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Water and soil quality in Mediterranean orchards managed with sustainable or conventional systems

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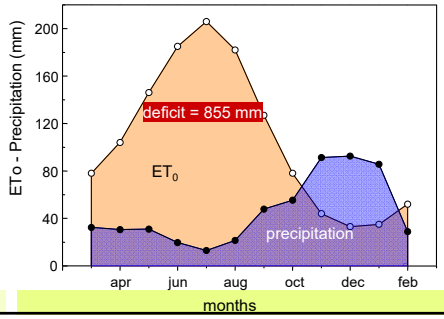
Basilicata Region – Matera city

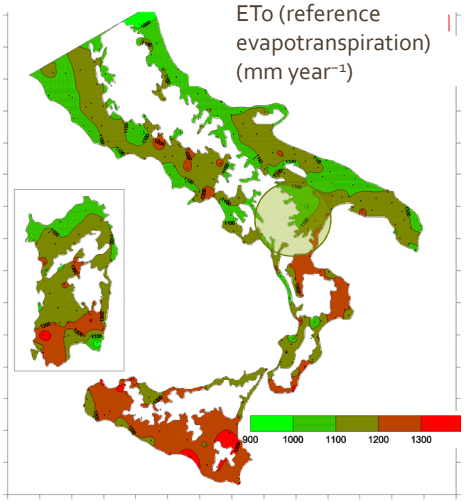
This year, Matera is the European city of culture.

Soils with organic matter less than 1% (w/w) are considered as desert from a microbiological point of view

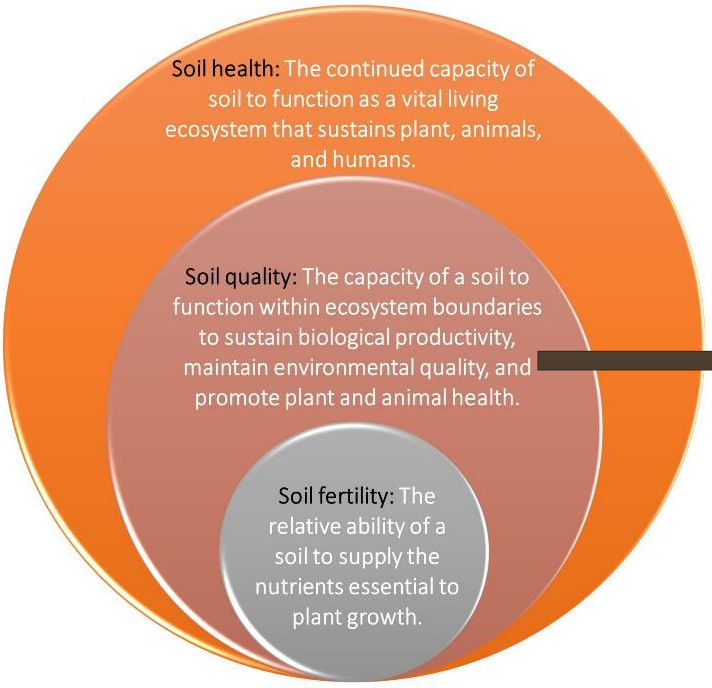
…in Basilicata, the mean soil organic matter of agricultural soils is 0.8 – 1.3% (w/w)

Source: Metapontum Agrobios and Regione Basilicata (2017)





(*Ravalli and Rota, 2004*)



Accept, hold, release and mineralize nutrients and other chemical constituents

Accept, hold and release water to plants, streams, and groundwater

Promote good root growth and maintain good biotic habitat for soil organisms

Resist degradation

The field site – Ferrendina (Matera province, Italy)

Mature olive orchard (plant age approximately 100 years)

20 years of differential management: sustainable (1 ha) and conventional (1 ha)

Why olive?

Pages from an early twelfth-century Benedectine encyclopedia (*Liber Floridus*, c 1121) with stilized but easily identifiable plants. It is possible to see an olive tree that sports tiny olives.

Hydrol. Earth Syst. Sci., 12, 293–301, 2008
www.hydrol-earth-syst-sci.net/12/293/2008/

Hydrology and Earth System Sciences

The olive tree: a paradigm for drought tolerance in Mediterranean climates

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Sustainable system

- No tillage - Spontaneous weeds and grasses mowed at least twice a year.
- Guided fertilization: fertigation based on a nutrient balance approach which takes into account nutrient input (by wastewater), output (by yield), and recycling/immobilisation in the grove system (by pruned material, senescent leaves, cover crops)
- The average values of organic C, N, P and K supplied with the treated wastewater are 124, 54, 3 and 50 kg ha^{-1} $year^{-1}$. An integrative amount of 40 kg ha^{-1} $year^{-1}$ of $N\text{-}NO_3$ distributed in the early spring
- Guided drip irrigation with treated municipal wastewater based on crop evapotranspiration
- Light winter pruning performed each year in order to reach vegetative-reproductive balance of trees. Pruning material cut and left on the ground as mulch





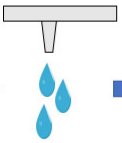
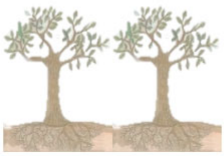
Clariflocculation, further sedimentation and bland disinfection, without biologically removing organic C and N.

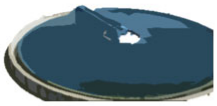

Pilot unit

Irrigation system

Olive orchard

Domestic sludge

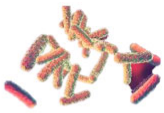


Wastewater

Treated wastewater

Drip irrigation

Microbiological risk (HPB)



Distributed from May to October by drip irrigation (2800 m^3 ha^{-1} $year^{-1}$; mean 2000-2016). N supply = 18.3 mg/L; P = 1.4 mg/L; K = 17.2 mg/L).

Municipal depuration plant

Secondary treatment (excepting sand filtration as a tertiary treatment)

Evaluation of the possible persistence of potential human pathogenic bacteria in olive orchards irrigated with treated urban wastewater

Adriano Sofo [1,*], Alba N. Mininni [a], Catia Fausto [a], Marina Scagliola [b], Carmine Crecchio [b], Cristos Xiloyannis [a], Bartolomeo Dichio [a]

«The irrigation with TWW can be considered a realistic and safe agronomic practice in Mediterranean orchards, and an opportunity for farmers and consumers.» (*Sofo et al., 2019*).

Conventional system

- Conventional tillage (milling at 10 cm soil depth) performed 2-3 times per year in order to keep the soil bare
- Mineral fertilization carried out empirically once per year by using granular product applied to the soil.
- NPK 20-10-10 fertilizer at doses ranging from 300 to 500 kg ha^{-1} $year^{-1}$
- Empirical irrigation (using excess water, without considering soil moisture and crop evapotranspiration)
- Heavy pruning carried out every two years - Pruned residues burned out of the olive grove

Sustainable management

Increase of soil C inputs

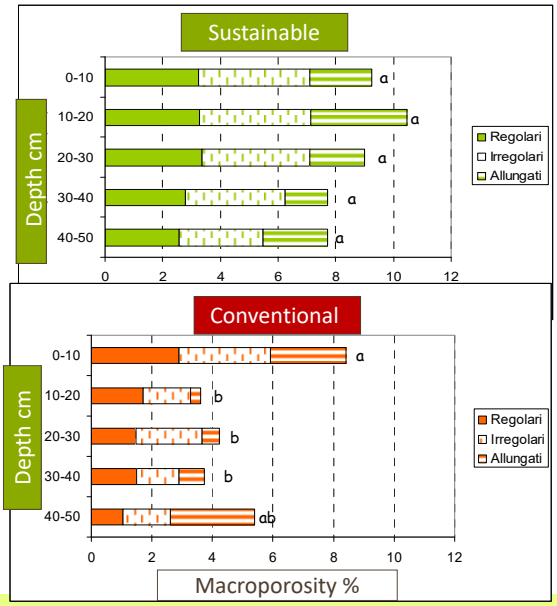
Internal C sources

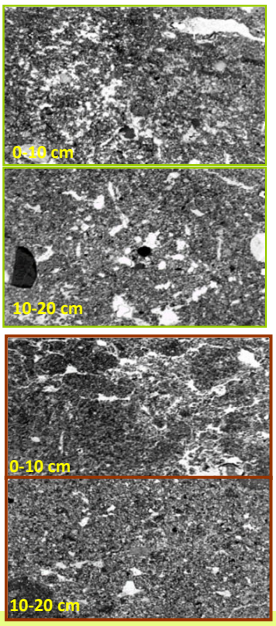
spontaneous grasses
pruning material
senescent leaves

External C sources

Fertigation
Very limited N mineral fertilization

The effects of differential managements on soil macroporosity





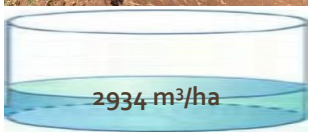
Increasing SOC impoves soil hydraulic condictivity

Evaluation of the vertical water flux (using a plastic tube as confined well)

Soil management	Soil water vertical infiltration (mm day^{-1})
Sustainable	160
Conventional	13

Soil water holding capacity and soil erosion

Conventional

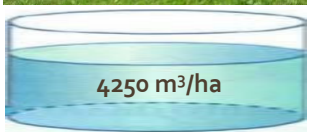


Mechanical tillage reduces water infiltration, causing runoff and erosion processes

Soil losses 60-105 t ha^{-1} y^{-1}

(a soil layer of about 1 cm!!!)

Sustainable



Sustainable management practices increase infiltration rate and water storage in soil

Soil losses < 1 t ha^{-1} y^{-1}

Palese et al. (2005)

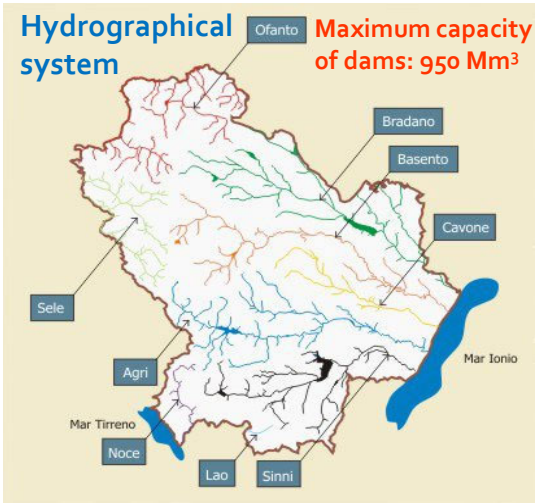
11 October 2013

… Responsabilities for soil management?

Are we sure that it was only due to rainfall intensity? What about soil management?

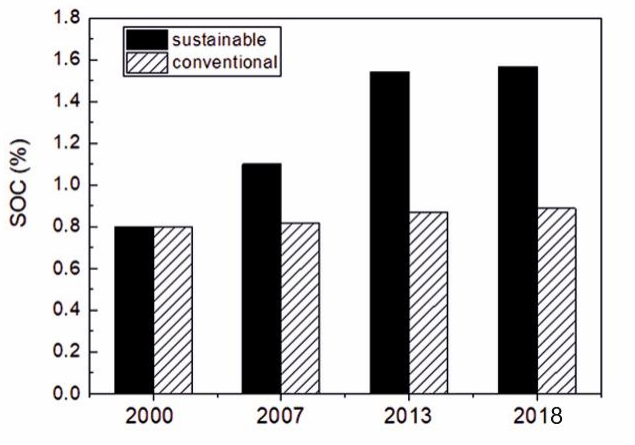
Environmental and economic effects of soil erosion on water supply

- Dams capacity losses
- Improvement of management costs
- Supplementary costs for drainage (10-30 € / m³)
- Frequent floods

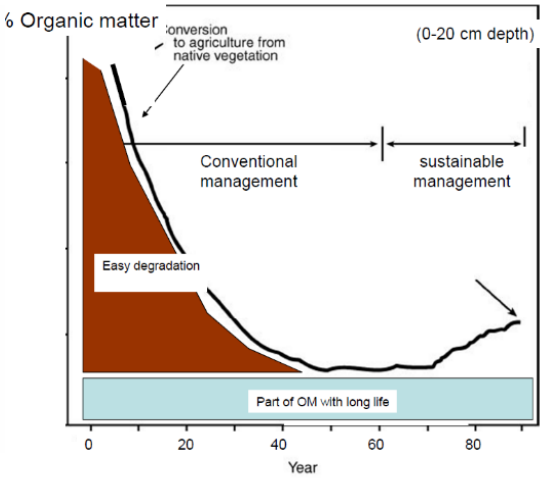


- Beginning of the activity in 1961 (105 Mm³ water storage capacity)
- Loss of capacity of 30 Mm³ in only 50 years
- Cost: 300 M € to clean up all the sediments

SOC changes in the topsoil (0-30 cm)

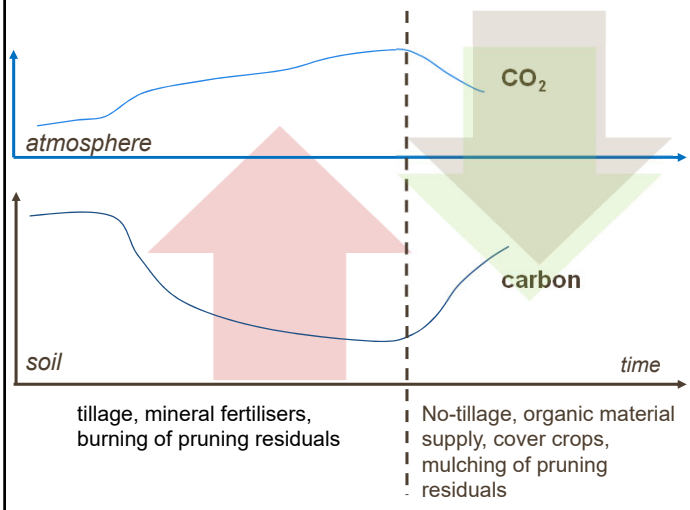


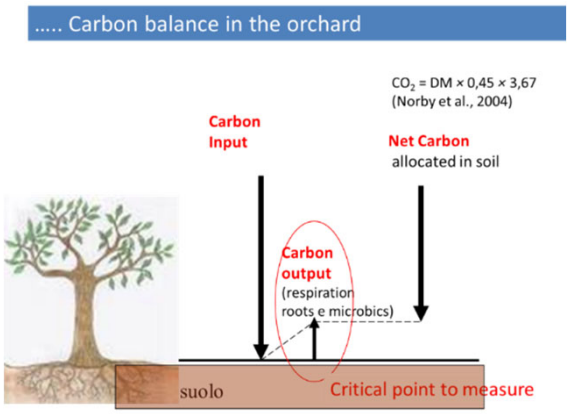
Adapted from Xiloyannis et al. (2018) and Sofo et al. (2019)



Rielaborato da WBGU Special Report:
The Accounting of Biological Sinks and Sources Under the Kyoto Protocol

Schematic impact of management practices on soil-atmosphere C fluxes

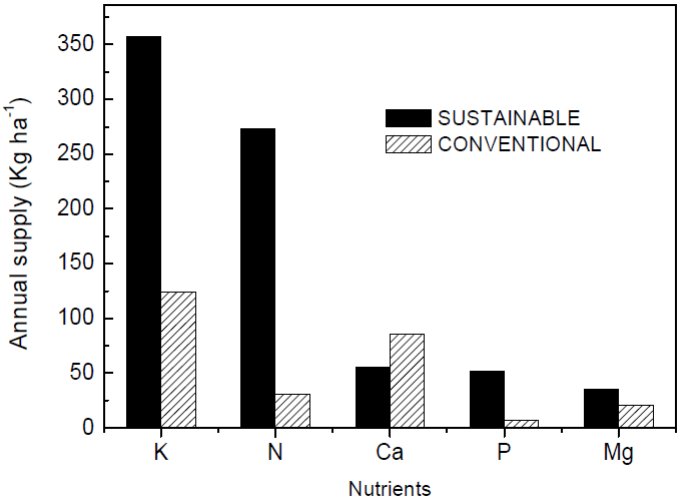




Average nutrients supplied annually as organic raw material and mineral fertilizers

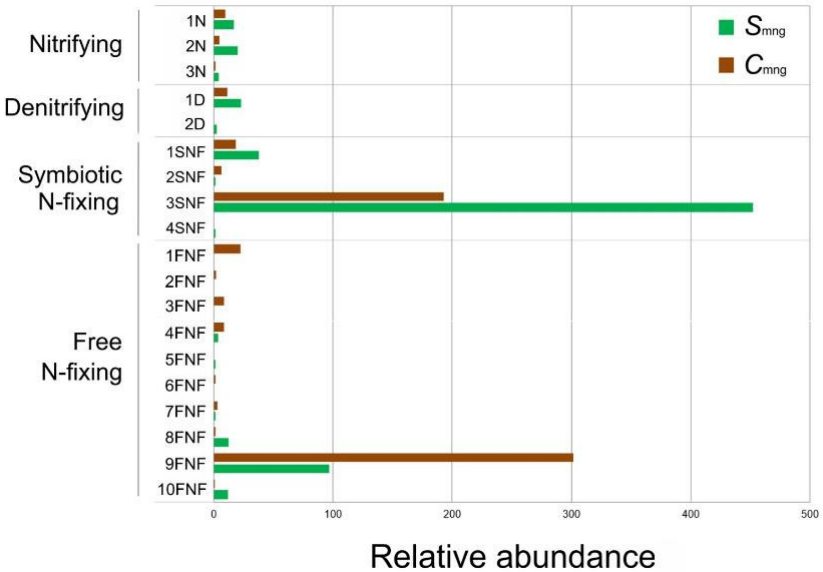
The sustainable management improves soil reserves of the macronutrients (N, P and K).

Sustainable orchards requires low (or none) external chemical fertilisers which contribute to off-set CO_2 emissions related to their production and transportation.



Adapted from Montanaro et al. (2012)

Soil N-cycling bacteria (16S-RNA based metagenomic analysis)

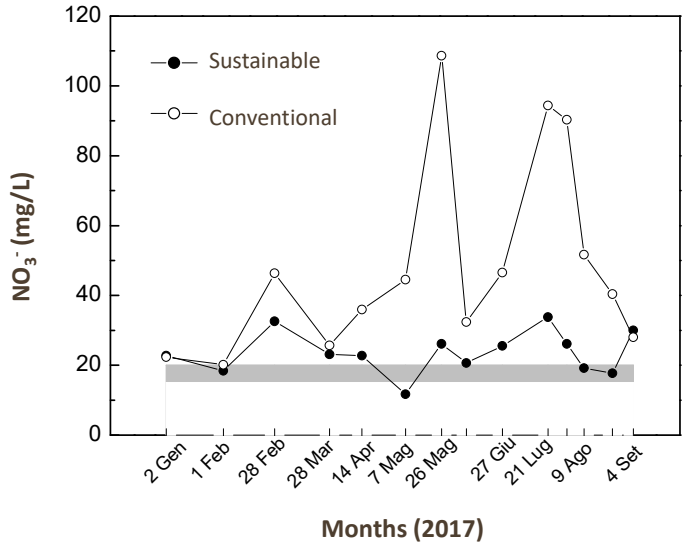


In the topsoil (0-30 cm) of the olive orchard

Management	Total N (g/kg)
Sustainable	2.56
Conventional	1.13

Sofo et al. (2019)

Nitrates in the soil solution (0-40 cm)



«Stability» of nitrates

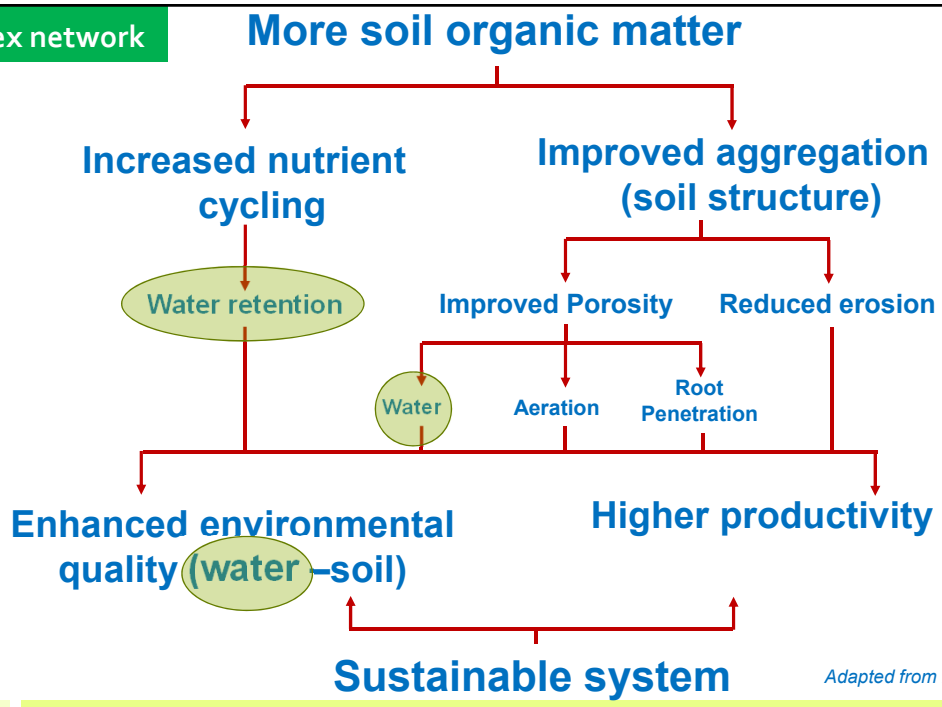
Slow mineral N release from SOM

Improves mineral nutrition

Low N-leaching from the root zone

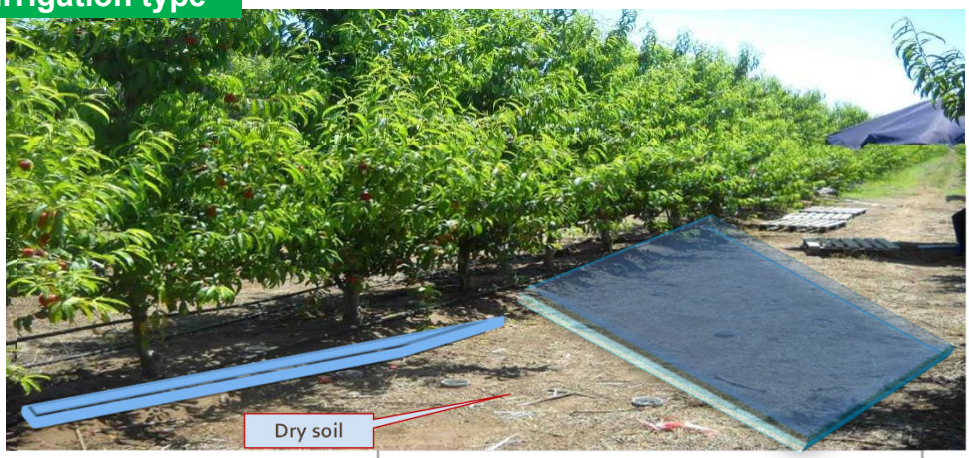
Low N-reduction in groundwater

A complex network



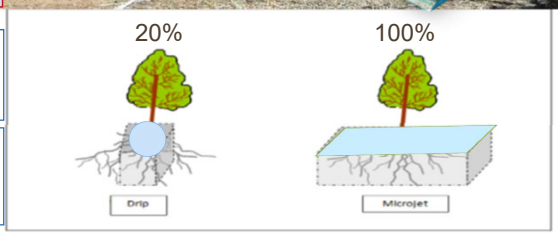
Adapted from Nichols (2004)

Effects of irrigation type

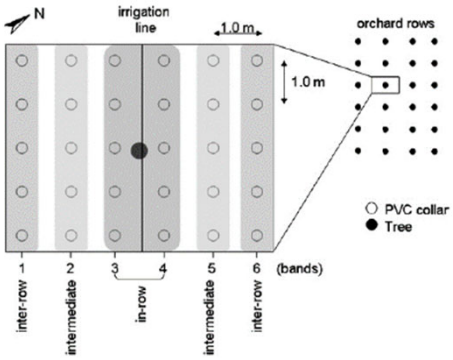


Drip - Irrigation in only **20%** of the field.

Microjet - Irrigation of the whole field (excess water and environmental problem).

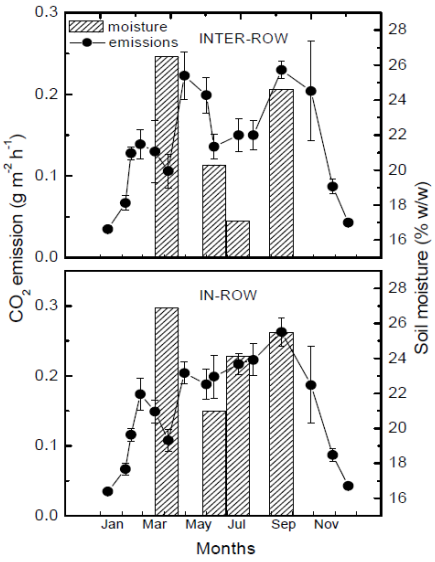


Irrigation and CO_2 emissions



CO_2 emissions at the in-row position are 11% higher than that at inter-row one in a sustainable orchard. This value rises up to 50% during the driest period.

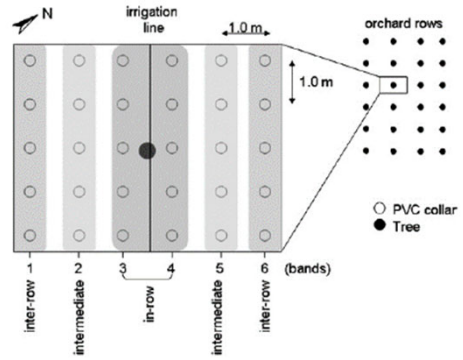
Due to higher root density and respiration and/or to microbial respiration?

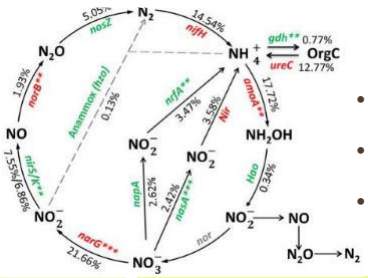


Seasonal trend of CO_2 emissions (•) and soil moisture (columns) measured at in-row and inter-row in a drip-irrigated peach orchard.

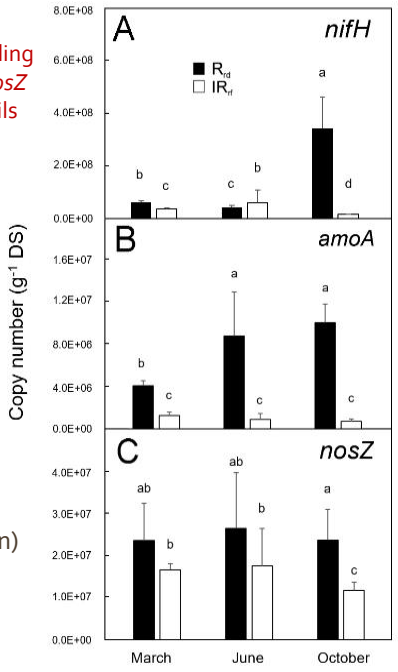
Montanaro et al. (2012)

Irrigation and N-cycling microorganisms



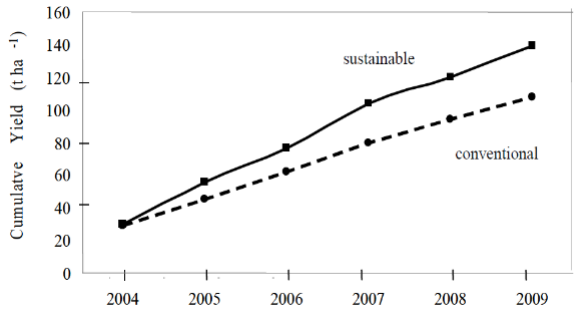


Abundance of the N-cycling genes *nifH*, *amoA* and *nosZ* measured by qPCR in soils from the olive orchard (*Pascazio et al., 2018*).



- nitrogen fixation (*nifH*)
- ammonia oxidation (*amoA*) (nitrification)
- nitrous oxide reduction (*nosZ*) (denitrification)

BENEFITS



Accounting orchard carbon sequestration:
Three main frameworks…

COMMERCIAL	ECOLOGICAL	ISTITUTIONAL
In farm and external processes, material… soil, litter seq. not considered	Biological carbon sequestration + farmer impact (In OUT)	Accounting Biological carbon sequestration in CROPLAND by 2021 within national GHGs inventory (EC 529/2013)

Benefits for the farmers?

Increasing benefit for growers may boost the adoption of environmental friendly water and soil management (water and soil quality)

FROM PILOT-SCALE TO FULL-SCALE WASTEWATER TREATMENT?

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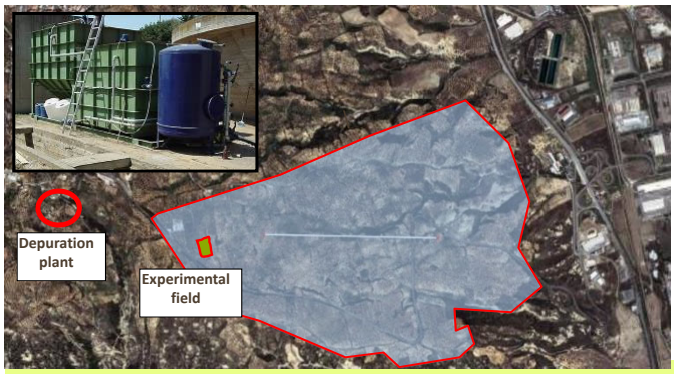
Dipartimento delle Culture Europee e del Mediterraneo

Università degli Studi della Basilicata
Scuola di Ingegneria

Agreenment



1 ha

180 ha

Policy makers ???

Agreenment
towards a green society

http://www.agreenment.it/index.php/en/

Thanks for your attention!

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