with lateral movement of water into soil => overestimate infiltration rate

Double-ring infiltrometer

www.turf-tec.com/IN7-Eng.jpg

# Infiltrometer: example calculation

- Single-ring infiltrometer, diameter = 13 cm
- 10 ml water added in 15 minutes
- What is infiltration rate in mm hour$^{-1}$?

$$\textit{Infiltration rate} = \frac{\textit{Vol water added per hour } (cm^3)}{\textit{surface area } (cm^2)}$$

$$= \frac{(10 \times 4)}{\left(\frac{13}{2}\right)^2 \times \pi} = \frac{40}{132.7}$$

= 0.301 cm hour$^{-1}$ = 3.01 mm hour$^{-1}$

BUT multiply by 0.6 correction factor

=> Infiltration rate = 1.8 mm hour$^{-1}$

# Infiltration rate, slope position and land use in the Bale Mountains, Ethiopia

http://upload.wikimedia.org/wikipedia/commons/8/85/Bale_mountains.jpg

Yimer et al. (2008) *Soil Use and Management*

*Infiltration rate* Mean ± SE (cm min$^{-1}$)

| Time (min) | | | |
|---|---|---|---|
| | Slope positions | | |
| | Lower | Middle | Upper |
| 01 | 1.79 ± 1.09 *a* | 1.01 ± 0.43 *a* | 1.15 ± 0.51*a* |
| 60 | 0.28 ± 0.16 *a* | 0.23 ± 0.05 *a* | 0.28 ± 0.14 *a* |
| | Land use types | | |
| | Cultivation | Grazing | Forest |
| 01 | 0.67 ± 0.02 *b* | 0.61 ± 0.09 *b* | 2.67 ± 0.66 *a* |
| 60 | 0.14 ± 0.03 *b* | 0.16 ± 0.01 *b* | 0.50 ± 0.08 *a* |
| *Cumulative infiltration* | | | |
| | Cultivation | Grazing | Forest |
| 60 | 14.63 ± 1.99 *b* | 12.98 ± 0.91 *b* | 45.72 ± 6.31 *a* |

No significant effect of slope position

Significant effect of land use

# Measurement of infiltration: disc permeameter

- Another disadvantage of infiltrometer is only measures flow under ponded conditions – so often unrepresentative of field situations with rainfall
- Disc permeameter/tension infiltrometer developed to overcome this
  - Creates negative air pressure above ponded water

Example – Using disc permeameters to determine effects of forest cover on field saturated hydraulic conductivity ($K_{fs}$)

Significantly higher infiltration under broadleaf mature forests suggests capacity for infiltrating rainfall during rainfall events

www.bgs.ac.uk

| Site | Median $K_{fs}$ (mm hour$^{-1}$) |
| --- | --- |
| 500 year broadleaf woodland | 174 |
| Adjacent grassland | 39 |
| 180 year broadleaf woodland | 119 |
| Adjacent grassland | 21 |
| 45 year conifer plantation | 42 |
| Adjacent grassland | 35 |
| Floodplain woodland | 8 |
| Adjacent grassland | 1 |

Archer et al. 2013, *Journal of Hydrology*