NATIONAL AGRICULTURAL RESEARCH FOUNDATION
INSTITUTE OF SOIL MAPPING AND CLASSIFICATION

WATER RETENTION CAPACITY OF AGRICULTURAL SOILS IN PINIOS RIVER BASIN CENTRAL GREECE

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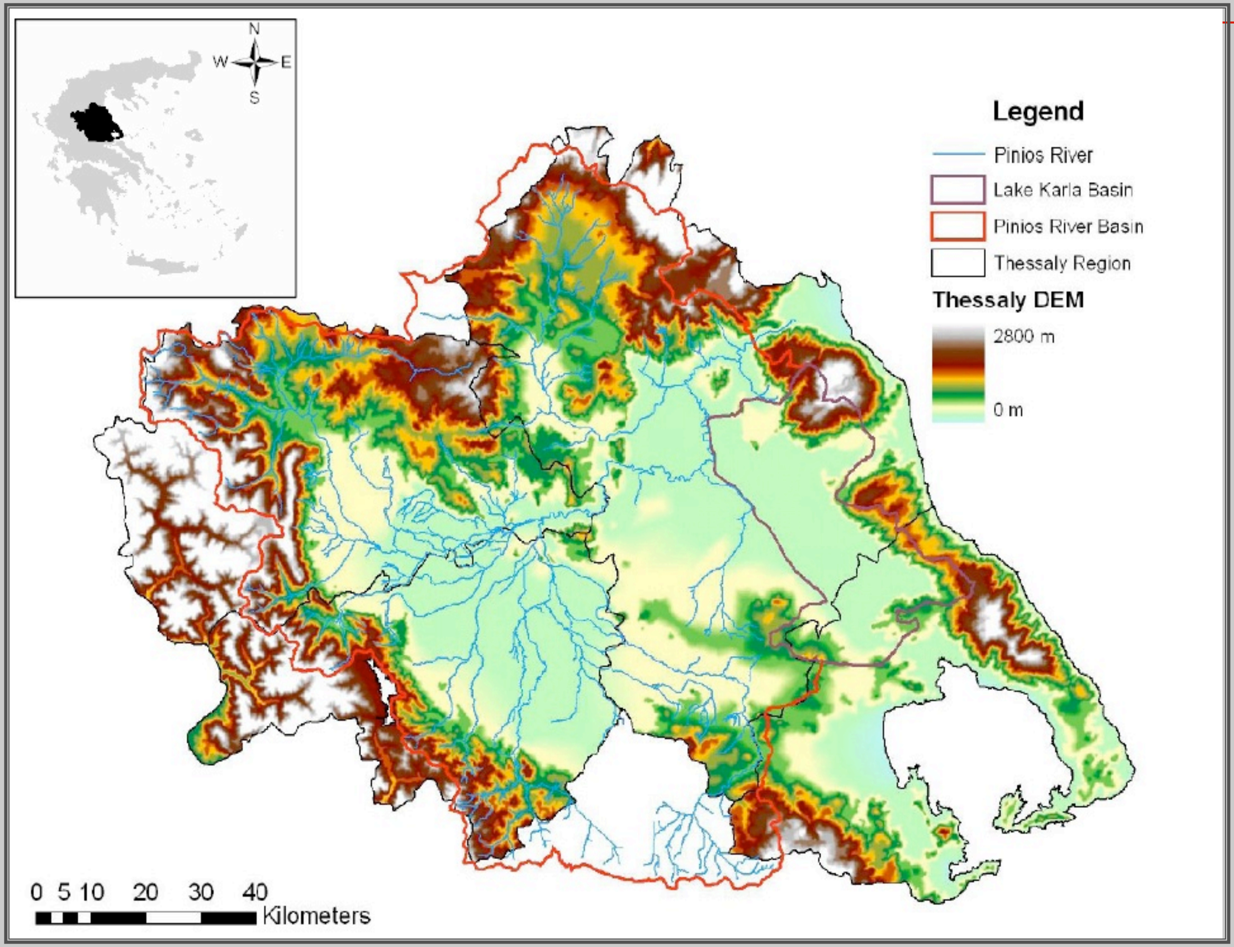
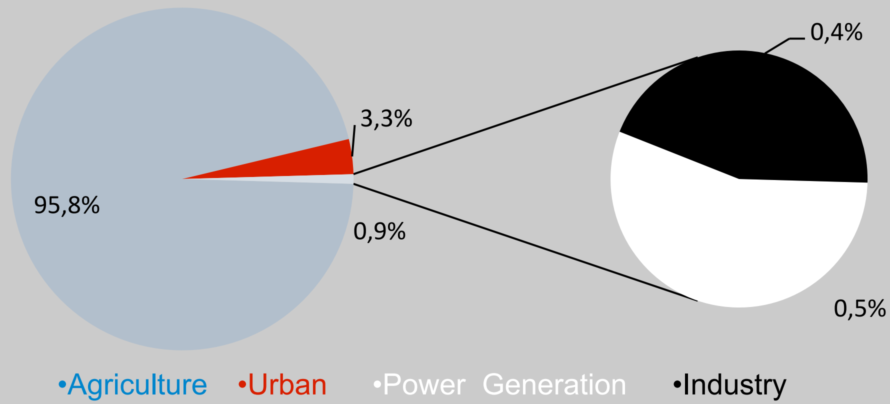
Hellenic Agricultural Organization – DEMETER - Institute of Soil Mapping and Classification

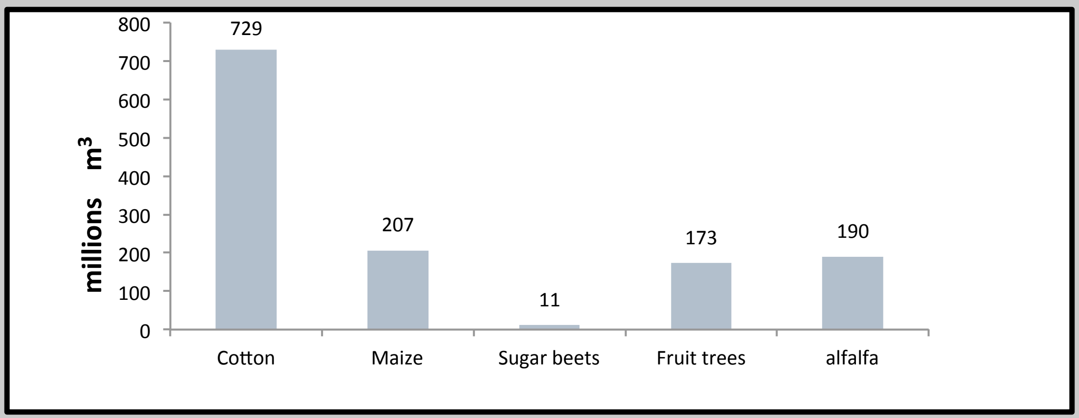
PINIOS RIVER BASIN



- Total area 1.050.000 ha
- 400.000 ha cultivated land
- Most important agricultural area in Greece
- 200.000 ha irrigated land
- Dry summers

WATER DEMAND IN PINIOS RIVER BASIN

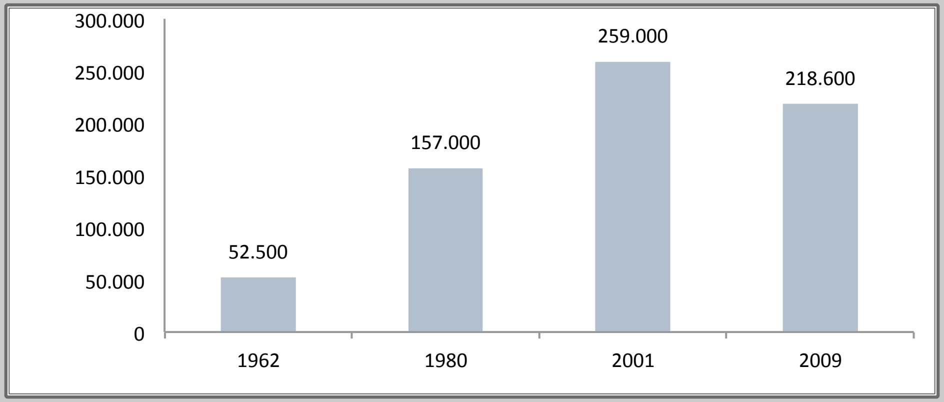




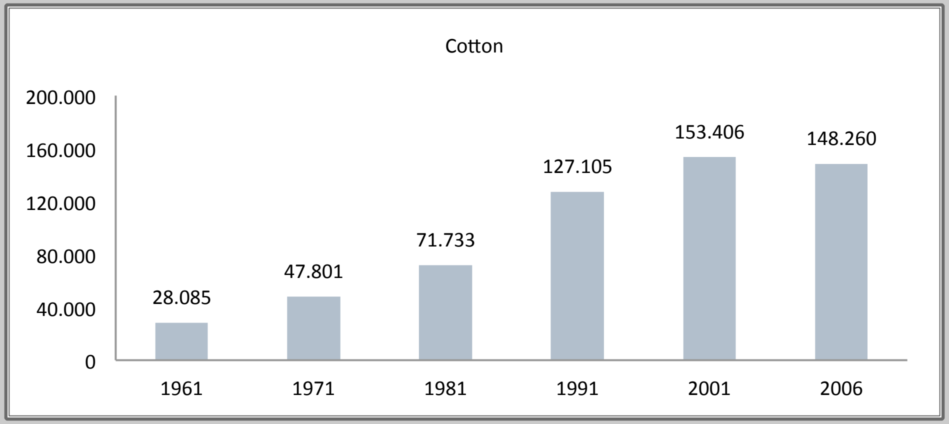
Total water consumption (millions m^3/year) of main cultivations in Thessaly

EXPANSION OF IRRIGATED LAND AND COTTON CULTIVATION AREA

Expansion of irrigated area (ha) in Thessaly

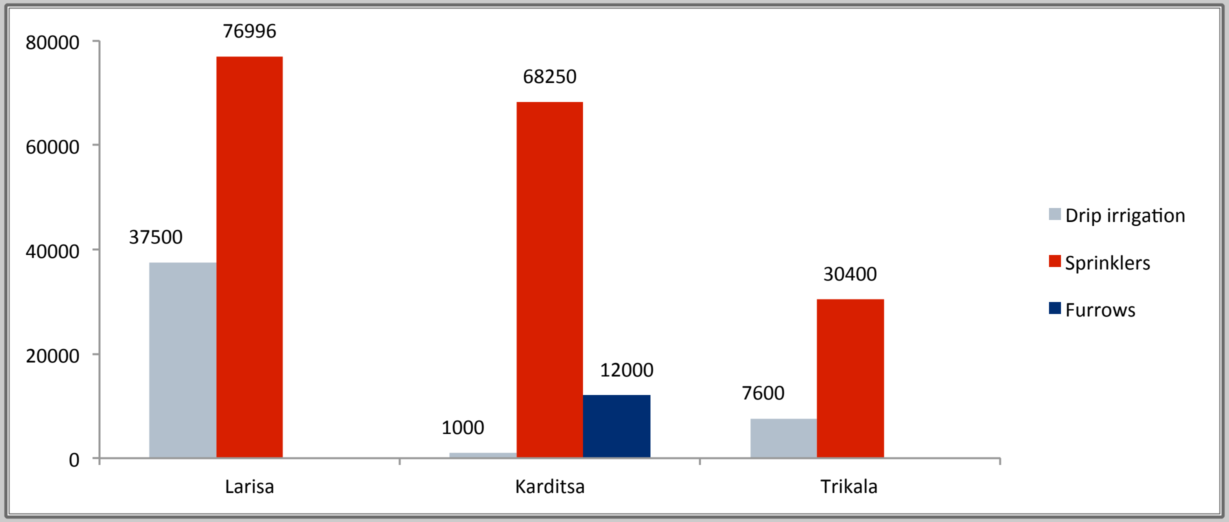


Evolution of cotton cultivation (ha) area in the Pinios river Basin



IRRIGATION METHODS

The most commonly used method of irrigation is artificial rainfall (50% of irrigated land) followed by surface irrigation and drip irrigation

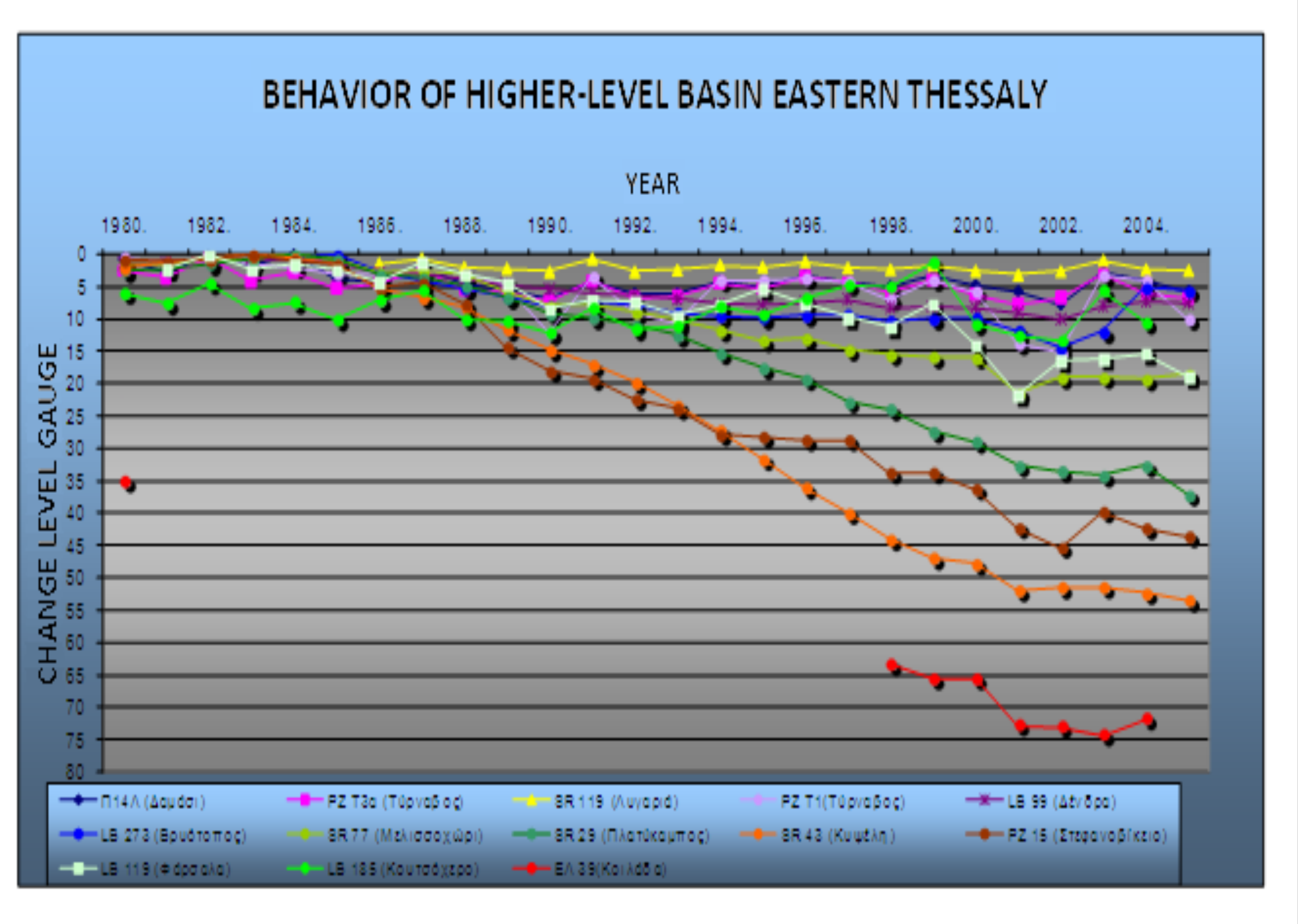


Drip irrigation :

- Accounts for approximately 50% of the cotton cultivated areas

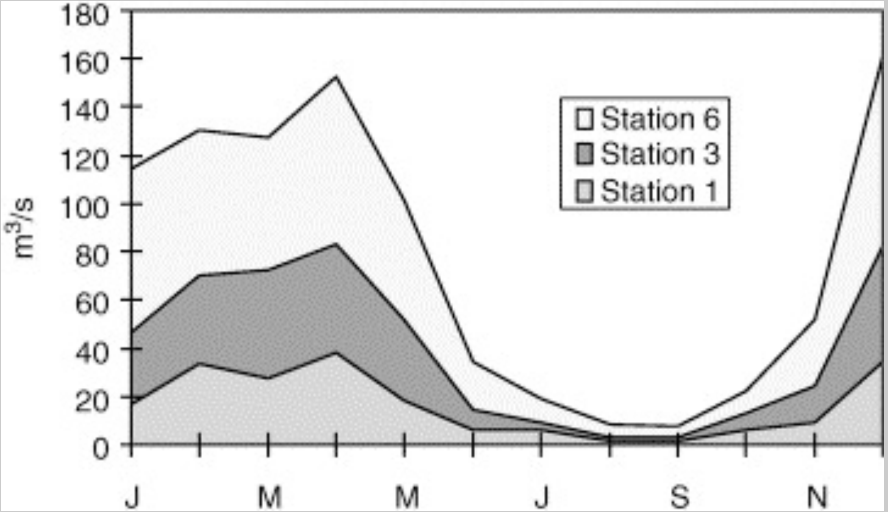
- High installation costs / relatively short life-span, it is currently being introduced primarily in areas that combine intense water shortage problems and lack of irrigation networks with high crop yielding capacity.

DECREASE OF GROUNDWATER LEVEL



DECREASE OF SURFACE WATER AVAILABILITY

River water abstractions during the dry period had led to drastic flow decreases in the past, even in the complete drying of the river



Seasonal variation of water flow in Pinios River (mean values for the years 1996–1998)

ESTIMATION: $45X10^6$ m^3 OF SURFACE WATER FROM THE PINIOS RIVER SERVES IRRIGATION PURPOSES

RESEARCH CARRIED OUT IN THE INSTITUTE OF SOIL MAPPING AND CLASSIFICATION

Mission: the accomplishment of the Soil Map of the agricultural soils of the country and carry out research focused on the maintenance and improvement of soil quality to may fulfill their functions, especially those related to the agricultural production and environmental quality.

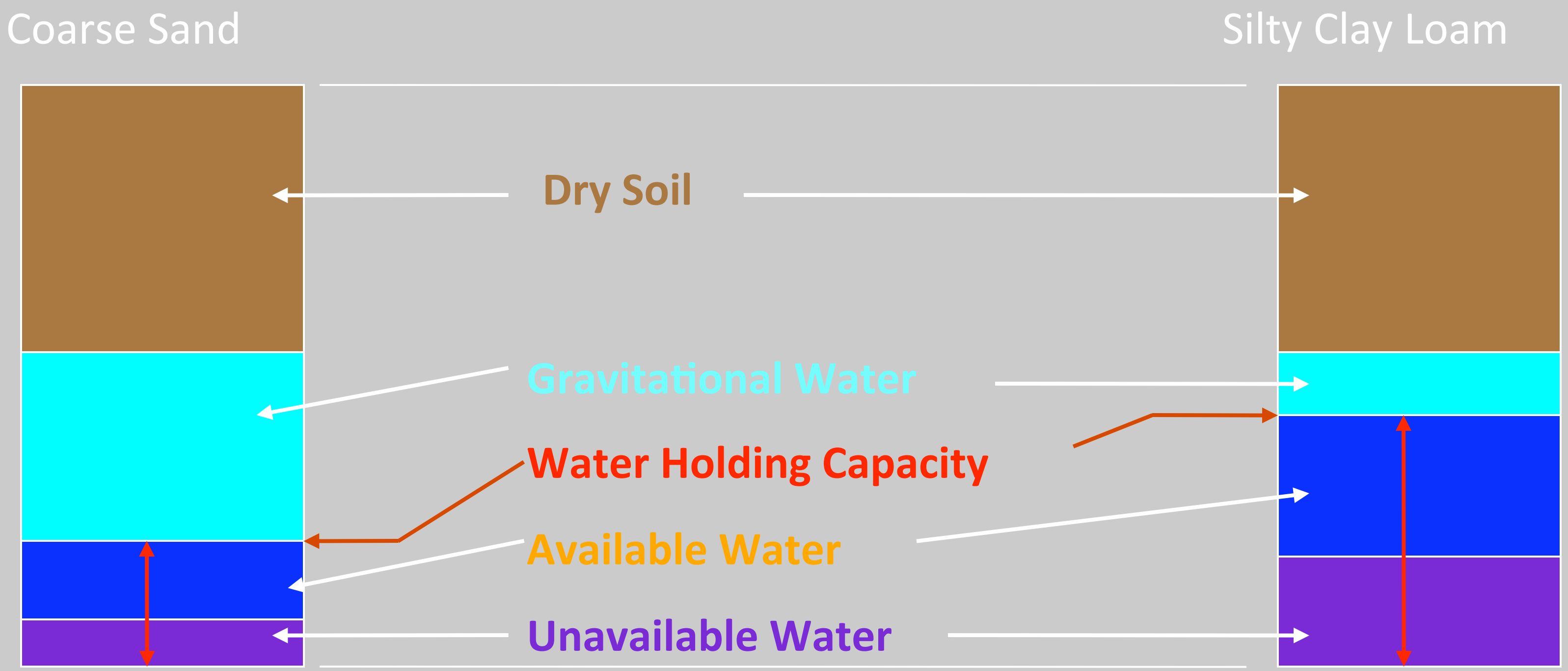
Last years research activities include:

- Sewage Sludge applications in agricultural soils
- Composting
- Precision Agriculture / Precision Irrigation
- Irrigation management

Recently for the needs of a DG Project (i-adapt) the Soil Water Holding Capacity map of Thessaly developed

SOIL WATER HOLDING CAPACITY

Water holding capacity designates the ability of a soil to hold water. It is necessary for irrigation scheduling, crop selection, groundwater contamination considerations, estimating runoff and determining plants water stress.



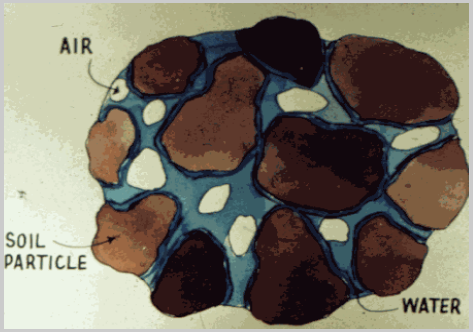
SOIL WATER HOLDING CAPACITY / WATER RETENTION CAPACITY

Gravitational water

- Excess water in soil pores
- drains out due to gravitational force
- Not available for plant growth

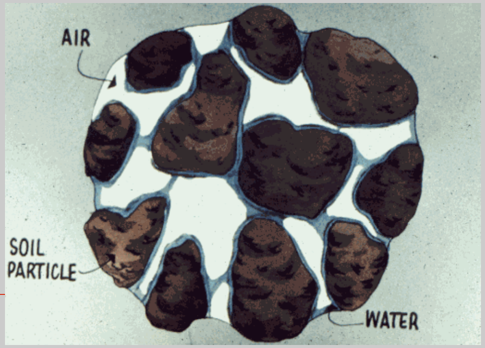
Capillary water

- Water left out in capillary pores after excess water has drained
- Held by surface tension – cohesive force 1/3-15 atmp.
- Available to plants



Hygroscopic water

- Water absorbed by a oven dry soil when exposed to a moist air
- Held at high tension - tightly held by adhesion force – water of adhesion 10000-31 atmp., water not available – permanent wilting point

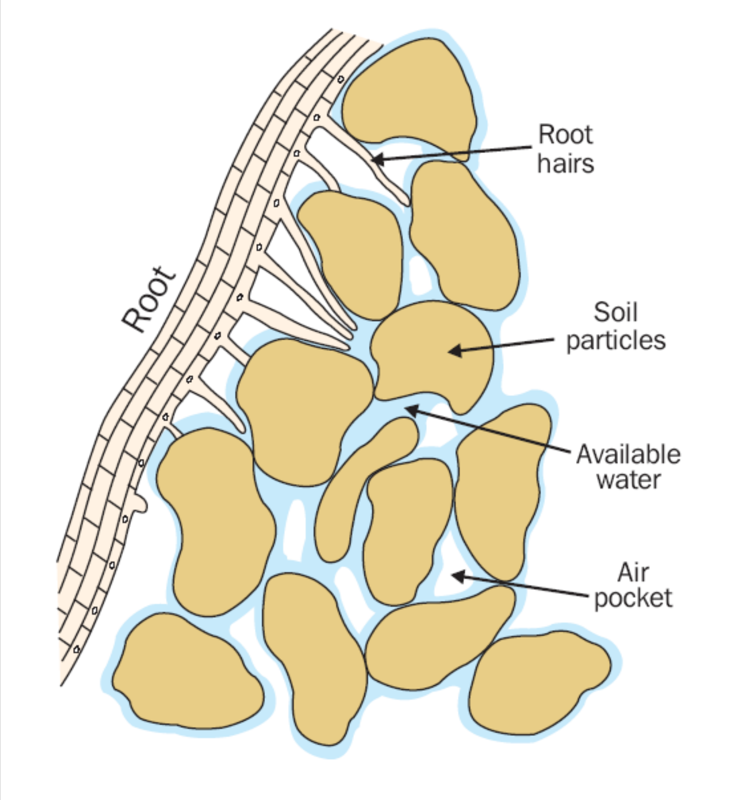


WATER HOLDING CAPACITY IN SOILS

Soils have different levels of water holding capacity depended mainly by their texture

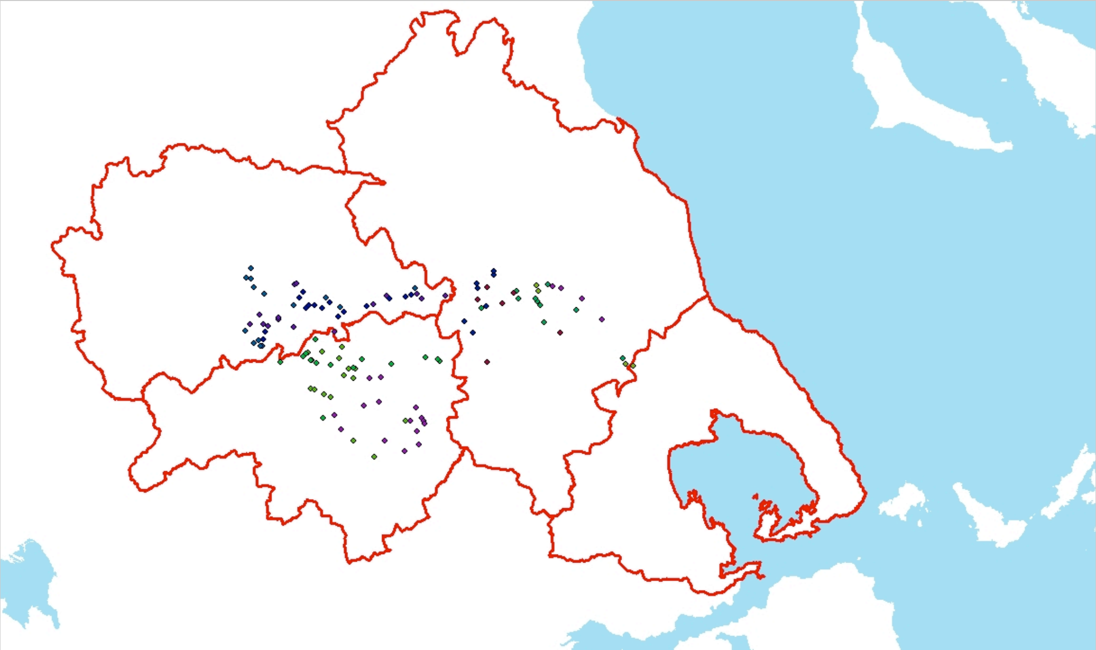
Capillary water is the water held within the pore spaces between soil particles against the forces of gravity.

- It is available to plants and may move upward or sideways by capillary action
- Clay soil holds more capillary water since it has more pore spaces.



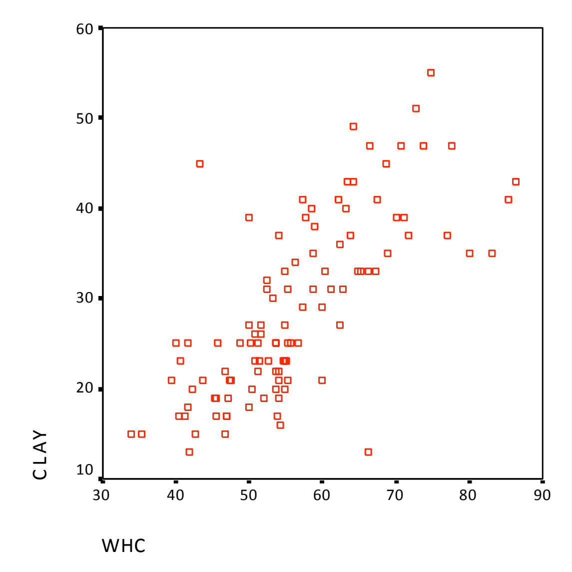
CREATION THE WATER HOLDING CAPACITY MAP OF PINIOS RIVER BASIN 1

1. Soil sampling of the most representative soil types in basin, 130 soil samples
   - Inceptisols , 40 Soil samples
   - Entisols 40 Soil samples
   - Alfisols 50 Soil Samples



CREATION THE WATER HOLDING CAPACITY MAP OF PINIOS RIVER BASIN 2

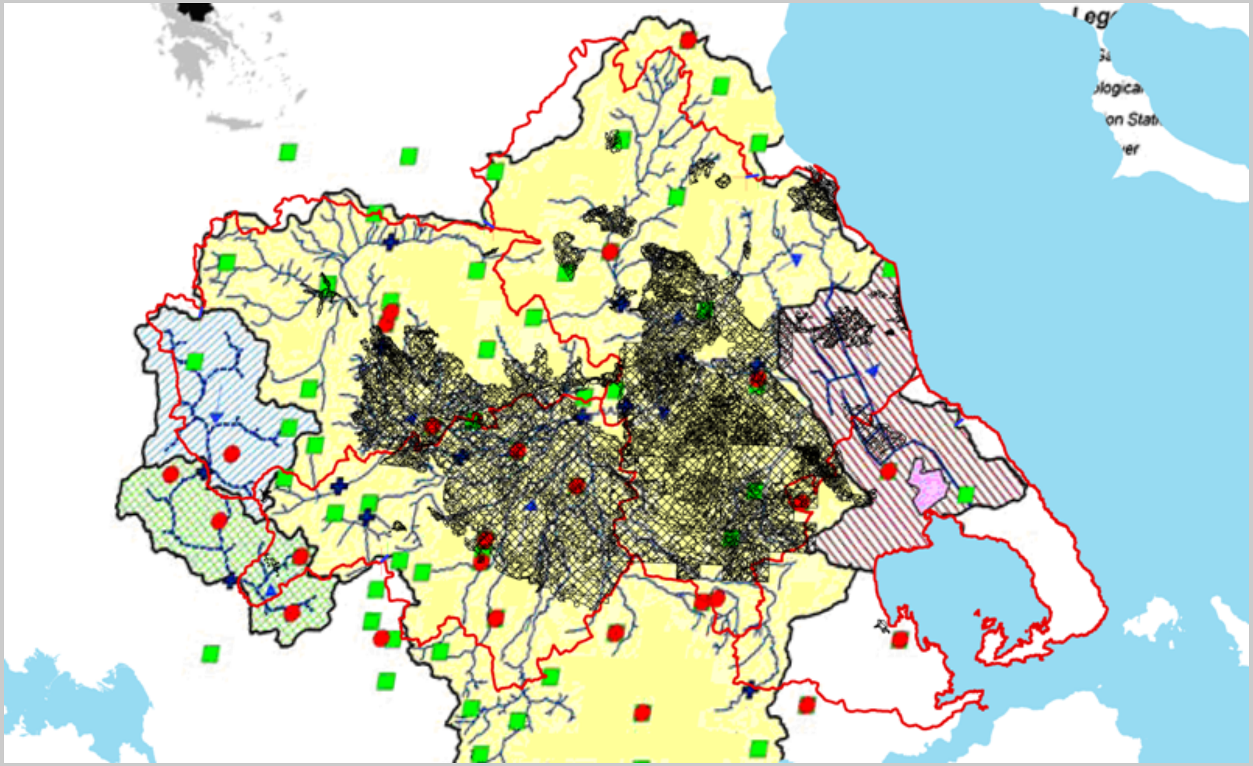
2. Laboratory determination a set of soil properties:
   - Water holding capacity (Volumetric method , Rothamsted Research)
   - Soil texture: Clay%, Silt%, Sand%
   - Soil Organic matter
   - Total nitrogen
   - pH
   - EC
   - $CaCO_3$



3. Development of pedotransfer function , Stepwise Regression Analysis
   - **WHC = 29.874 + 0.617*Clay + 5.444*Soilorg. mat , r^2 = 0,642**

CREATION THE WATER HOLDING CAPACITY MAP OF PINIOS RIVER BASIN 3

4. Application of the WHC pedotransfer function to the soil map data of Pinios River Basin
5. Application of geostatistical methods (kriging) for evaluation of the WHC map



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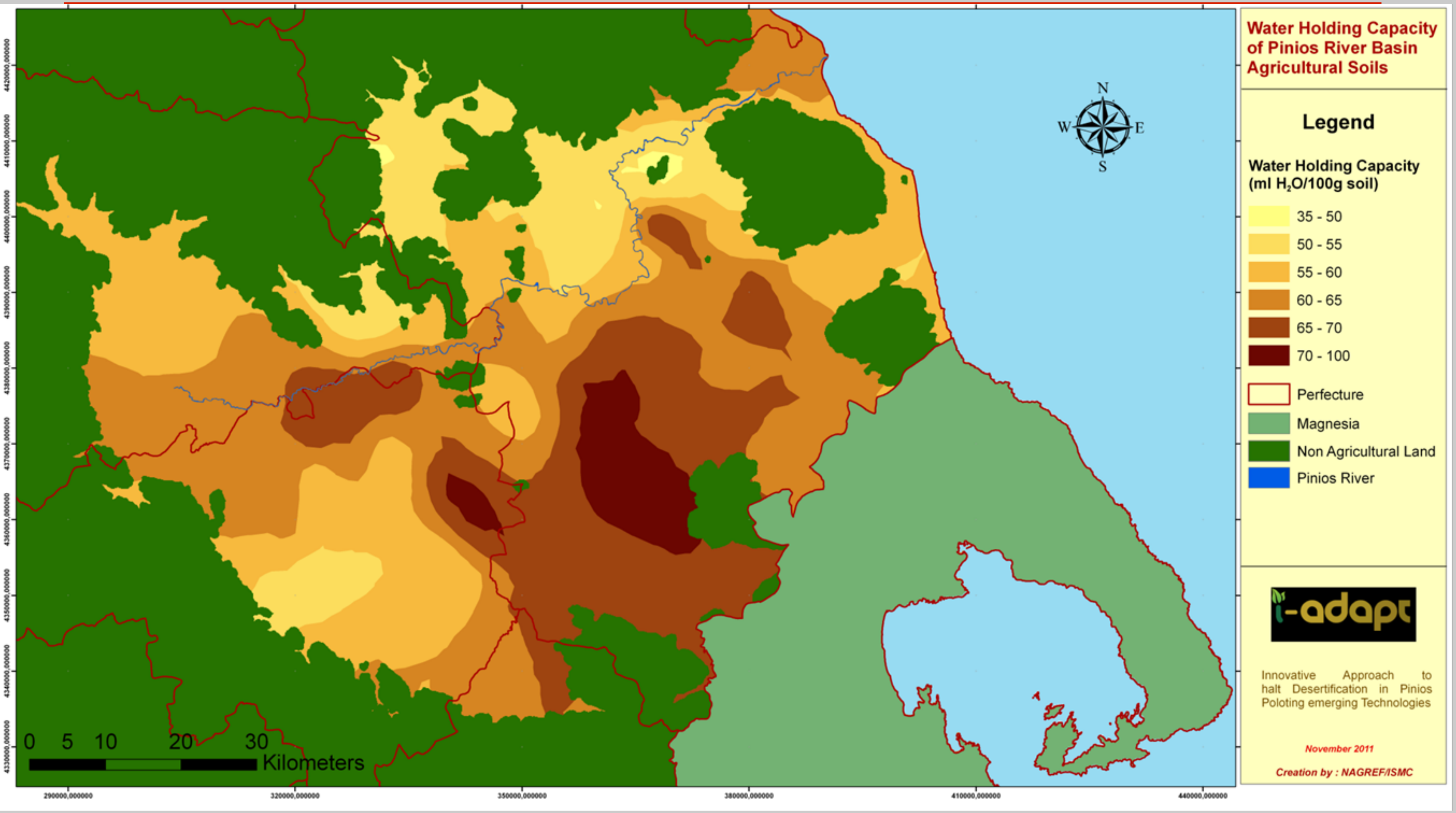
WATER HOLDING CAPACITY MAP OF PINIOS RIVER BASIN



PRECISION AGRICULTURE RESEARCH

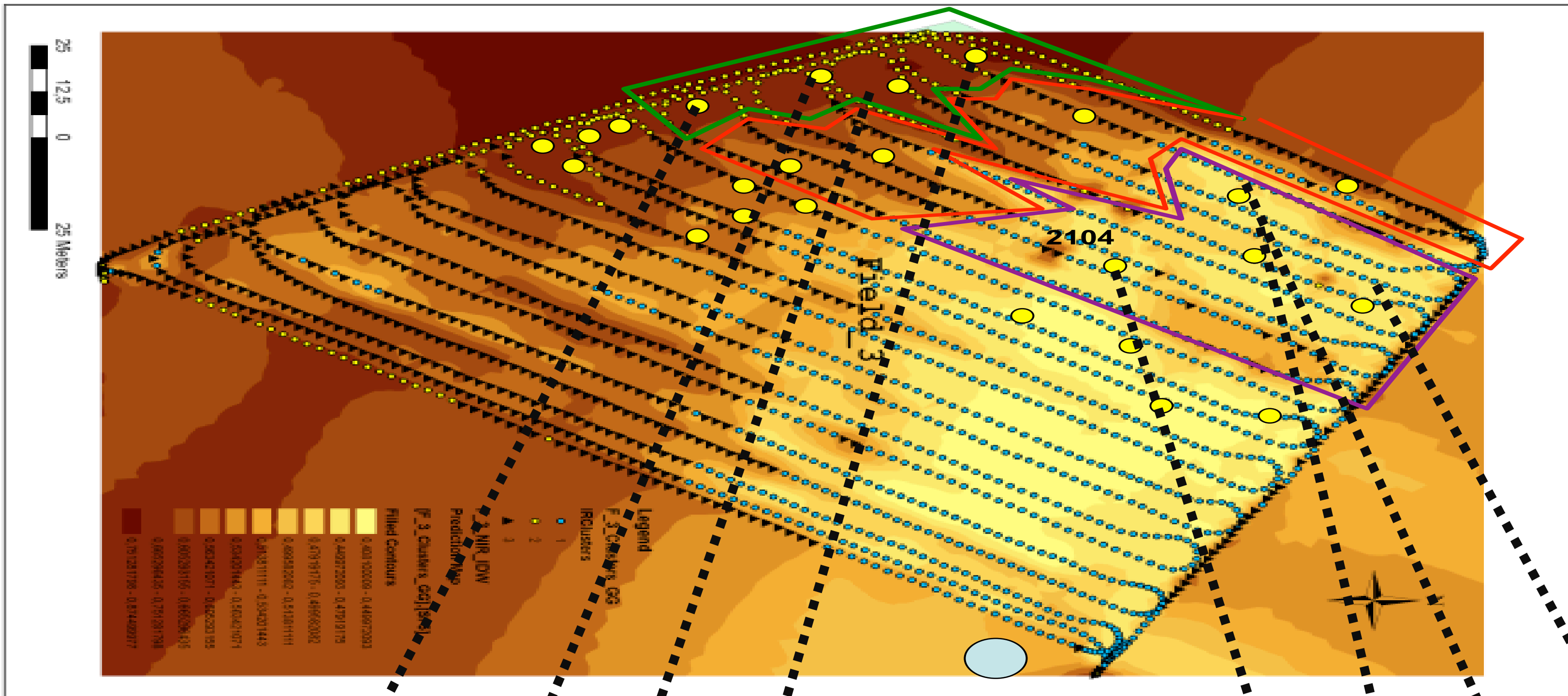
SOIL PROPERTIES VARIABILITY WITHIN A FIELD

Fields without variability in soil color

Fields with variability in soil color

PRECISION AGRICULTURE PILOTS

Vardoulis: pilot area=120m x 50m =0.6 ha



SOIL ORGANIC MATTER(%)	0,64	0,94	0,97	0,70	1,74	1,78	1,68	1,58
CLAY(%)	43	45	40	43	56	59	50	53
WATER HOLDING CAPACITY(%)	61	58	65	63	74	75	70	71

AGRICULTURAL PRACTICES AND SOIL ORGANIC MATTER CONSERVATION ON SOIL ORGANIC CARBON

Mechanisms for soil C sequestration in agriculture

Activity	Practice	Specific management change	Increase C inputs	Decrease C losses	Reduce disturbance
Cropland management	Agronomy	Increased productivity	X		
		Rotations	X		
		Catch crops	X		
		Less fallow	X		
		More legumes	X		
		Deintensification			X
		Improved cultivars	X		
	Nutrient management	Fertilizer placement	X		
		Fertilizer timing	X		
	Tillage / residue management	Reduced tillage			X
		Zero tillage			X
		Reduced residue removal	X		X
		Reduced residue burning	X		X
	Upland water management	Irrigation	X		
		Drainage	X		
	Set-aside and land use change	Set aside	X		X
		Wetlands	X	X	
	Agroforestry	Tree crops inc. Shelterbelts etc.	X		X
Grazing land management	Livestock grazing intensity	Livestock grazing intensity		X	
	Fertilization	Fertilization	X		
	Fire management	Fire management		X	
	Species introduction	Species introduction	X		
	More legumes	More legumes	X		
	Increased productivity	Increased productivity	X		
Organic soils	Restoration	Rewetting / abandonment		X	X
Degraded lands	Restoration	Restoration	X	X	X

Smith et al. (2008)

INFLUENCE OF SUAGE SLUDGE APPLICATION ON AGRICULTURAL SOILS

As a soil conditioner sludge :

- ✓ reduces bulk density and increases porosity
- ✓ improves structural stability
- ✓ enriches soil with organic carbon

Increase water retention capacity soils and, in the long-term, enhance water transmission properties and resistance to soil erosion

Sewage sludge application to soil

INFLUENCE OF SEWAGE SLUDGE APPLICATION ON AGRICULTURAL SOILS

Sewage sludge application to soil

INFLUENCE OF SEWAGE SLUDGE APPLICATION ON AGRICULTURAL SOILS

Research carried out by the Institute

Projects titles:

1. **1989-1990**: Investigation of alternative uses of sewage sludge of the city of Larissa and organization of management plan. DEYAL
2. **1988-1989**: Impacts of sewage sludge and waste water use in agriculture on soil physical and chemical properties: bilateral Greek-Bulgarian cooperation
3. **1996-2000**: Investigation of the suitability of the sewage sludge of the city of Volos for agricultural and other uses. DEYAMV.
4. **2000-2002:**Influence of sewage sludge application on soil quality: bilateral Greek-Albanian cooperation.
5. **2000-2002**: Influence of fly ash from coal combustion and municipal sewage sludge application on soil quality. Bilateral Greek- China cooperation.
6. **2005-2007**: Influence of sewage sludge application on soil quality indices of soils vulnerable to degradation. Bilateral Greek-Romania cooperation.
7. **2005-2007:** Investigation of agro-environmental effects from fly ash produced by cola combustion and sewage sludge reuse. Bilateral Greek-China cooperation.
8. **2005-2007**: Restoration of disturbed lands from mining activities with sewage sludge use. ARCHIMEDES I project

INFLUENCE OF SEWAGE SLUDGE APPLICATION ON AGRICULTURAL SOILS

Research carried out by the Institute

Cotton




INFLUENCE OF SEWAGE SLUDGE APPLICATION ON AGRICULTURAL SOILS

Research carried out by the Institute

RESULTS

Influence on soil properties

- Soil pH: increase of acid soils, decrease of alkaline soil
- Soil salinity: Increase (from 0.14 to 0.7 mmhos/cm)
- **Organic matter content: Increase from 9.46 to 24.27 g/kg**
- Phosphate: Increase 4fold
- Zinc: Increase
- Copper: Increase
- Iron and manganese: no significant effect

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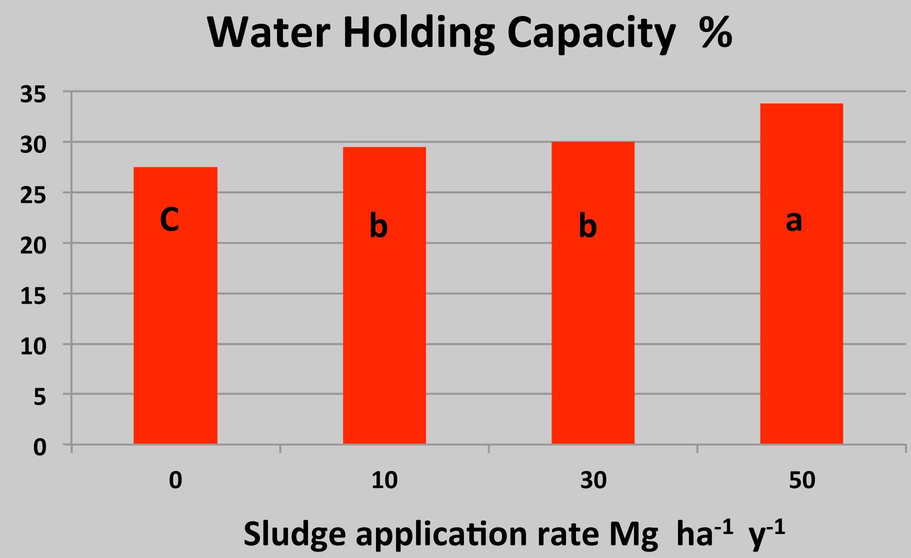
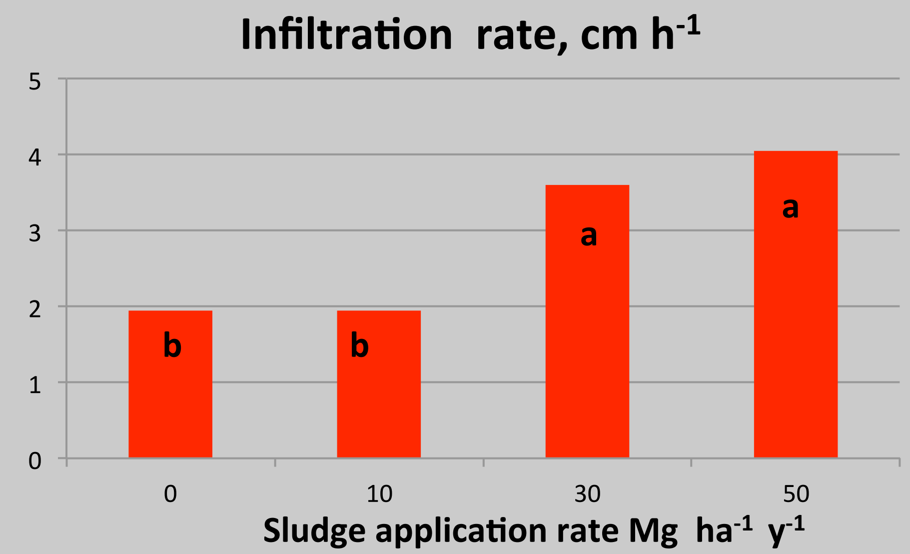
INFLUENCE OF SEWAGE SLUDGE APPLICATION ON SOIL PHYSICAL PROPERTIES

Water holding capacity increased with increasing application rate of sewage sludge

The water infiltration rate doubled in the 50 Mg ha^{-1} sludge application in comparison to the control





Repeated sludge application over four growing seasons improved soil fertility by means of increased soil organic matter, associated nutrient content and improvement of soil physical properties

LIMITATIONS OF SEWAGE SLUDGE APPLICATION IN AGRICULTURAL SOILS (European Union Directive 86/278)

CRITICAL VALUES OF HEAVY METALS CONCENTRATION IN SOILS IN WHICH SEWAGE SLUDGE IS GOING TO BE APPLIED, mg/kg	
Cadmium, Cd	1-3
Copper, Cu	50-140
Nickel, Ni	30-75
Lead, Pb	50-300
Zinc, Zn	150-300
Mercury, Hg	1-1.5

LIMITATIONS OF SEWAGE SLUDGE APPLICATION IN AGRICULTURAL SOILS (European Union Directive 86/278)

CRITICAL VALUES OF HEAVY METALS CONCENTRATION IN SEWAGE SLUDGE WHICH IS GOING TO BE APPLIED TO SOIL, mg/kg	
Cadmium, Cd	20-40
Copper, Cu	1000-1750
Nickel, Ni	300-400
Lead, Pb	750-1200
Zinc, Zn	2500-4000
Mercury, Hg	16-25

LIMITATIONS OF SEWAGE SLUDGE APPLICATION IN AGRICULTURAL SOILS (European Union Directive 86/278)

UPPER PERMITTED QUANTITIES OF HEAVY METALS TO BE APPLIED IN AGRICULTURAL SOILS THROUGH SEWAGE SLUDGE FOR A PERIOD OF 10 YEARS, g/ha/year	
Cadmium, Cd	0.15
Copper, Cu	12
Nickel, Ni	3
Lead, Pb	15
Zinc, Zn	30
Mercury, Hg	0.1

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INFLUENCE OF COMPOST APPLICATION ON SOIL ORGANIC MATTER CONCENTRATION



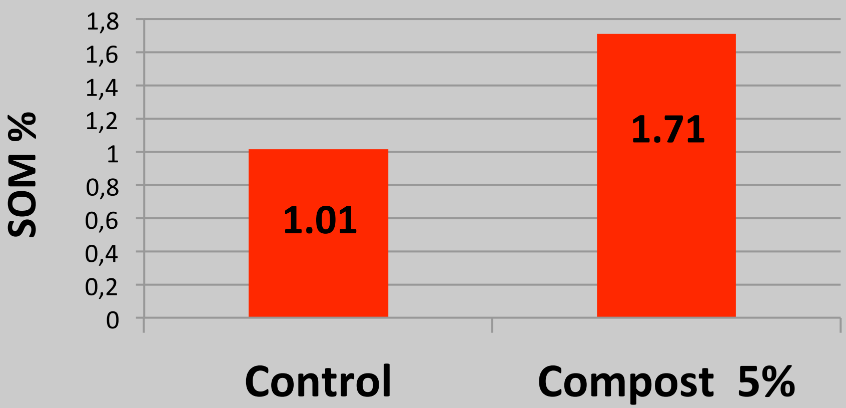




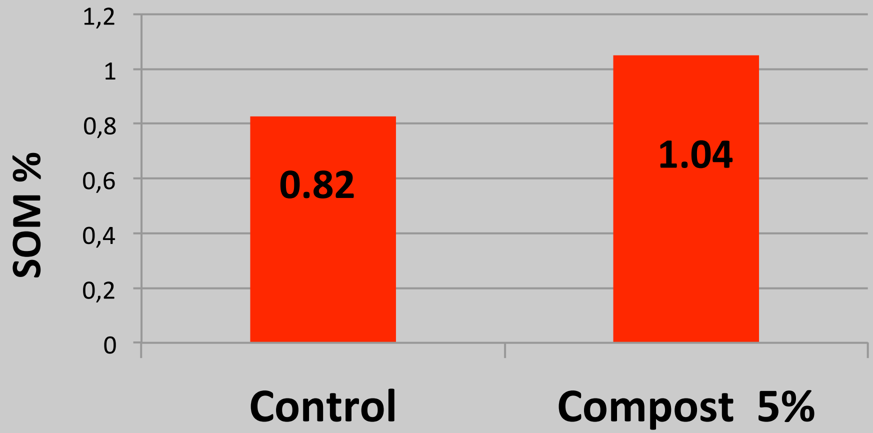


INFLUENCE OF COMPOST APPLICATION ON SOIL ORGANIC MATTER CONCENTRATION

- Compost Sludge : Wheat straw = 1:1.5 (v/v)
- Soil : compost = 5% (1000g soil, 50g compost)
- 90 days incubation (temp. 25 ^{0}C, moisture 60% field capacity)



Soil A: Typic Xerochrept



Soil B: Typic Rodoxeralf

INFLUENCE OF SEWAGE SLUDGE APPLICATION ON AGRICULTURAL SOILS

- Sludge application is an attractive option for eroded soils of dry Mediterranean climates that often have low organic matter content

- Relatively large quantities of sludge, of the order of 30 Mg ha^{-1}, are generally required to raise soil C, N content significantly and have a measurable effect on soil physical properties

- These rates, however, may exceed crop N requirements and may cause undesirable changes in soil chemical properties leading to environmental contamination :
  - ✓ ammonia volatilization and denitrification,
  - ✓ excessive soil acidification from nitrification of ammonia,
  - ✓ accumulation of nitrates in sludge-treated profiles,
  - ✓ increased nitrate leaching from susceptible loamy soils

SOIL ORGANIC MATTER CONCENTRATION AND SOIL WATER RETENTION

An example:

- Soil organic matter of a typical soil (Clay 40%) increase from 1.4% to 1.8% .
- WHC increase from 62.17% to 64.35%.
  - ✓ 100g of the soil “hold” 2.18 ml more water.
- For 1 ha of soil, 30 cm depth, 1,65 g/cm^3 Bulk density
  - ✓ **The soil retain 107.91 m^3 more water**

THANK YOU FOR YOUR ATTENTION