Soil moisture mapping using ground-penetrating radar as a pillar to sustainable and optimal environmental and agricultural management

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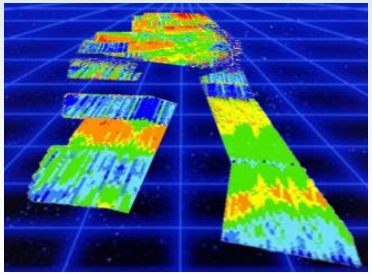

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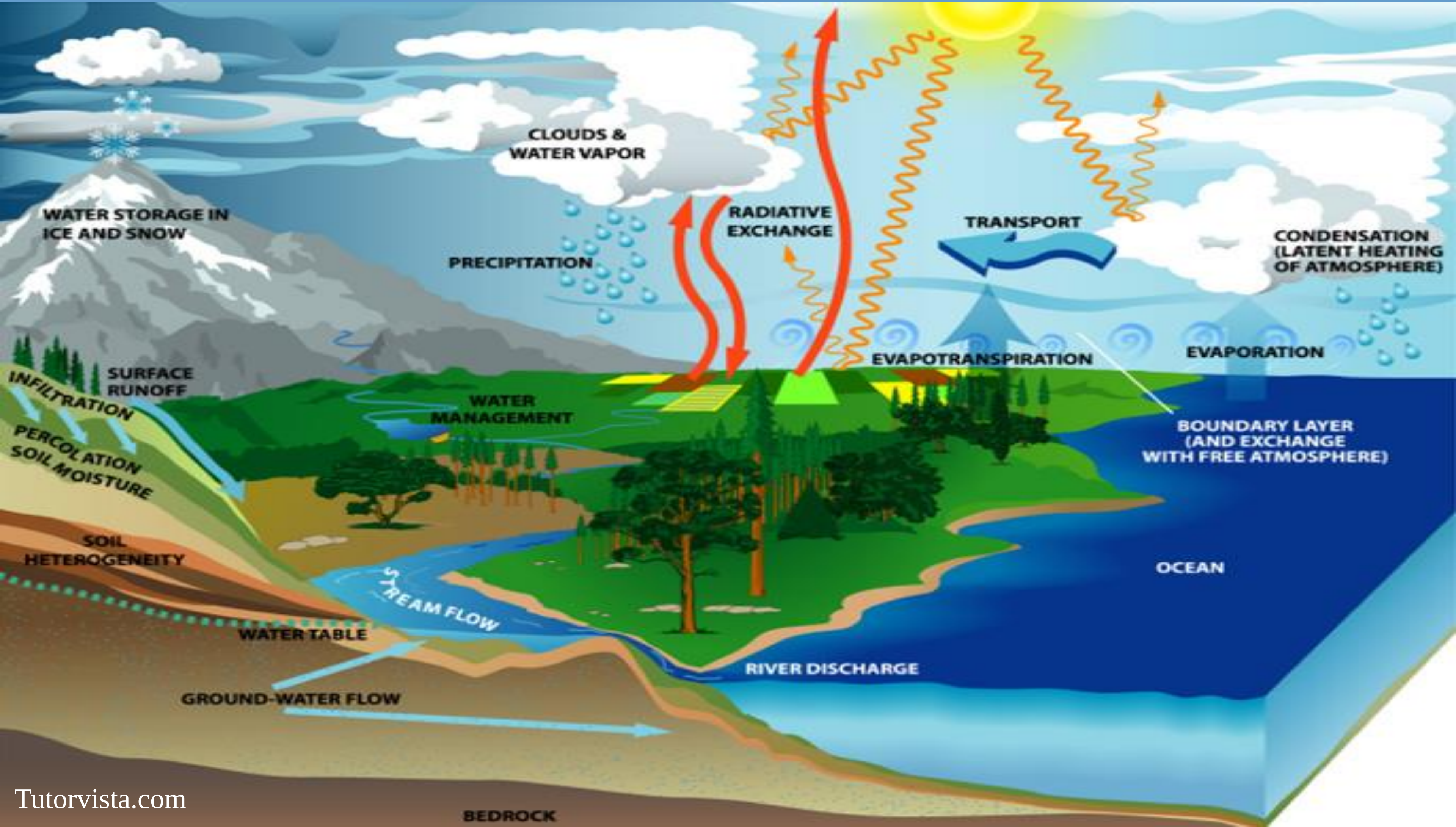
Introduction

Soil moisture governs: infiltration and runoff, evaporation, energy exchanges with atmosphere, plant growth (food & energy), contamination



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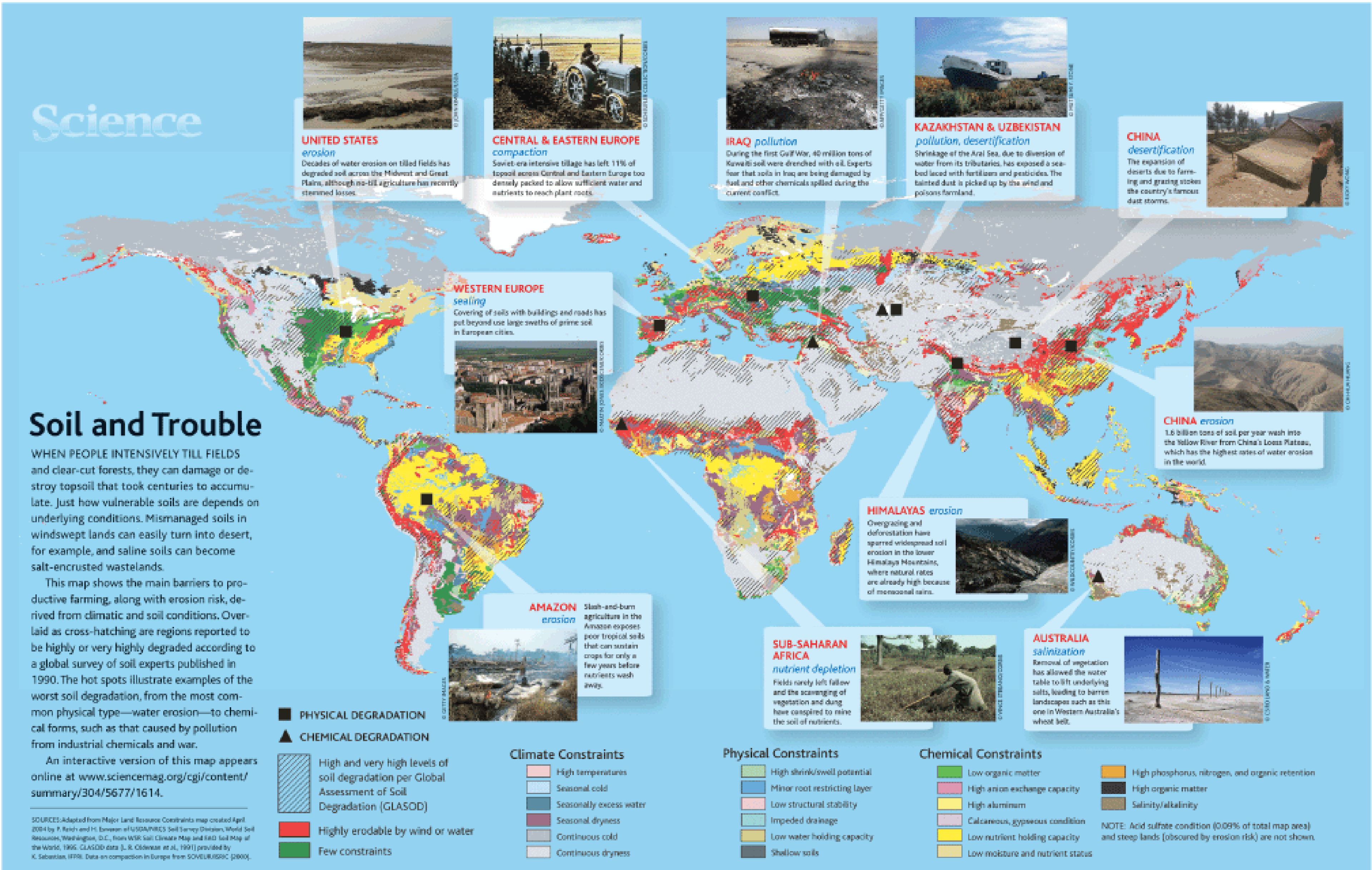
Human activities, but also natural processes, lead to soil degradation worldwide:

erosion, compaction, pollution, desertification, sealing, salinization, nutrient depletion



➡ from observations to sustainable and optimal soil and water management

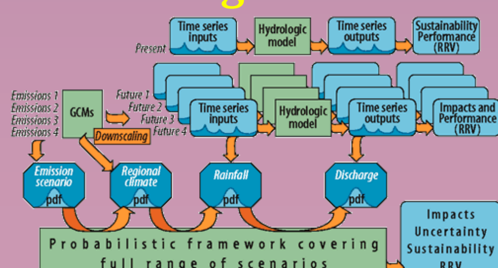
Observation: characterizing and monitoring the environment

Innaccessibility
Variability

Process understanding and modeling

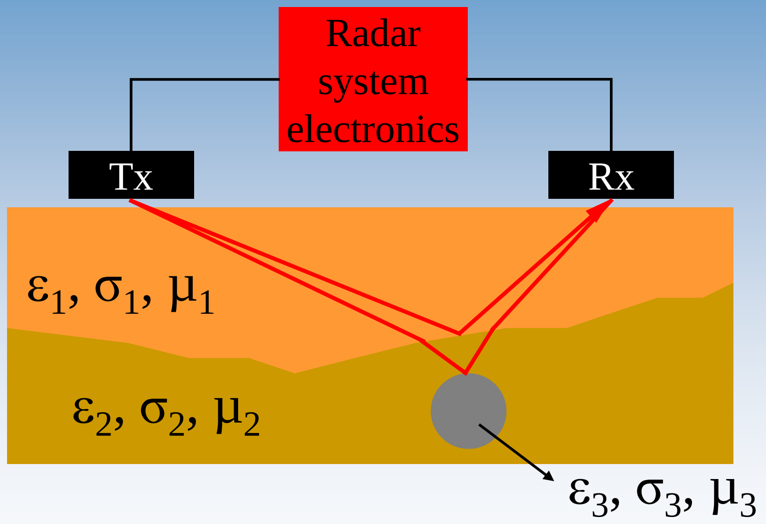
Illustration of the results of the WetSpa model of VUB (Belgium), partial runoff model results of the Tisza Basin and scenario analysis of a sub catchment (Zagyva basin, H)

Management strategies and decision support



Bridging the scale gaps between observations, modeling, and management

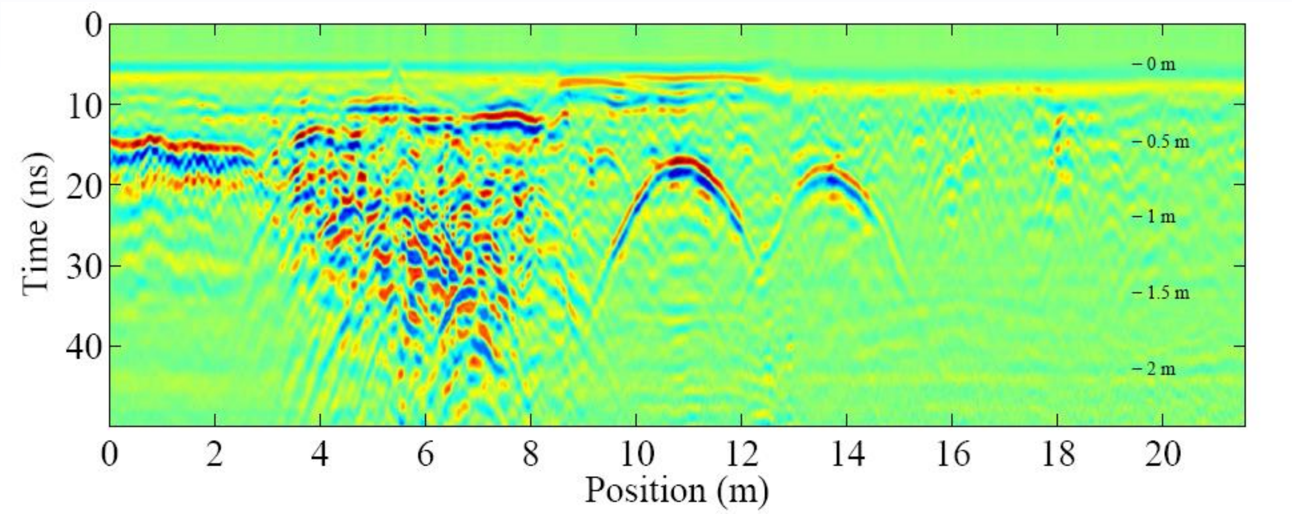
Ground-penetrating radar (GPR)



- Dielectric permittivity ε ➡ wave velocity
- Electric conductivity σ ➡ wave attenuation
- Magnetic permeability μ

Electromagnetic contrasts

➡ Reflection, transmission



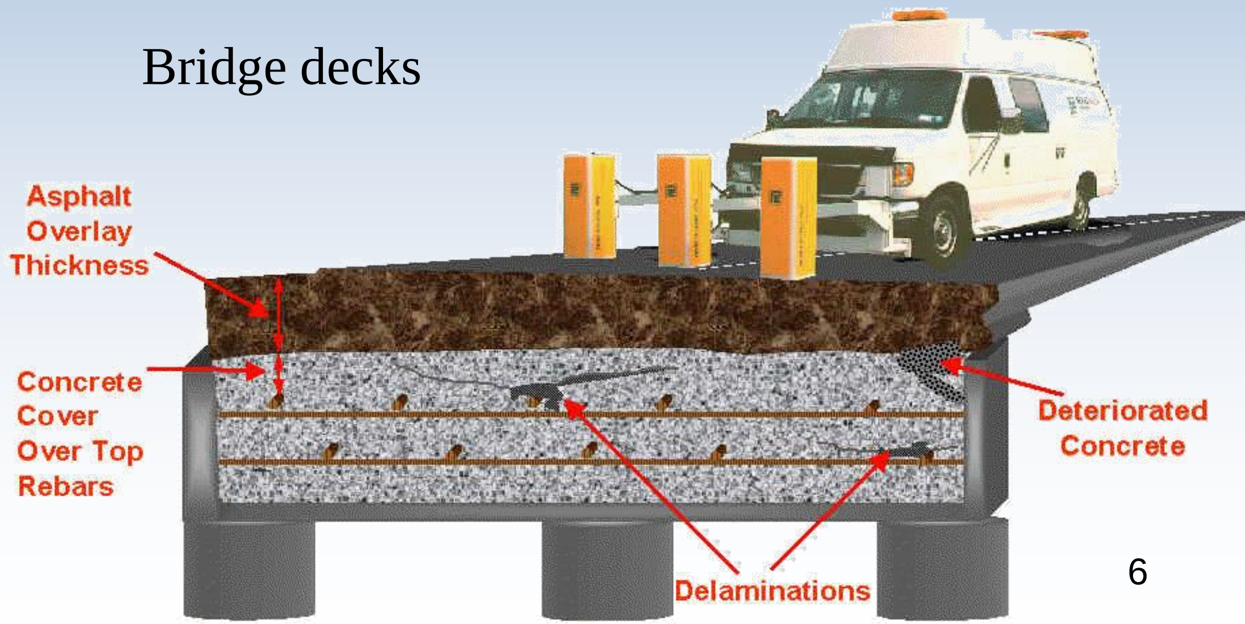
Management of city infrastructures: project control, monitoring and maintenance

Roads, underground pipes and cables

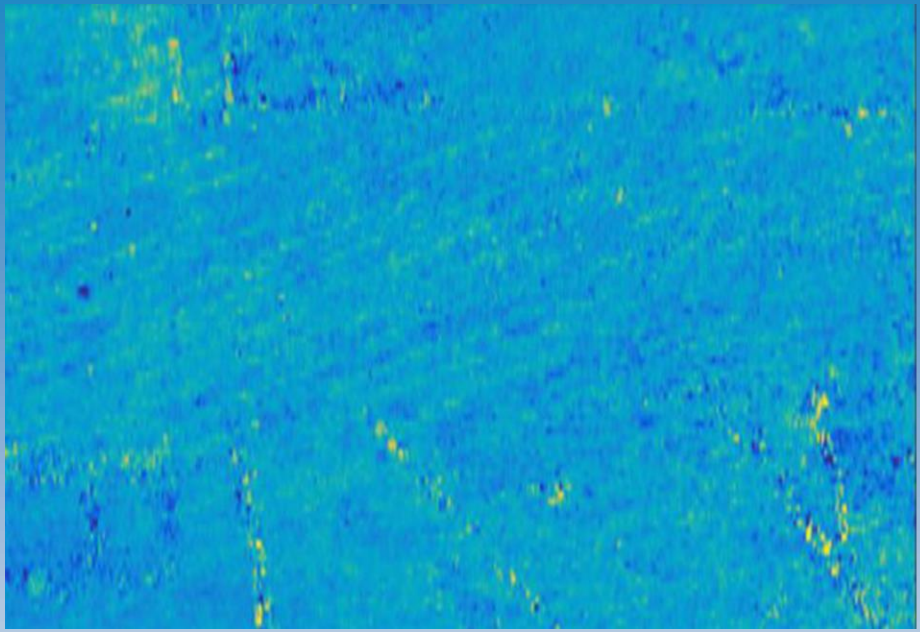
Buried tanks

Tunnels

Bridge decks



Archeology



Geology

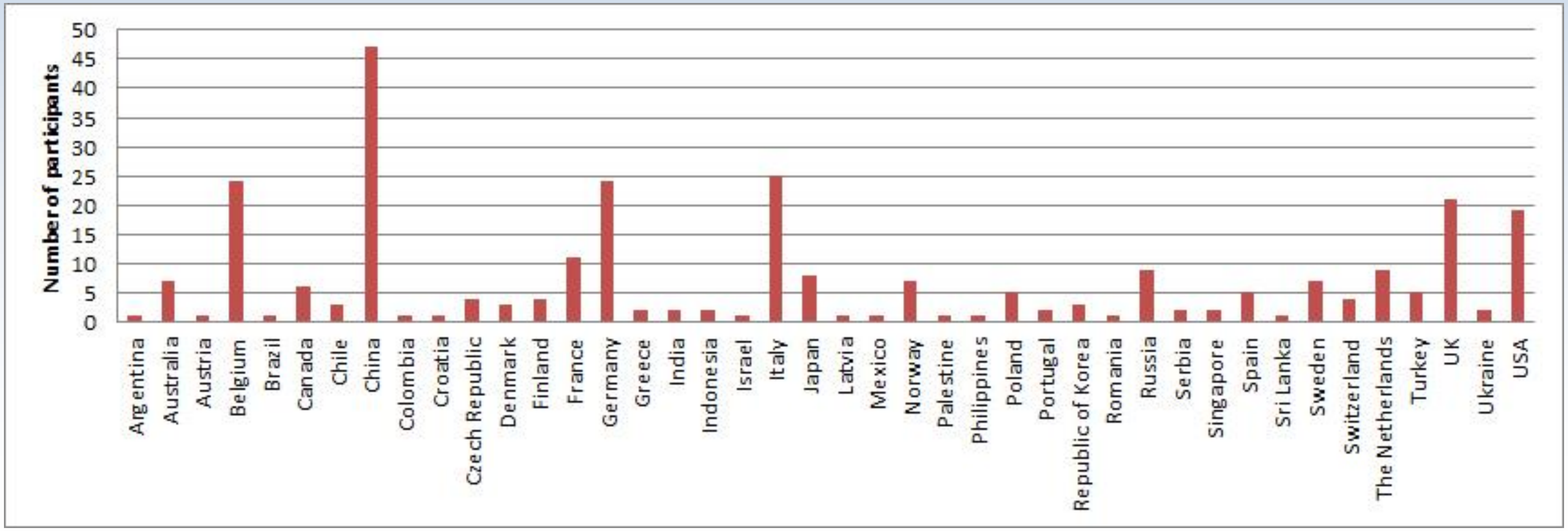
Security and natural disasters

Forensics

Evolution of GPR research in the world

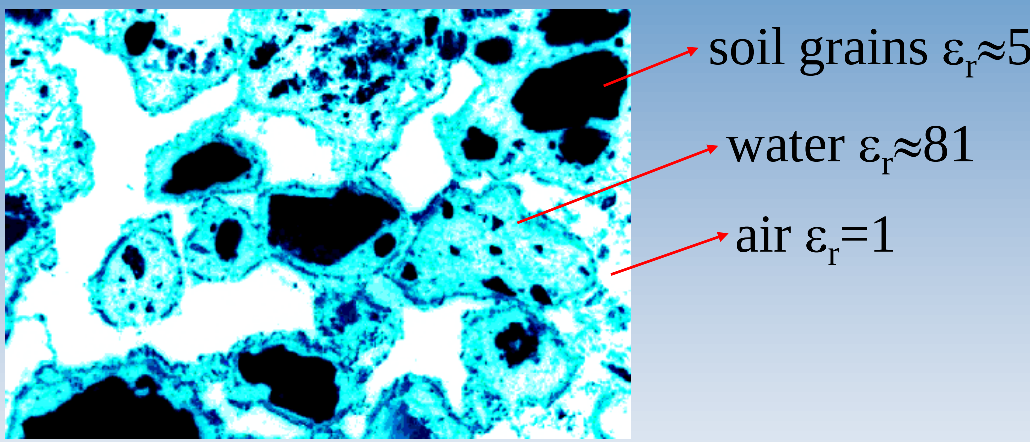
Applications follow…

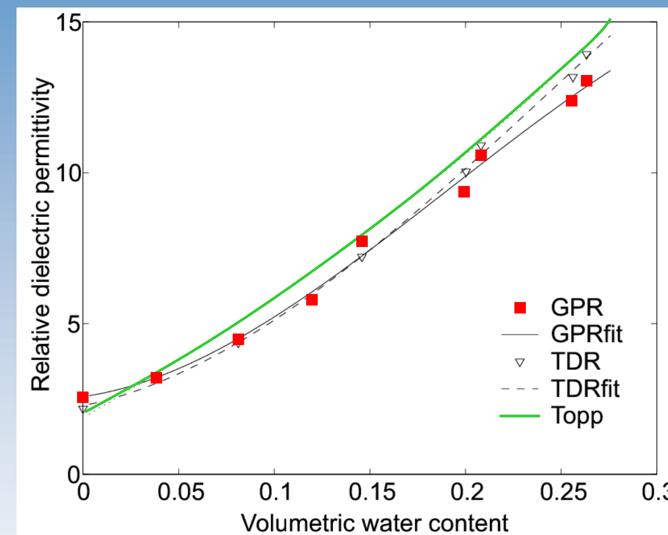
GPR 2014



Soil water content determination

Relationship between soil water content and dielectric permittivity





Empirical Topp's equation:

$$\theta = -5.3\times10^{-2} + 2.92\times10^{-2}\varepsilon_r - 5.5\times10^{-4}\varepsilon_r^2 + 4.3\times10^{-6}\varepsilon_r^3$$

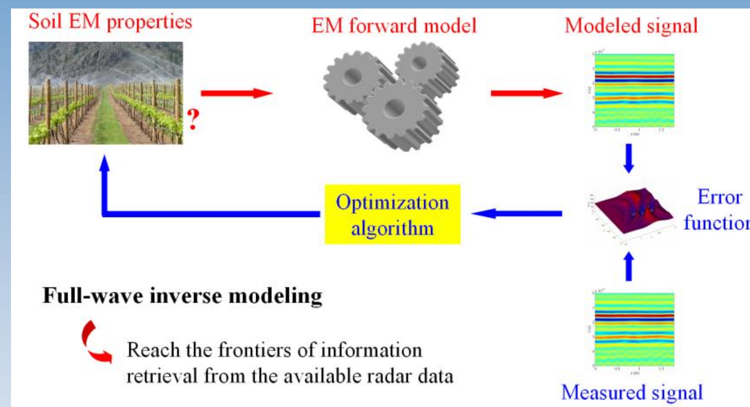
Dielectric mixing models (e.g., Complex Refractive Mixing Model CRIM):

$$\theta = \frac{\varepsilon_b^\alpha - (1-n)\varepsilon_s^\alpha - n\varepsilon_a^\alpha}{\varepsilon_w^\alpha - \varepsilon_a^\alpha}$$

GPR for determining the electrical properties of materials

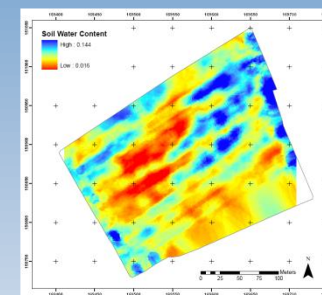
➡ Resorting to full-wave forward and inverse modeling of the GPR data is necessary to maximize information retrieval capabilities

System design



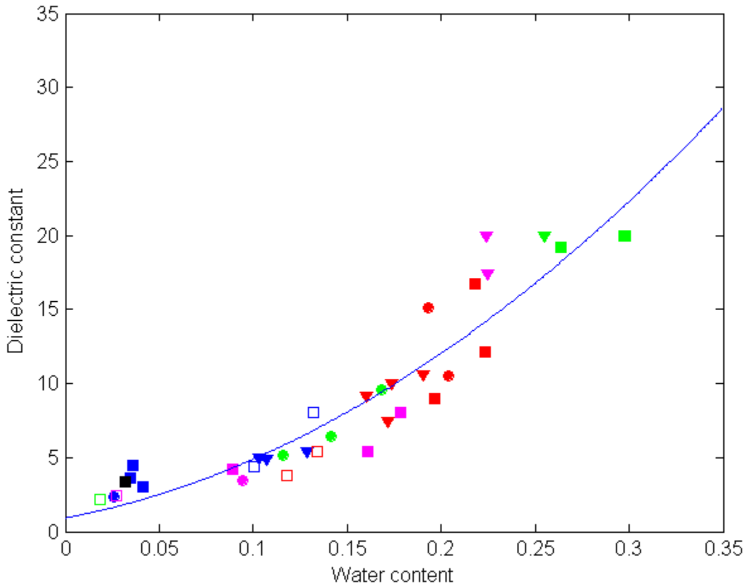
Signal inversion

Product

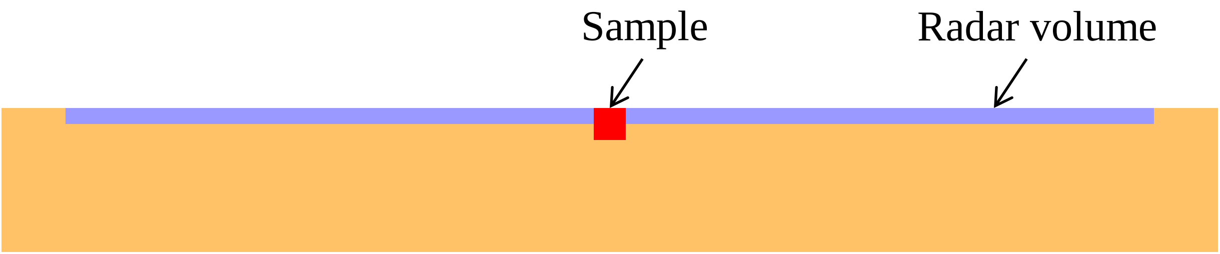


Examples of application (Lambot et al., NSG, 2008)

Irrigation areas in Tunisia

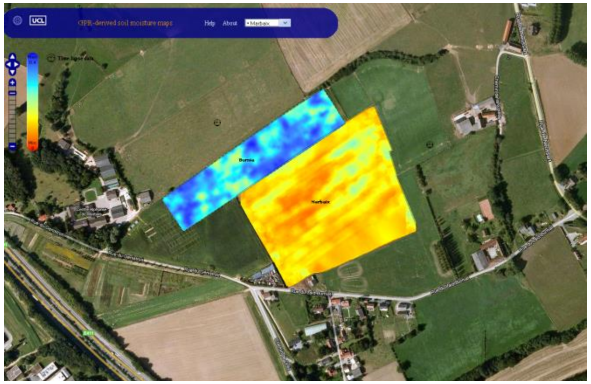


Different characterization scales and inherent variability

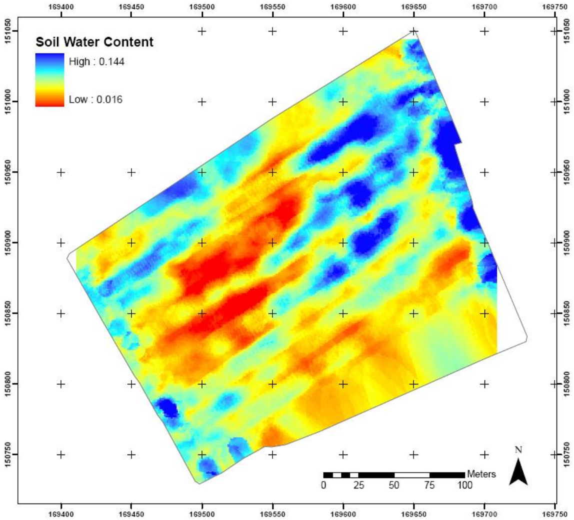


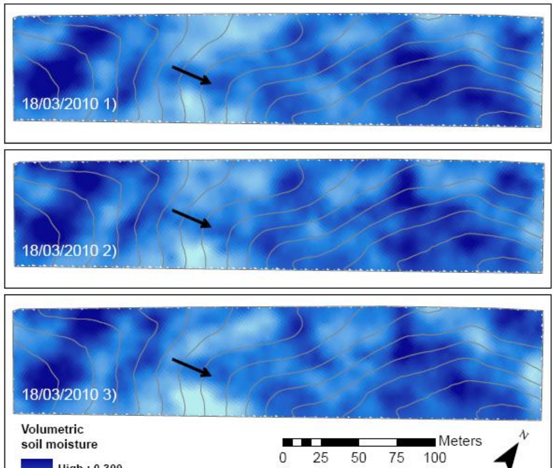
High-resolution, real-time mapping of soil moisture

Handheld system	Automated platforms



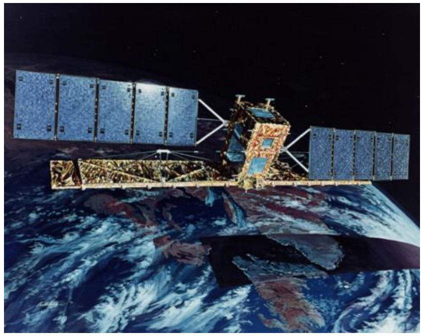
(e.g., EU-FP7 DIGISOIL, BELSPO SENSAR projects)





(Minet *et al.*, 2011)

Radarsat

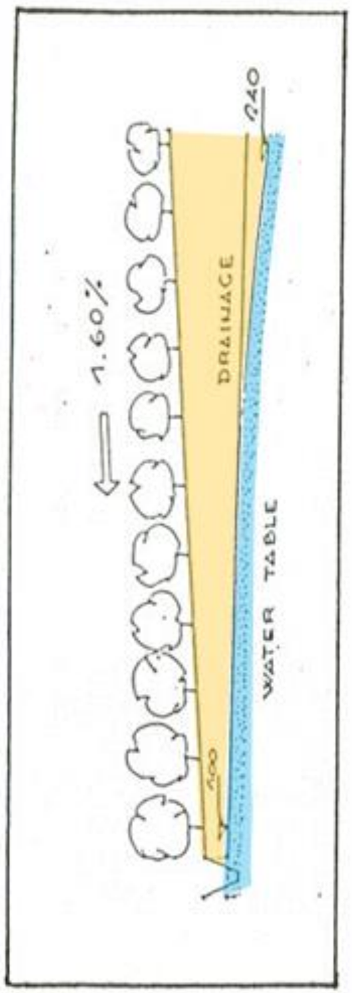


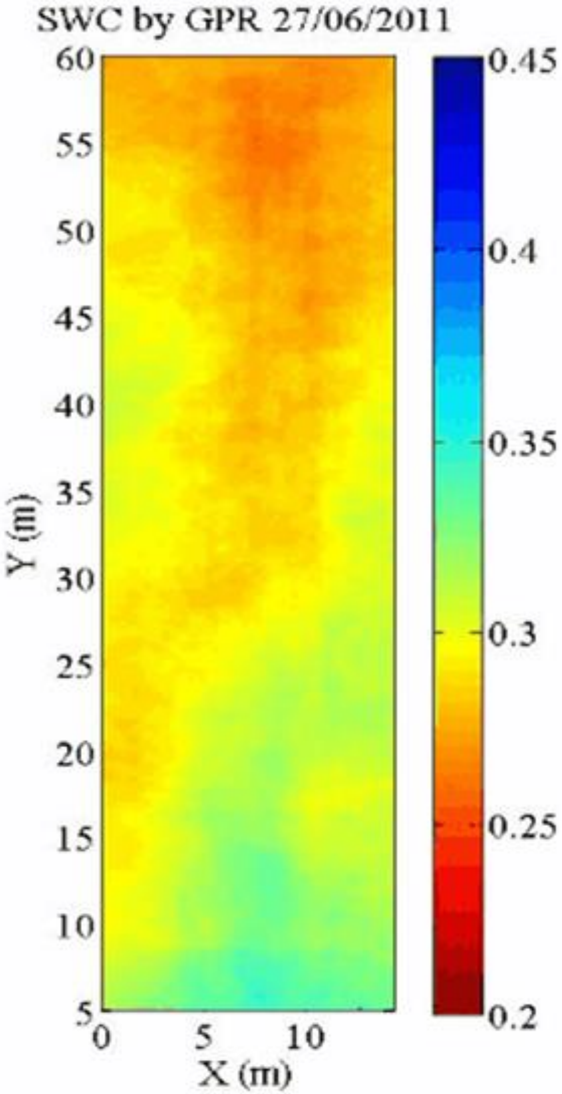
Catchment scale

➡ Towards digital soil mapping – improving remote sensing data products

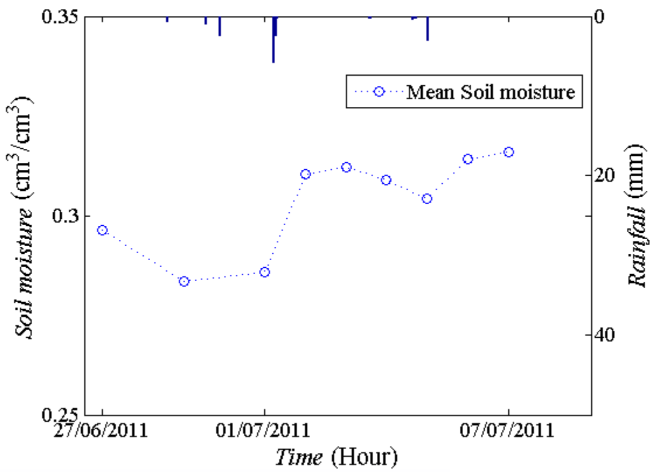
Field-scale applications

Test site in Bologna (Italy)



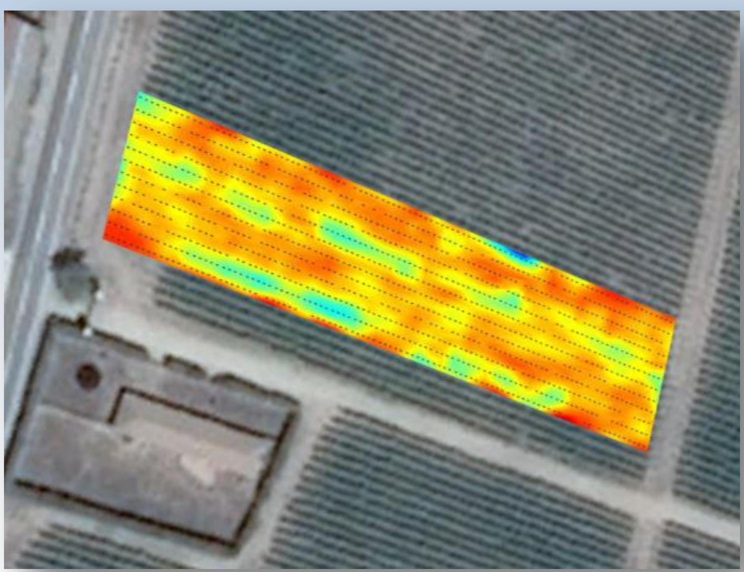


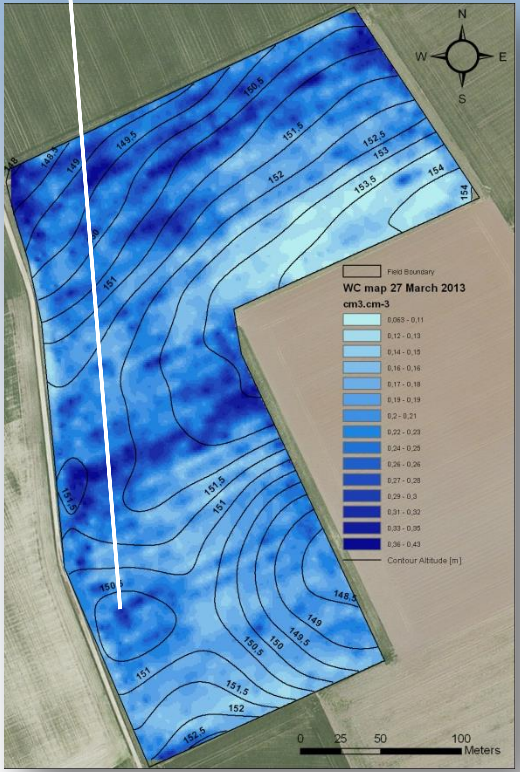
400 MHz GSSI antenna



Time-lapse monitoring

Root-zone soil moisture characterization





Conclusions

• *New GPR full-wave inverse modeling techniques have been developed for non-invasive soil characterization*

• *High-resolution soil moisture maps can be obtained at the field scale*

→ *Shallow characterization for improving remote sensing*

→ *Root-zone characterization for precision agriculture*

Precision agriculture perspectives

Integrating the technology in a digital soil mapping applied context

(e.g., improve irrigation efficiency)

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