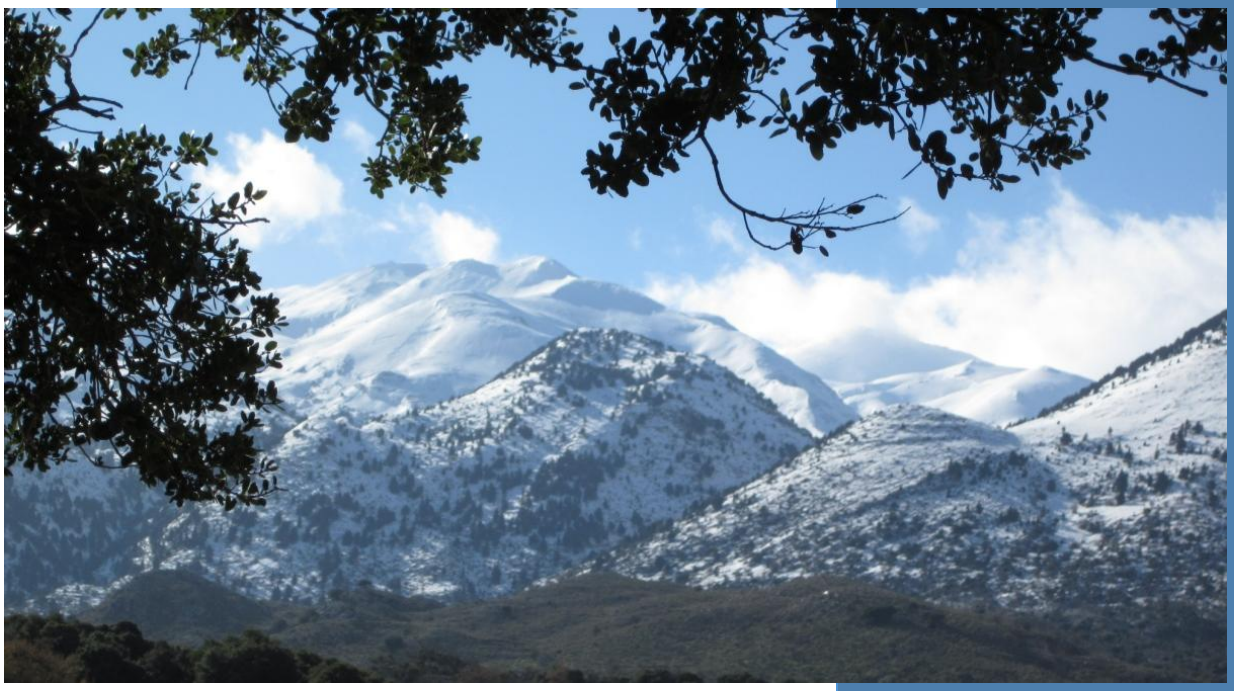
WEFE Nexus

Solutions and Tools Workshop
Field TRIP Handout



Koiliaris CZO - Towards integrated water and land management

LENSES

Learning and action alliances for Nexus environments in an uncertain future

Towards Integrated Water and Land Management - The Water-Ecosystem-Food Nexus and Nature-Based Solutions

Technical University of Crete

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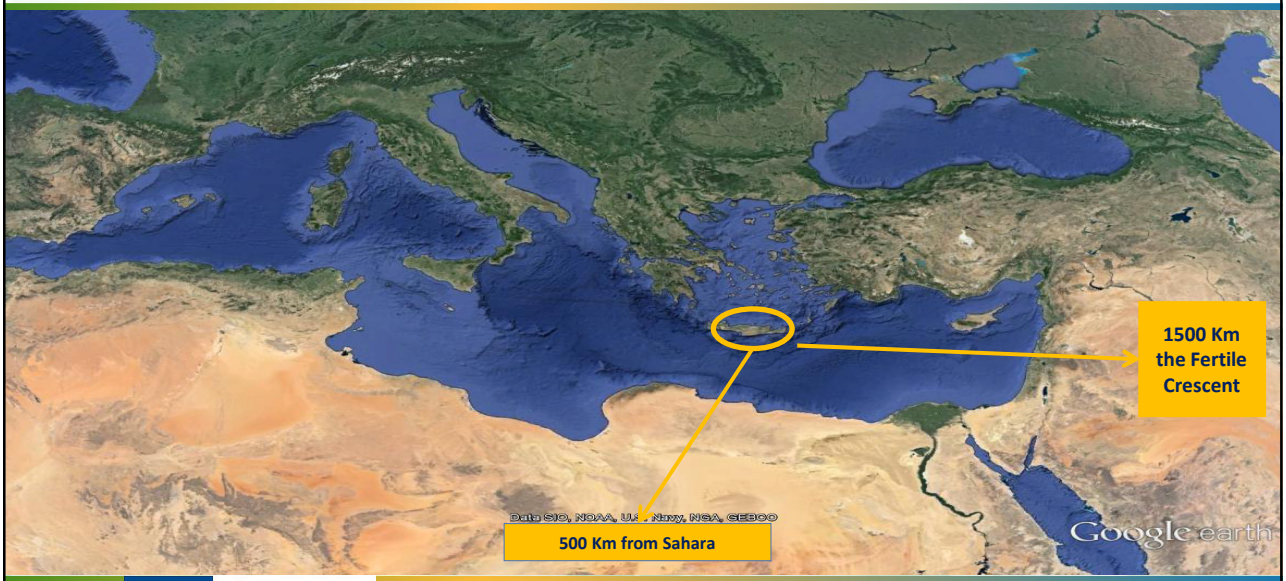
1

Climate Change and Crete



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2

2

WEFE Nexus and Climate Change

Water Security

Food Security

Climate Change

Energy Security

Ecosystem Sustainability

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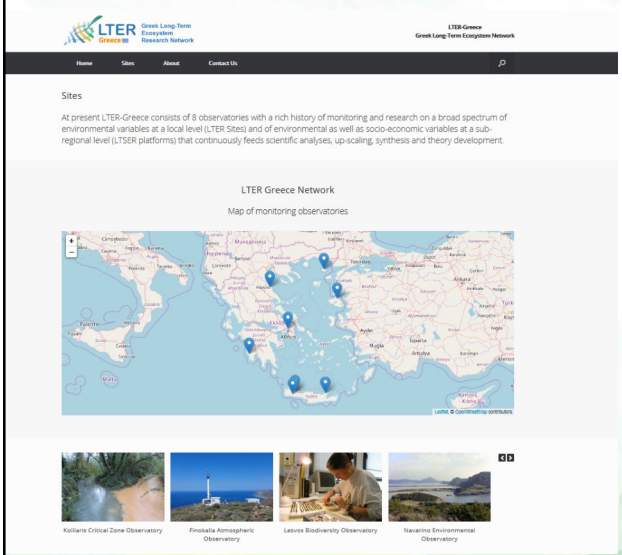
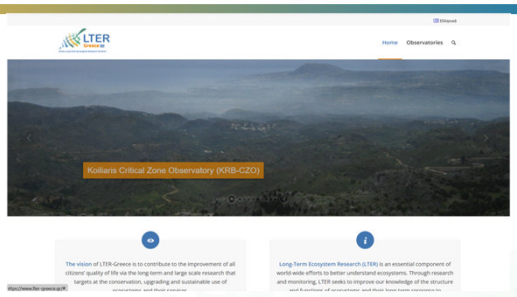
LTER-Greece Network - Koiliaris CZO





https://lter-greece.tuc.gr

- 21 years of hydrologic and geochemical data
- >50 papers in international journals
- Participation in Networks (LTER-Europe, LTER-Greece, ILTER, CZEN)

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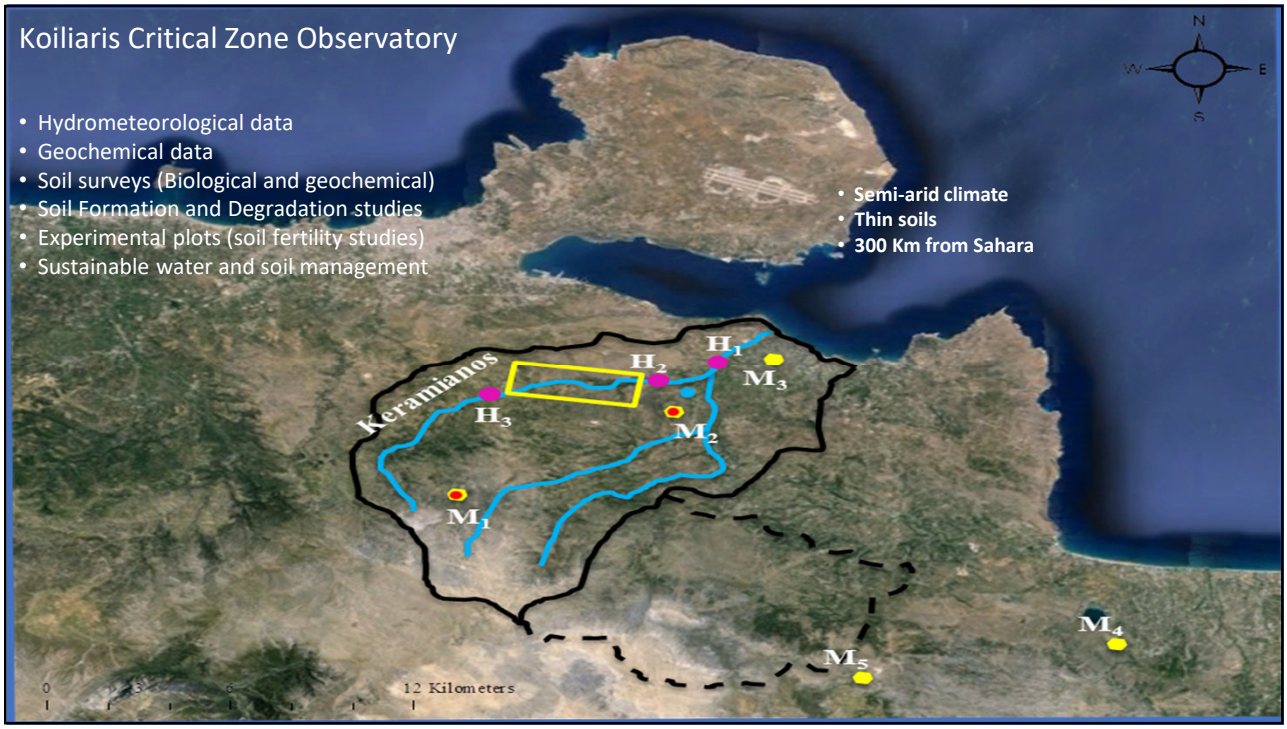
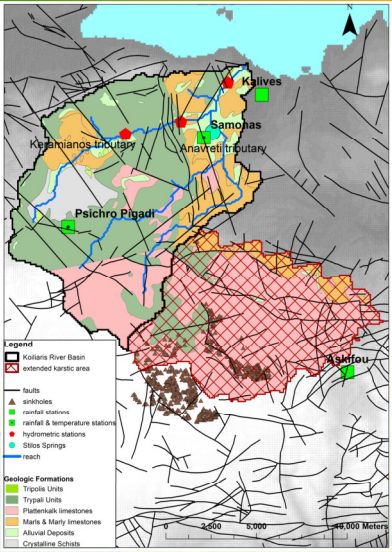

Koiliaris Critical Zone Observatory
• Hydrometeorological data
• Geochemical data
• Soil surveys (Biological and geochemical)
• Soil Formation and Degradation studies
• Experimental plots (soil fertility studies)
• Sustainable water and soil management
• Semi-arid climate
• Thin soils
• 300 Km from Sahara
N
W
E
S
Keramianos
H1
H2
H3
M1
M2
M3
M4
M5
12 Kilometers

5


Greek Speleological Society: Chania
1110 m below surface (1600 -490 m)
Liontari sinkhole

6

Koiliaris CZO



The White Mountains karstic system

(Moraetis et al., 2010, Nikolaidis et al., 2013, Lilli et al., 2020)

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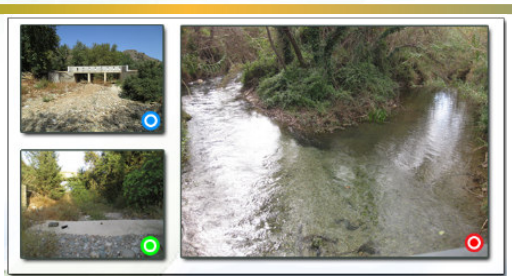
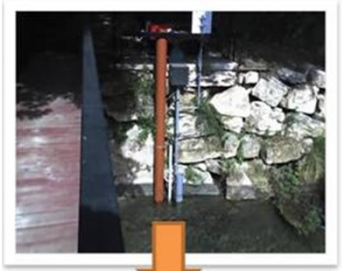
Koiliaris CZO

Temporary Rivers and Flush Floods





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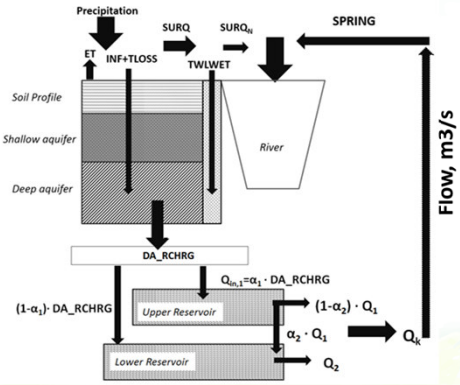
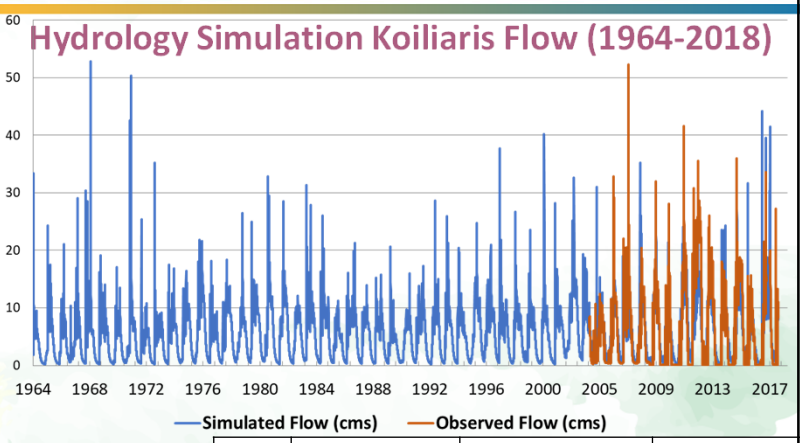
Developing and Upscaling Hydrologic Models





Karst-SWAT

Nikolaidis et al., 2013.

	Calibration Period (9/2010 - 7/2018)		Verification Period (7/1/2004 - 7/31/2010)		Goodness of fit
	Daily	Monthly	Daily	Monthly	Criteria
NSE	0.60	0.7	0.58	0.8	>0.5
PBIAS	5.13	16.4	-6.22	-6.0	25.0
RSR	0.63	0.52	0.65	0.48	<0.7

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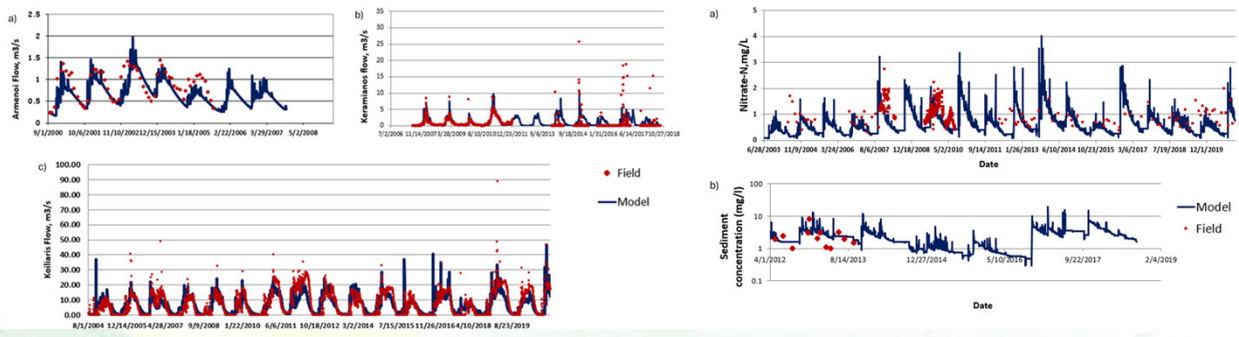
Hydrologic and Geochemical Models

Hydrologic and Water Quality Model Results for Koiliaris River Basin



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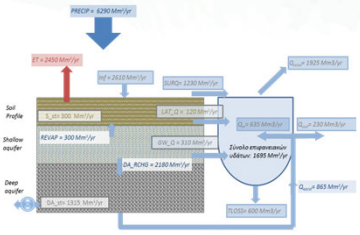
Hydrologic modeling of Crete - Scaling – up

Malago et al., 2016. Journal of Hydrology, v. 540

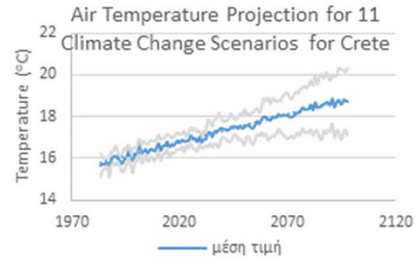
11

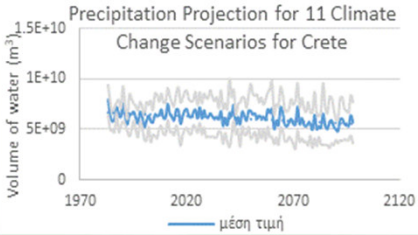
Available Water and Impacts of Climate Change

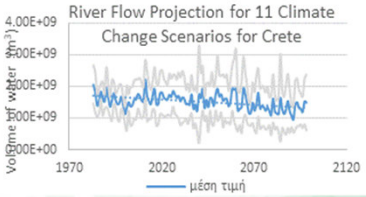


Υδρολογικό Ισοζύγιο Κρήτης

10^9 m^3/yr	Available water	Rivers	Springs
Average	1.93	1.06	0.87
Dry Year	0.78	0.27	0.51
Wet Year	3.43	2.1	1.33







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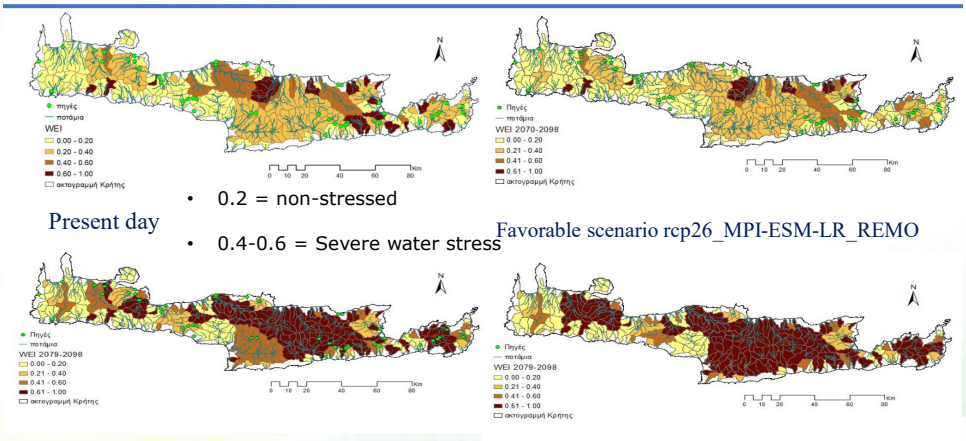
Available Water and Impacts of Climate Change



Present day

- 0.2 = non-stressed
- 0.4-0.6 = Severe water stress

Favorable scenario rcp26_MPI-ESM-LR_REMO

Intermediate Scenario rcp45_ MPI-ESM-LR_REMO

Extreme Scenario rcp85_MPI-ESM-LR_REMO

WEI = (total annual freshwater abstraction for all uses)/ (long term annual average of freshwater resources)

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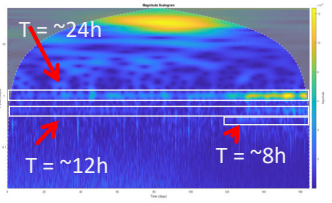
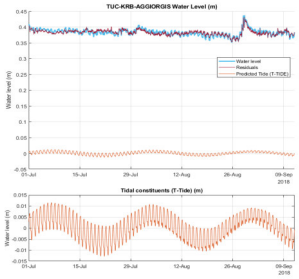
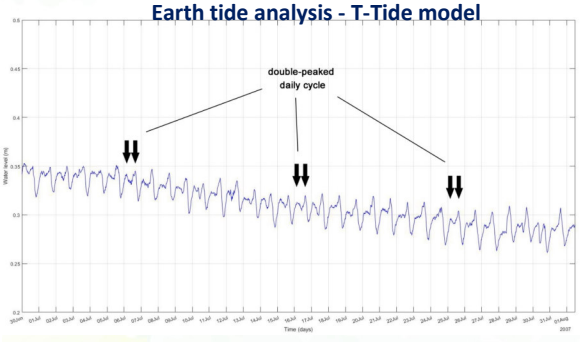
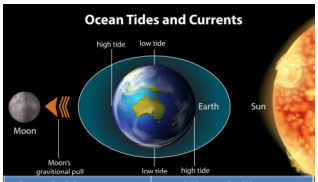
Impacts from the Sun and the Moon



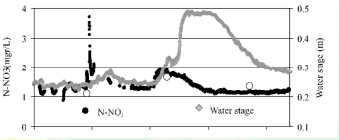


Earth tide analysis - T-Tide model



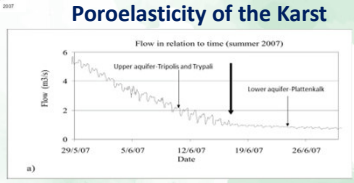


Diurnal Tides	Semidiurnal Tides
Lunar Frequencies (cycles per day)	Lunar Frequencies (cycles per day)
K1 – 0.9973 cpd O1 – 1.0758 cpd OO1 – 0.9294 cpd	K2 – 0.4986 cpd M2 – 0.5175 cpd
Sun Frequencies	Sun Frequencies
K1 – 0.9973 cpd P1 – 1.0027 cpd	K2 – 0.4986 cpd S2 – 0.5000 cpd



- 2 Reservoir system
- First flush from the karst

Poroelasticity of the Karst



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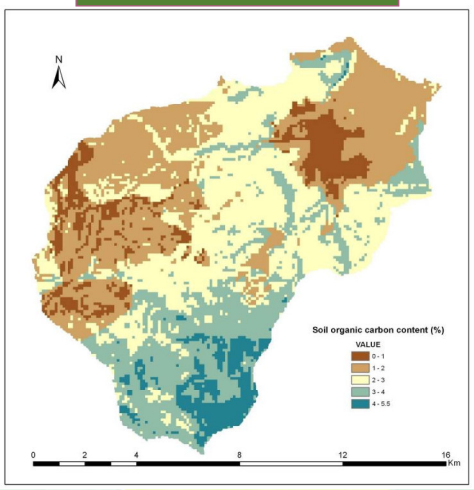
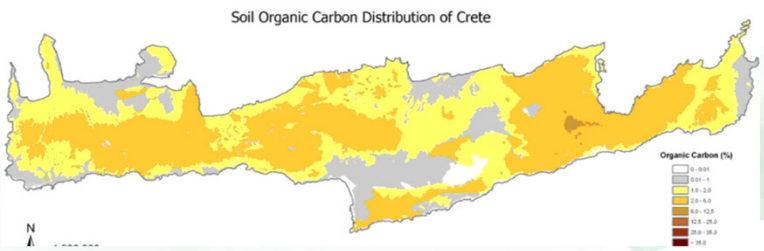
Land Degradation

Soil Organic Content





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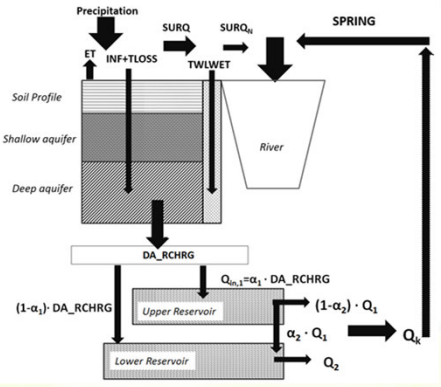
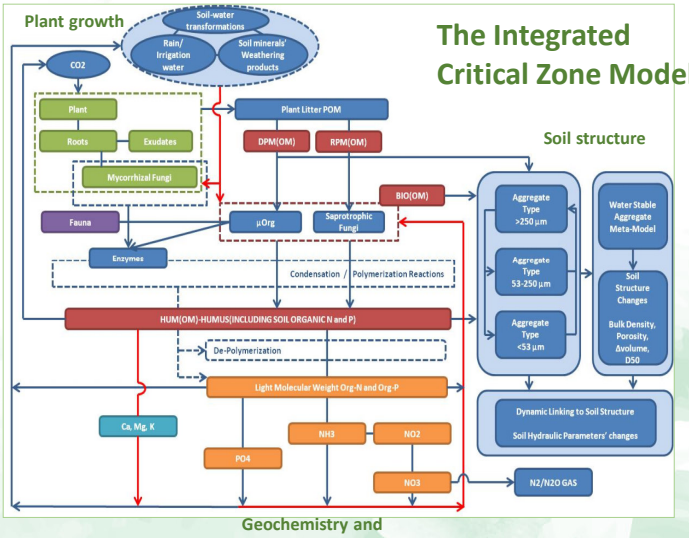
Hydrologic and Geochemical Models



Karst-SWAT

Nikolaidis et al., 2013.

The Integrated Critical Zone Model



Geochemistry and Cycles C, N, P, K

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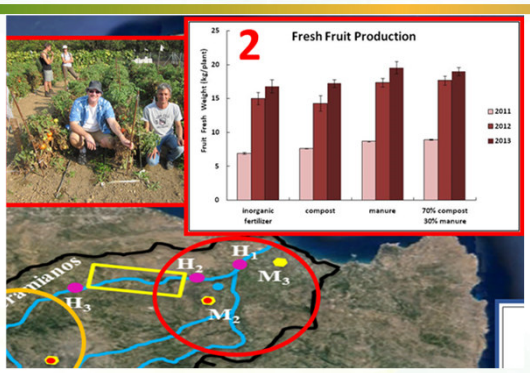
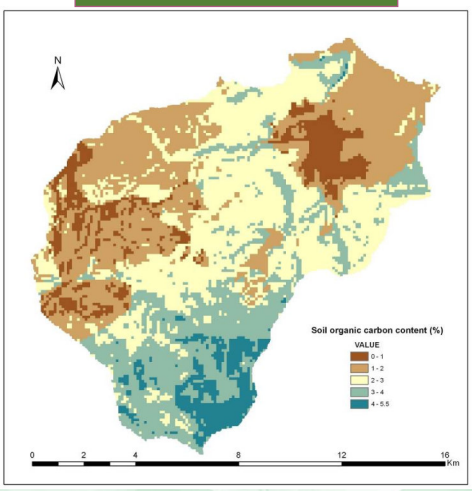
Soil regeneration: Agro ecological practices simulation & assessment



NBS bundles for soil regeneration

- Follow agro ecological practices
- Use soil organic matter, organic fertilization and conservation measures for soil improvement
- Incorporate manure, compost, biosolids, or crop residues to enhance carbon storage

Soil Organic Content



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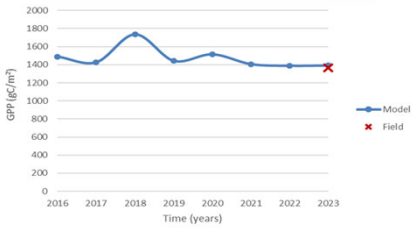
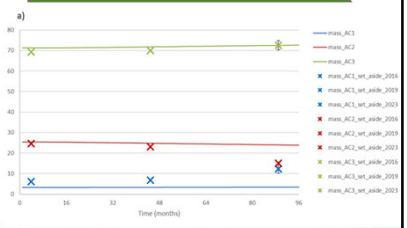
Modeling Ecosystem Functions of Avocado

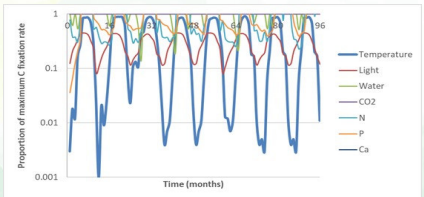
Biomass Production



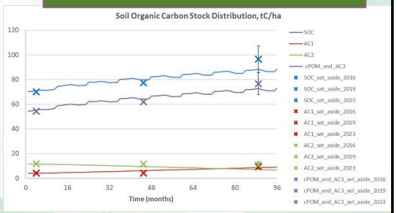
Water Stable Aggregates



Limitations to Growth



SOC Fractionation



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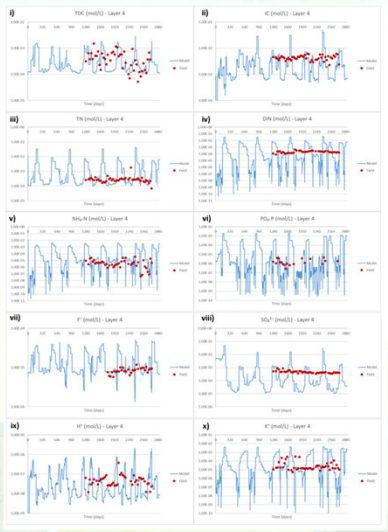
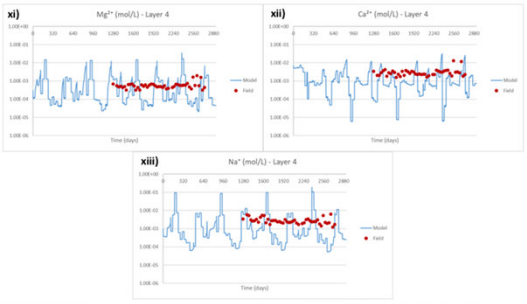
Modeling of leaching chemistry to groundwater





Modeling soil ecosystem services: Food production, nutrient sequestration, water filtration and transformation & biodiversity

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Ecosystem services derived from agroecological practices

Soil dynamics and structure parameters (related to soil fertility and soil health)	
WSA_AC3 (%)	71.9
WSA_AC2 (%)	24.7
WSA_AC1 (%)	3.4
Sand (%)	75.9
Silt-clay (%)	24.1

Nutrient sequestration	
cPOM (tC/ha)	65.0
Below ground N (tN/ha)	6.2
cPOM (tN/ha)	2.1
C/N (below ground)	13.0
CO_2 emissions (tC/ha)	8.3

Biomass production	
Above ground C (tC/ha)	14.7
Below ground C (tC/ha)	80.7

Leaching of chemicals to groundwater	
TOC, (g/m^2)	1.3
TN, (g/m^2)	14.6
PO_4–P, (g/m^2)	2.2
K, (g/m^2)	7.1

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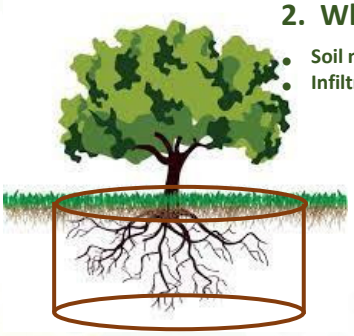
Focus on Farmers - Optimize Irrigation with NBS

Pilot #2
Greece

1. Rules of irrigation

- Replenish soil moisture of the roots only
- Don't let water go below the root zone
- Acknowledge that the roots are very efficient to transfer moisture to the planyt

Volume of soil (for avocado a cylinder with radius of 1.5-1.7 m and depth 0.5 m)

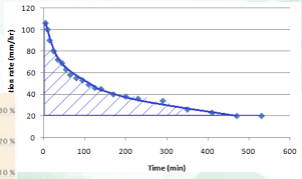


2. What do we need

- Soil moisture meter
- Infiltration experiment

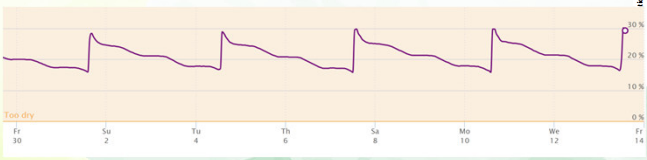
Infiltration experiment

Rate of infiltration



3. What do we get

- The rate of irrigation
- The duration of irrigation



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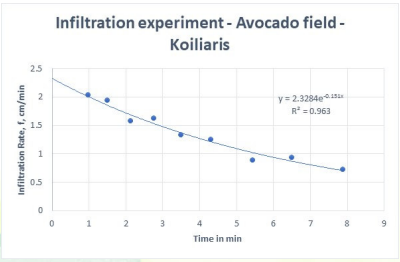
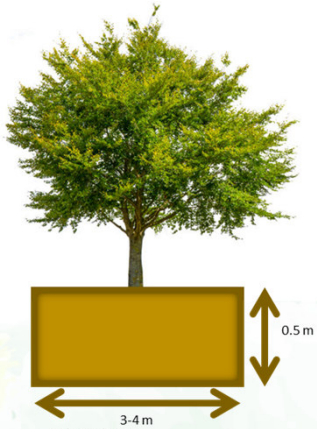
Optimize Irrigation with NBS

Drip irrigation

- Pipe around the tree – 1 m from the trunk
- 24 locations of drip
- 2 L/hr per drip
- 50 L/hr total irrigation



Fc = Infiltration rate= 12.5 cm/hr
Kf = Hydraulic conductivity = 12.7 cm/hr



Irrigation
2020 ➔ 8550 L/tree
2021 ➔ 8660 L/tree
2022..➔ 5100 L/tree

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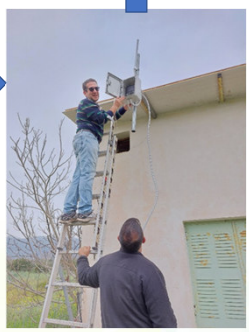
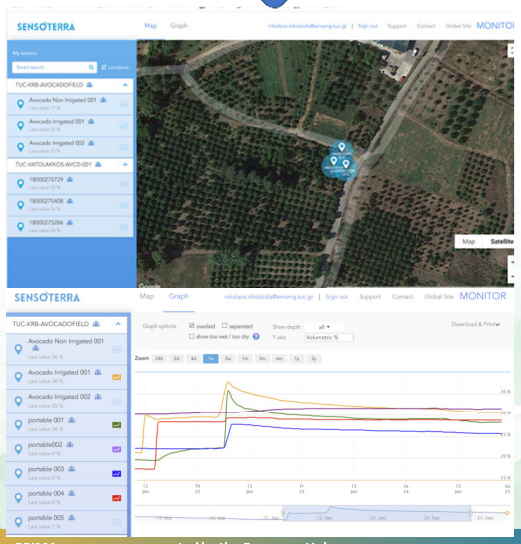
Optimize Irrigation with NBS





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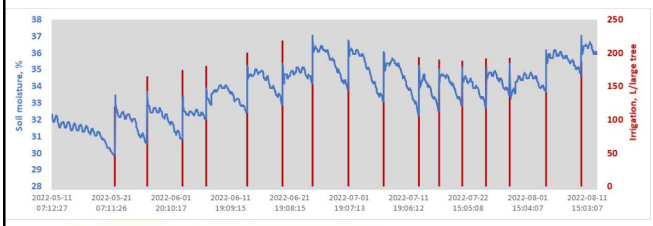
Optimize Irrigation



Άρδευση ανά δέντρο
2020 → 10.55 m³ → Duration 7-9 hrs
2021 → 8.66 m³ → Duration 7-9 hrs
2022 → 5.5 m³ → Duration 3 hrs
2023 → 5.5 m³ → Duration 3 hrs

Για 24 δέντρα/στρέμμα
132 m³/ στρέμμα

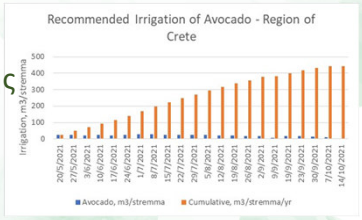
Υπουργείο Γεωργικής Ανάπτυξης
608-727 m³/στρέμμα

Προσδιορισμός κατώτατων και ανώτατων ορίων των αναγκαίων ποσοτήτων νερού στην άρδευση

	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
	I		II		III		IV		V		VI		VII		VIII	
ΑΠΡΙΛΙΟΣ	63	74	69	81	75	88	80	94	86	101	92	108	98	115	138	162
ΜΑΙΟΣ	82	99	90	108	98	117	105	126	112	135	120	144	127	153	180	216
ΙΟΥΝΙΟΣ	93	113	102	123	110	133	119	143	127	154	136	164	144	174	204	246
ΙΟΥΛΙΟΣ	102	121	111	132	120	143	129	154	139	165	148	178	157	187	222	264
ΑΥΓΟΥΣΤΟΣ	96	115	105	126	114	136	122	147	131	157	140	168	149	178	210	252
ΣΕΠΤΕΜΒΡΙΟΣ	77	93	84	102	91	110	98	119	105	127	112	136	119	144	168	204
ΣΥΝΟΛΟ	513	615	561	672	608	727	653	783	700	839	748	896	794	951	1122	1344

I: Εσπεριδοειδή, Ελιές, Αμπέλια II: Καπνά αντ. Τύπου, Σανός III: Οπωροφόρα , Ακρόδρυα, Όσπρια, Βαμβάκι, Φράουλες, Άνθη, Αβοκάντο
IV: Καπνά δυτ. Τύπου, Κηπευτικά, Μποστανικά, Πατάτες, Ζαχαρότευτλα, Ηλίανθος, Αραχίδα
V: Σιτηρά, Καλαμπόκι, Σόργο, Γραισίδια, Λεύκες VI: Τριφύλλι, Τεχν. Λειμώνες, Ακτινίδιο VII: Μηδική VIII: Ρύζι

Περιφέρεια Κρήτης
441 m³/στρέμμα
17.5 m³/δέντρο



This project is part of the PRIMA programme supported by the European Union.
GA n° [2041] [LENSES] [Call 2020 Section 1 Nexus IA]

Stakeholder Engagement

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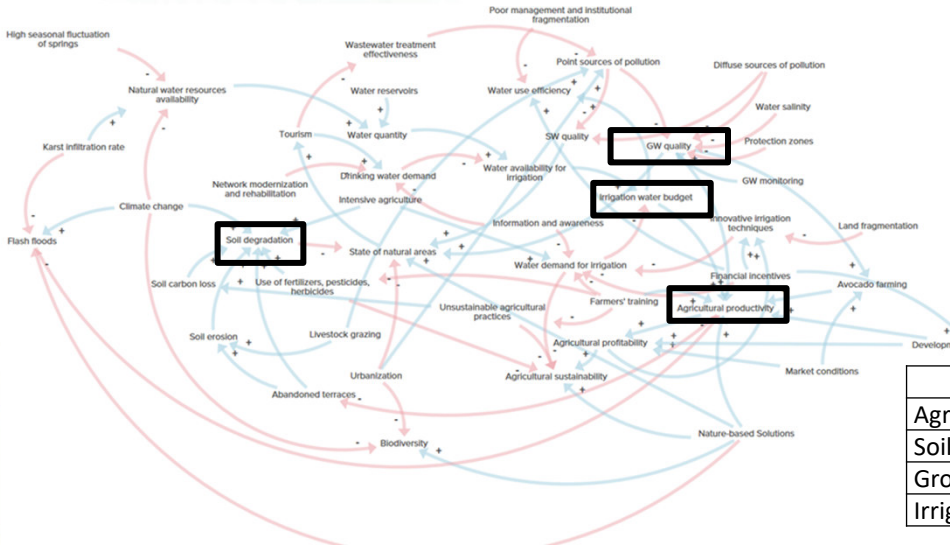
2. Causal Loop Diagram



Nexus challenges
Agricultural development
Soil degradation
Groundwater quality
Irrigation water budget

26

water

MDPI

Article

A Multi-Disciplinary Approach to Understand Hydrologic and Geochemical Processes at Koiliaris Critical Zone Observatory

Maria A. Lilli [1,*], Dionissis Efstathiou [1], Daniel Moraetis [2], Jonathan Schuite [3,4], Sofia D. Nerantzaki [1] and Nikolaos P. Nikolaidis [1]

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check for updates

Abstract: Koiliaris CZO is a European Critical Zone Observatory (CZO) typical of the Mediterranean karstic geomorphology, which represents watersheds affected by humans over the centuries. This study aims to provide information that underpins the hydrologic and geochemical processes functioning at Koiliaris CZO. Linking geomorphologic and tectonic analysis improved the delineation of a karstic area which extends outside of the Koiliaris watershed and identified how structural elements influence the regional hydrology. The fluctuation in the river flow represents processes occurring in the karst and the periodic signal is related to Earth tide stressing of the karstic reservoirs. The conceptualization of a two-reservoir, well-mixed karstic system is confirmed by both the geomorphologic and tidal analysis. The hydrologic response is fast and it is manifested especially during extreme events where 70% of the precipitation becomes surface runoff, creating major flood events. The different sampling sites in the Koiliaris CZO were geochemically clustered and the quantification of the weathering fluxes showed that 25 mm/1000 years and 39 mm/1000 years of carbonate were removed by chemical weathering for the Keramianos ephemeral river and the springs, respectively. These studies illustrate the importance of critical zone science and transdisciplinary studies on water and soil management.

Keywords: karst; critical zone; hydrology; geomorphology; tidal analysis; weathering rates

sustainability

MDPI

Article

Vision-Based Decision-Making Methodology for Riparian Forest Restoration and Flood Protection Using Nature-Based Solutions

Maria A. Lilli [1,*], Sofia D. Nerantzaki [1], Christos Riziotis [1], Manolis Kotronakis [1], Dionissis Efstathiou [1], Dimitris Kontakos [2,3], Petros Lymberakis [2], Manolis Avramakis [2], Antonis Tsakirakis [2], Konstantinos Protopapadakis [1] and Nikolaos P. Nikolaidis [1]

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Abstract: Nature-based solutions (NBS) are actions that use natural processes in a resource efficient manner to solve societal challenges. The lack of supportive legislature, and financial, communication and social barriers complicate the process of NBS implementation. It is an urgent need to develop approaches to design and implement NBS that would act as drivers to overcome potential barriers and enhance the social acceptability of the project. The vision-based decision-making methodology and participatory process created in this study has been carried out in the Koiliaris Critical Zone Observatory in Crete to design erosion and flood protection NBS and restore the riparian forest. The methodology consists of four distinct steps as follows: i) develop a vision of the area, ii) conduct a baseline assessment study, iii) NBS design and co-design, and iv) procurement and implementation. The methodology overcame multiple barriers because of the effective stakeholder engagement and the vision "drove" the project and created the necessary consensus that is necessary to achieve the objective of converting privately owned prime agricultural land to riparian forest. It offers an exemplar of a functional ecosystem restoration project that protects the river in a sustainable way, improves its biodiversity and water quality and improves the quality of life and social cohesion.

Keywords: nature-based solutions; climate change; ecological restoration; flood risk management; stakeholder involvement; decision-making

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forests

MDPI

Article

Riparian Forests as Nature-Based Solutions within the Mediterranean Context: A Biophysical and Economic Assessment for the Koiliaris River Watershed (Crete, Greece)

Mauro Masiero [1,*], Giorgia Bottaro [1], Caterina Righetti [1], Nikolaos P. Nikolaidis [2], Maria A. Lilli [2] and Davide Pettenella [1]

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Abstract: The Mediterranean Basin is severely impacted by anthropogenic changes affecting both natural ecosystems and human livelihoods. The region is highly vulnerable to natural hazards, with floods being considered the most important, due both to their frequency and impacts. Koiliaris watershed (northwest of Crete Island, Greece) represents a relevant case study as past land-use changes via deforestation and intense cultivation practices induce soil organic matter losses, making soils susceptible to water erosion and desertification. The restoration of native riparian forests has been identified as the most effective nature-based solution (NBS) for the area. Through modeling, our study assessed the effectiveness of this NBS in addressing flood risk and erosion while providing additional ecosystem services (carbon sequestration and biodiversity conservation). A cost–benefit analysis has been then implemented to also investigate the sustainability of the investment from an economic point of view. Our results show the NBS would be successful in ensuring a better flow of targeted ecosystem services compared to the business-as-usual conditions. The associated investment would result in economic sustainability and associated costs would be paid back in five years. Though site-specific, our study provides lessons learned for dealing with future land-restoration challenges in the Mediterranean to cope with climate change-related challenges.

Keywords: ecosystem services; flood; carbon; climate change; habitat; WEFE Nexus; hazards; cost–benefit analysis

Citation: Masiero, M.; Bottaro, G.; Righetti, C.; Nikolaidis, N.P.; Lilli, M.A.; Pettenella, D. Riparian Forests as Nature-Based Solutions within the Mediterranean Context: A Biophysical and Economic Assessment for the Koiliaris River Watershed (Crete, Greece). *Forests* **2024**, *15*, 760. https://doi.org/10.3390/f15050760

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frontiers | Frontiers in Water

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Optimizing the water-ecosystem-food nexus using nature-based solutions at the basin scale

Antonia Maragkaki, Evangelia A. Koukianaki, Maria A. Lilli*, Dionissis Efstathiou and Nikolaos P. Nikolaidis

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The water ecosystem food (WEF) nexus duly acknowledges the complex interdependencies among water, ecosystems, and food production, underscoring nature based solutions (NBS) as an efficacious strategy for navigating these interconnections. In this research, four different NBS (terraces, riparian forest, livestock management and agro ecological practices) were assessed in terms of their impact to WEF nexus. The Karst-SWAT and the one-dimensional integrated critical zone (1D-ICZ) models were used to simulate the impact of NBS on water quantity and quality as well as on soil ecosystem services of Koiliaris River Basin, which serves as an illustrative example of a basin that has experienced severe soil and biodiversity degradation. The Karst-SWAT model showed that a combination of NBS of terraces and riparian forest can reduce soil erosion and the sediment load by 97%. The 1D-ICZ model successfully simulated the soil-plant-water system and showed that agro ecological practices affect biomass production, carbon and nutrient sequestration, soil structure and geochemistry.

Sustainability **2020**, 12, 3305; doi:10.3390/su12083305

sustainability

MDPI

Article

Vision-Based Decision-Making Methodology for Riparian Forest Restoration and Flood Protection Using Nature-Based Solutions

Maria A. Lilli [1,*], Sofia D. Nerantzaki [1], Christos Riziotis [1], Manolis Kotronakis [1], Dionissis Efstathiou [1], Dimitris Kontakos [2,3], Petros Lymberakis [2], Manolis Avramakis [2], Antonis Tsakirakis [2], Konstantinos Protopapadakis [1] and Nikolaos P. Nikolaidis [1]

Ecosystem Restoration NBS Case Study

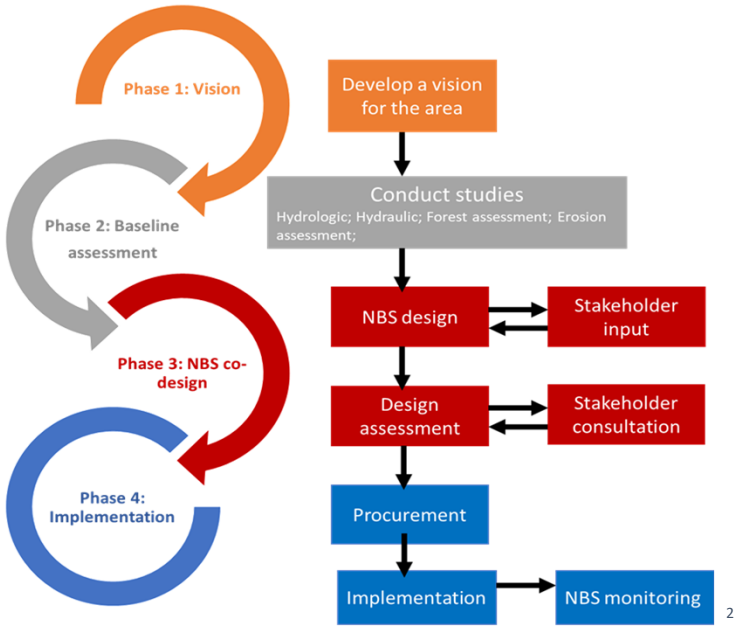
Koiliaris CZO – Riparian Forest Restoration and Flood Protection

1

Decision-making methodology scheme for NBS implementation

Objective:

Develop a vision-based decision-making approach to designing and implementing NBS that would act as a driver to overcome potential barriers and enhance the social acceptability of the project.



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2

Phase 1 – Developing the Vision

3

4


Erosion has been identified as a major problem for the riparian forest.

5


Nature-Based Solution
Orange tree vs Sycamore Tree Roots

6

Phase 1 – Developing the vision

The vision of the project was to develop bank erosion protection and flood protection using NBS and restore the extent of the riparian forest to 20 m on both sides of the river, creating a 5-km riparian forest corridor that will become the trade mark for the agricultural development of the area.

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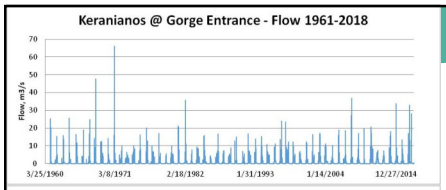
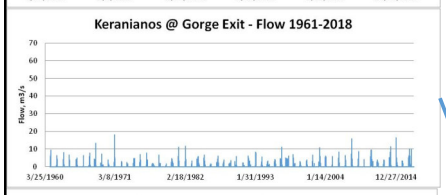
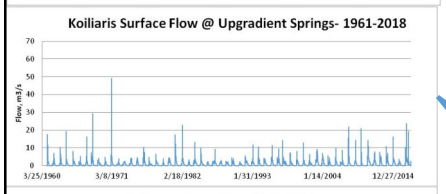
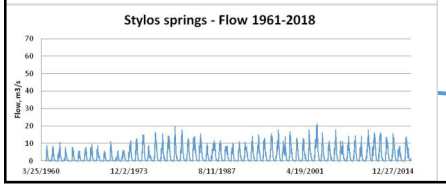
Phase 2 – Baseline assements

8

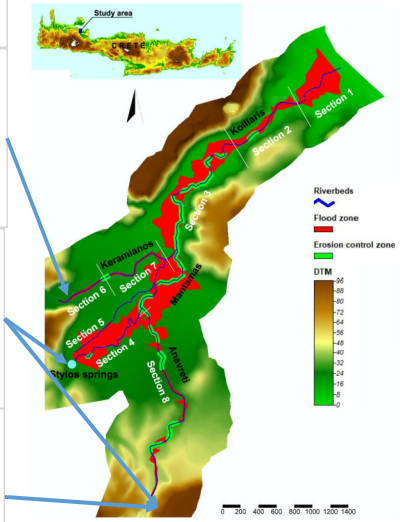


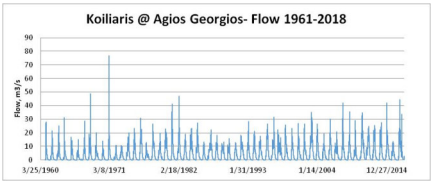






Karst-SWAT (Hydrology), HEC-RAC (Hydraulics), BSTEM (Bank Erosion)



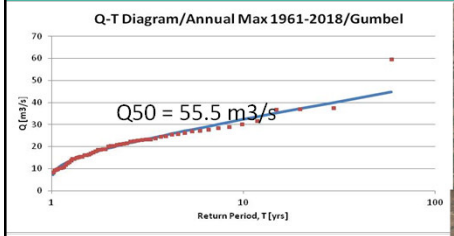


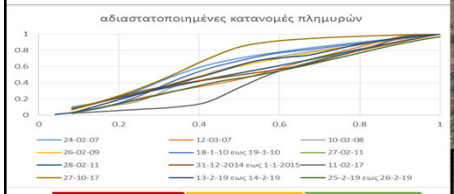
Modeling 1961-2018	Average Flow (Mm3/yr)
Keramianos tributary	10.1
Stylos Spring	58.5
Anavreti Spring and runoff	69.9
Total Flow	138.5

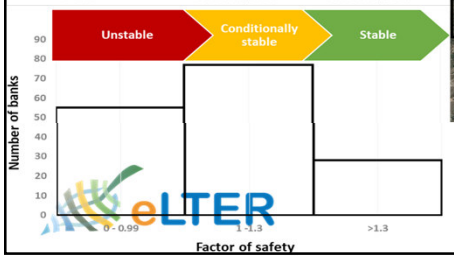
9

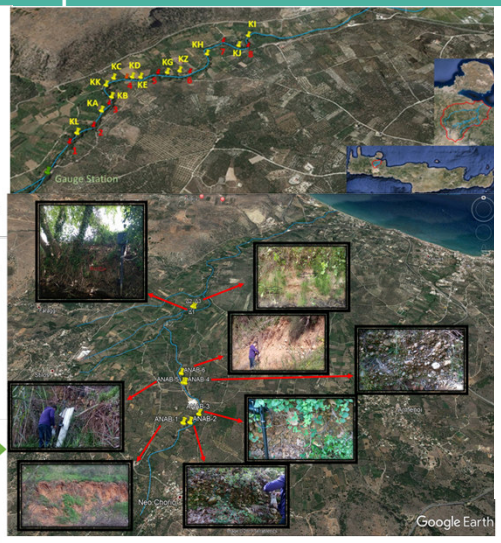
9

River bank erosion and riparian forest studies



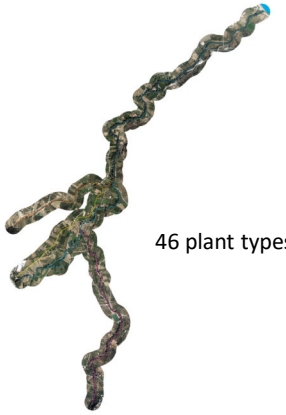






River bank measurements

Riparian forest studies



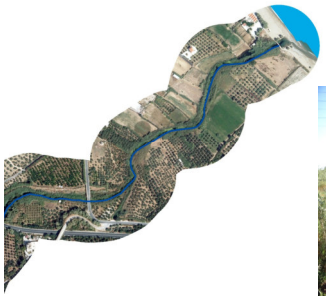
46 plant types

12 allochthones
34 autochthones

10

10

Part 1 - Arundo donax *and* Phragmites australis.



Part 2 - Arundo donax *flowed by Sicamore and white willows*

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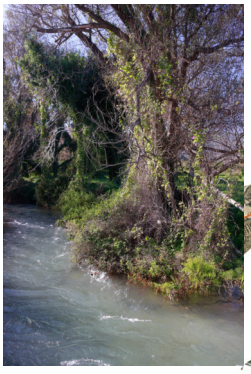
Part 3 – Riparian forest of Sicamore and White Willow

Part 4 Riparian vegetation with white willows *(*Salix alba*) and sycamore trees (*Platanus orientalis*) interrupted by agricultural fields*



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Phase 3 – NBS co-design

13

Phase 3 – Co-design of NBS

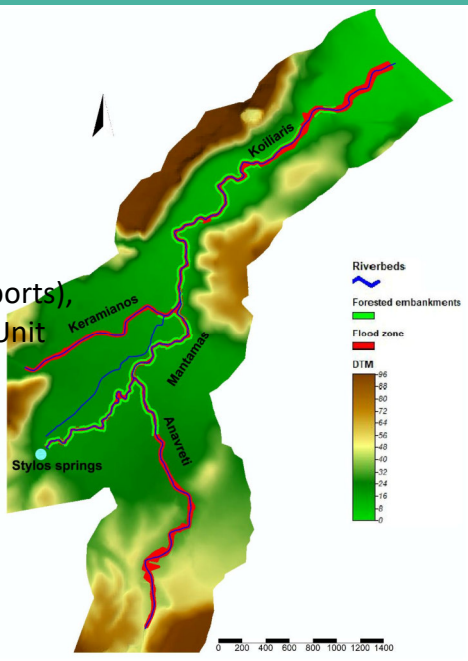
Stakeholders

Municipality of Apokoronas
Municipality of Apokoronas Council (4 major parties)
The Departments of the Decentralized Administration:
- Environment and Spatial Planning
- Water Division and
- Forestry

Ephorate of Antiquities of Chania (Ministry of Culture and Sports),
Environmental and Water Resources Unit –Chania Regional Unit
Regional Council

Local Farmer's Association
Development Organization of Crete
Various related NGOs

Ministry of Environment



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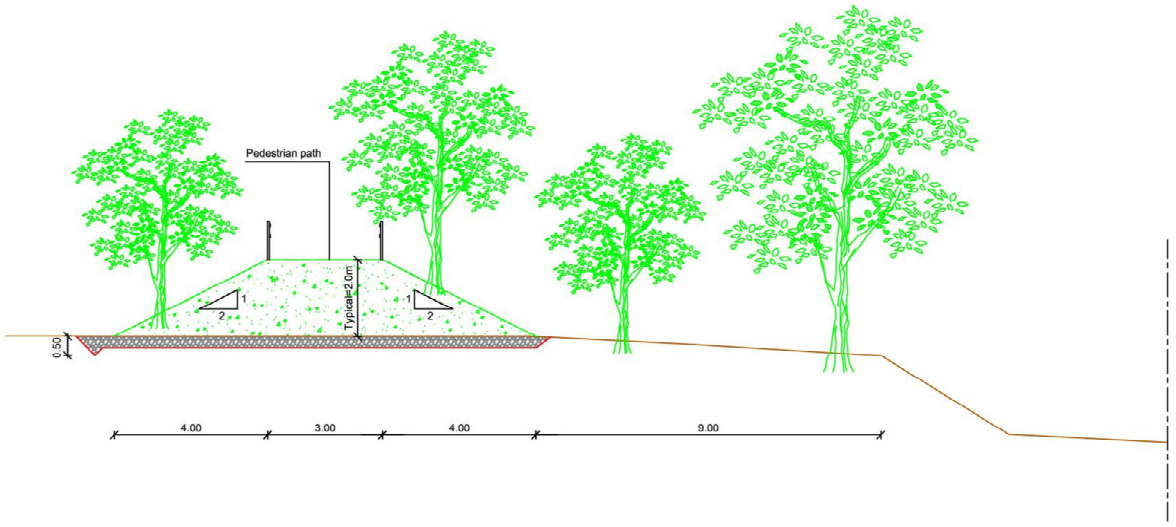
Design of flood protection and restoration riparian forest



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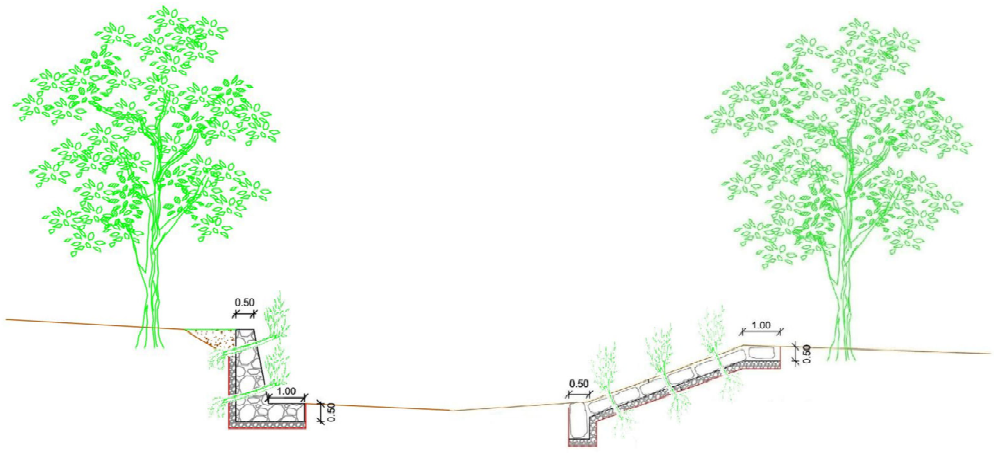
Design of the restoration of the eroded banks with vegetated walls and rip-raps



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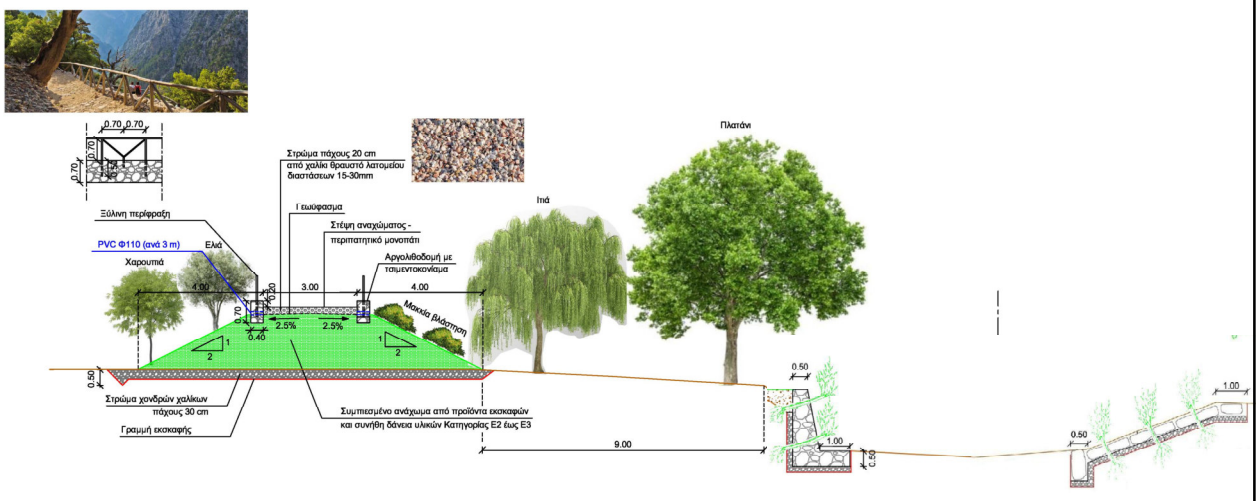
Design of the restoration of the eroded banks with vegetated walls and rip-raps



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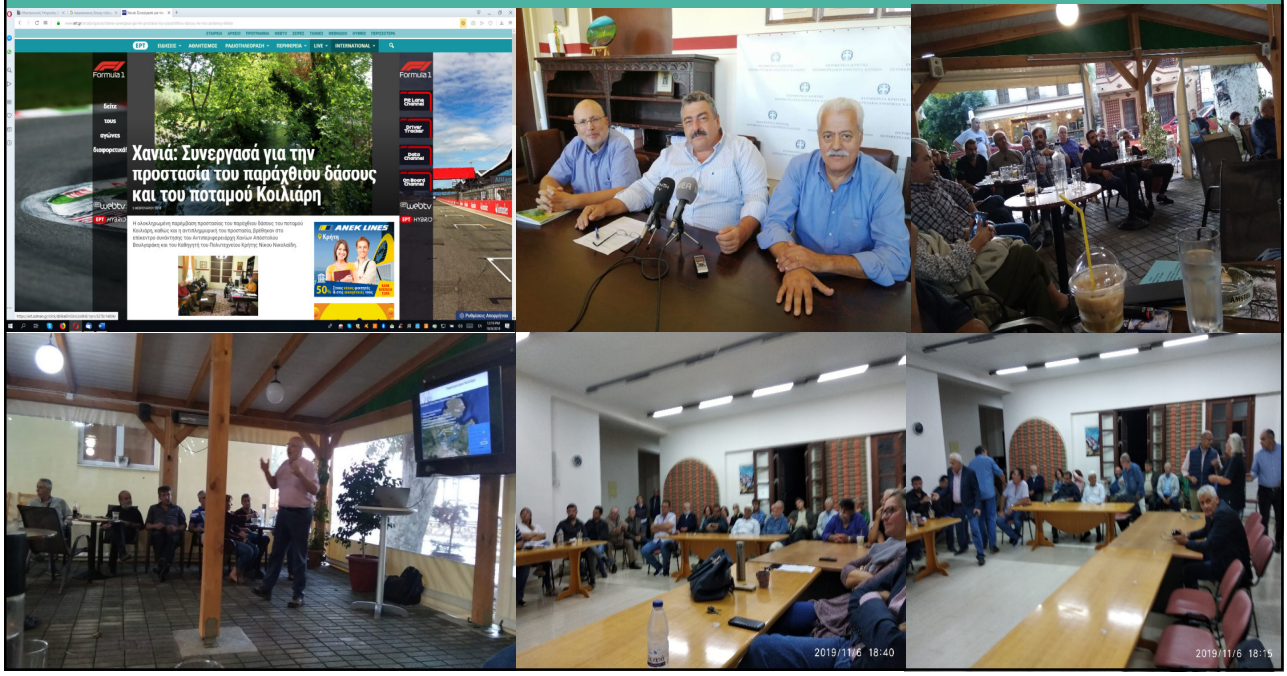
Public Consultation



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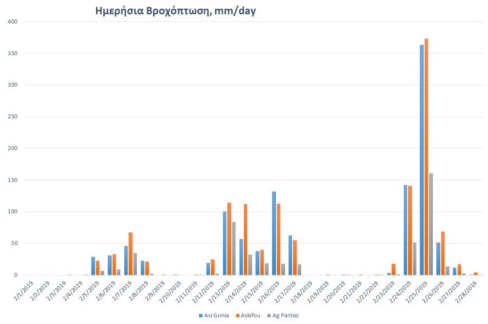
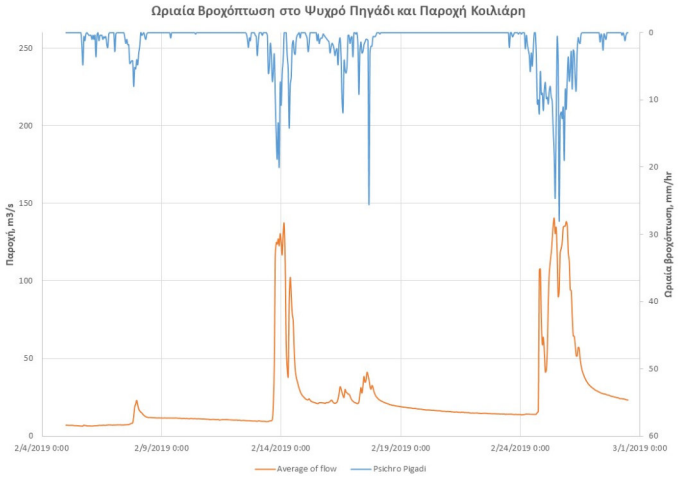
February 2019 Floods

	12-17/2/2019	24-27/2/2019
Ασή Γωνιά	408	569
Ασκύφου	458	604.2
Αγιοι Πάντες	172.2	229.4
Ψυχρό Πηγάδι	346.6	433





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February 2019 Floods

20

February 2019 Floods

21

Phase 4 – Implementation

22

Phase 4 - Implementation

1. Have obtain **approval of the Environmental Impact Study from the Ministry of Environment and waiting for the publication of the delineation of the flood area in the government gazette.** from various Departments of the Decentralized Administration of Crete - The procurement details with the estimated cost have been prepared for the tender.

2. Securing **funding** (around EUR 5.5 million) - The project can be included in the funding of the structural funds, or obtain national funding

Benefit-Cost Analysis

NPV (€)	B/C	IRR	PB
11,364,940	7.67	40.49%	5

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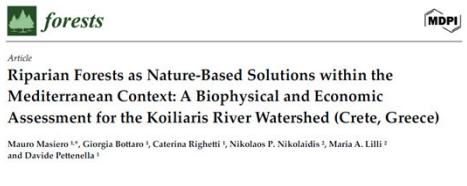
forests MDPI

Article

Riparian Forests as Nature-Based Solutions within the Mediterranean Context: A Biophysical and Economic Assessment for the Koiliaris River Watershed (Crete, Greece)

Mauro Masiero [1,*], Giorgia Bottaro [1], Caterina Righetti [1], Nikolaos P. Nikolaidis [2], Maria A. Lilli [2] and Davide Pettenella [1]

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Key performance indicators per NBS challenge to be solved for Koiliaris CZO

NBS challenge	Indicators	Current Impact	Expected Impact
Climate mitigation and adaptation	Carbon storage and sequestration in vegetation and soil	Low density agricultural vegetation, limited riparian forest and 1-2% org soil carbon	40 m length high density riparian forest, soil carbon to increase to 3-4% at maturity.
Water management	Reduction of flood risk	None	50-year flood or maximum hourly flow of 127 m^3/s
	Areas (ha) exposed to flooding	56	31
Participatory planning and governance	Number of meetings held with citizens to explain the progress of the project	2 meeting during the design phase and 1 with municipality	To be determined
	Numbers of persons involved in the activities carried out under the project	50 people per meeting	To be determined
	Number of public officials who have been involved in the execution of activities in the execution of the project	Mayor, Municipality Council, Deputy Governor of Chania, Regional officials	Mayor, Municipality Council, Deputy Governor of Chania, Regional officials
Public health & well-being	Increase in walking and cycling in and around areas of interventions	Minimum	High
Potential of economic opportunities and green jobs	New businesses attracted	Minimum	High

24

Benefits and co-benefits

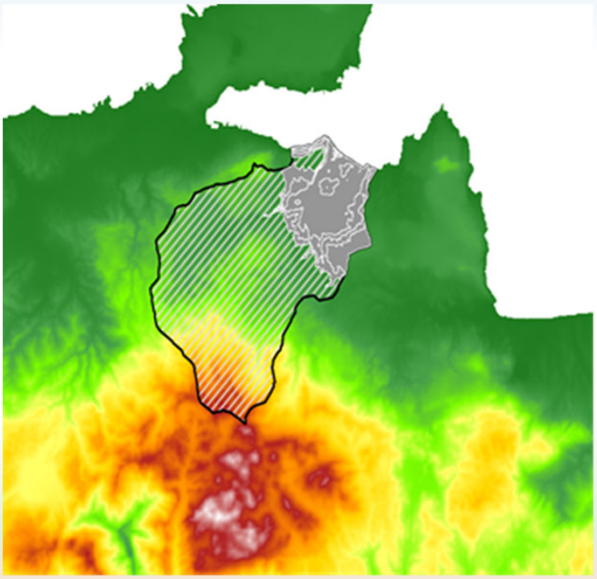
- Protection of the river in a sustainable way
- Improvement of river and riparian biodiversity
- High ecological value recreational area
- Improvement of quality of life and social cohesion
- Collaboration of tourism and agricultural sectors with the potential of new job creation
- Creation of riparian forest by reclaiming agricultural land – it is the reference point for agricultural development of unique and high quality agricultural products – marketing tool

25

26

Nexus Labs

Living Lab Koiliaris CZO



TECHNICAL UNIVERSITY OF CRETE

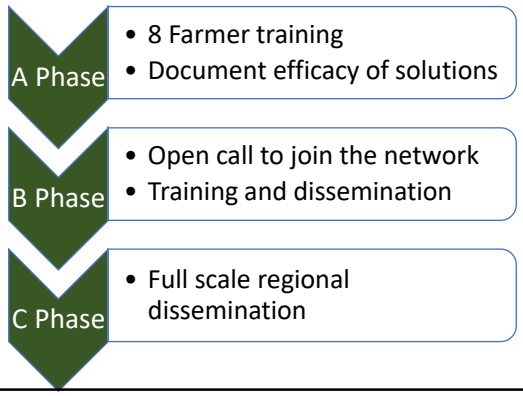
PRIMA

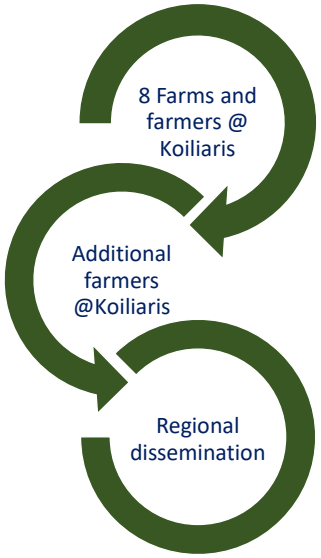
Grant agreement No. 2422

1

Stakeholders

- **Stakeholder mapping & engagement**:
  - 8 farms and farmers – key stakeholders
  - Additional farmers and regional stakeholders





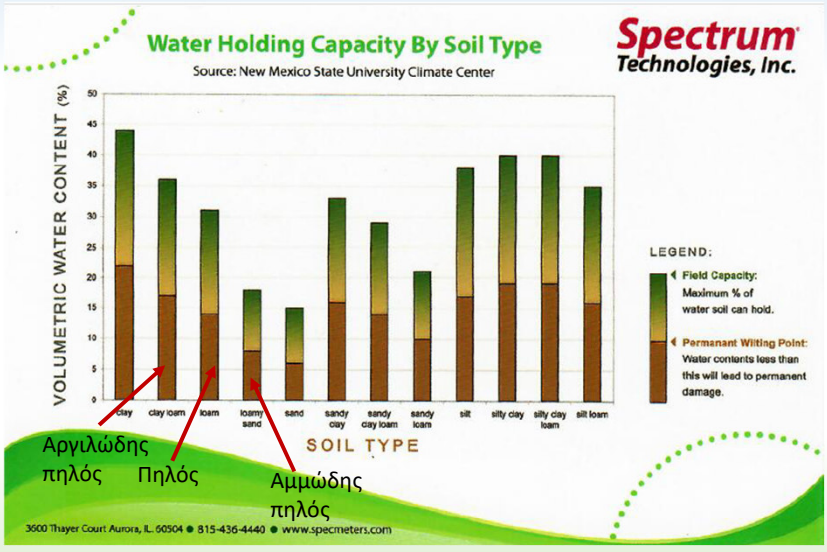
PRIMA

2

Smart Irrigation

3

Εδαφική Υγρασία

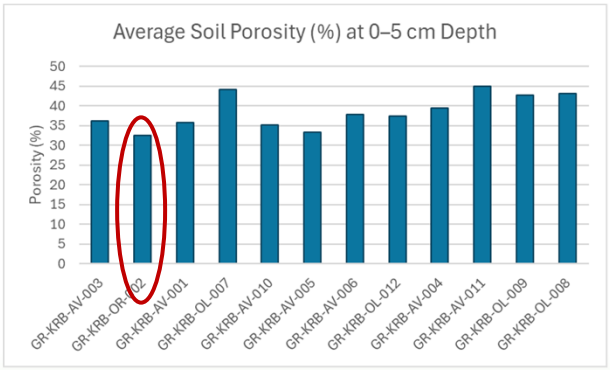


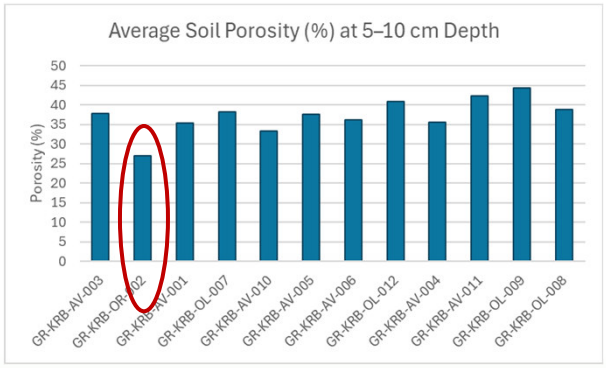
Field capacity -

Permanent Wilting point –

4

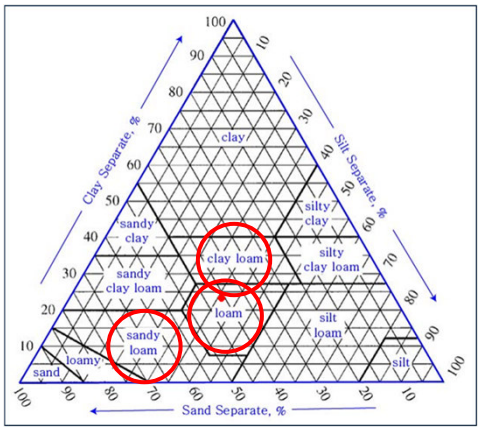
Soil Moisture

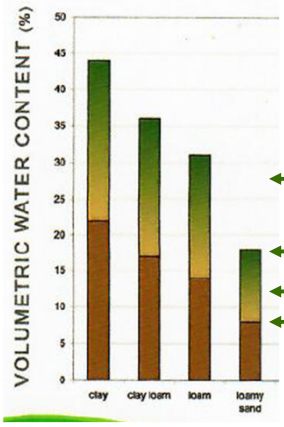




5

Soil Moisture





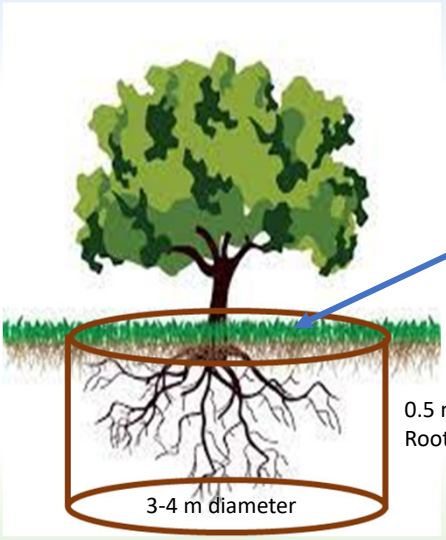
Porosity

Field Capacity

Άρδευση
Wilting Point

6

Soil Moisture



Volume of cylinder
$(\pi*3^2/4)*0.5 = 3.5\ m^3$
$(\pi*4^2/4)*0.5 = 6.3\ m^3$
Πορώδες 30-40%

Pore volume =
$1.1 – 1.4\ m^3$
$1.9 – 2.5\ m^3$

7

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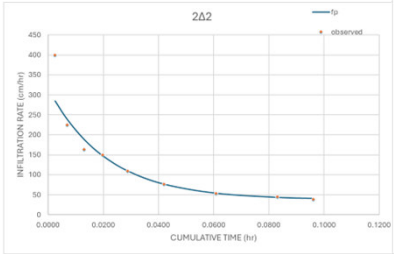
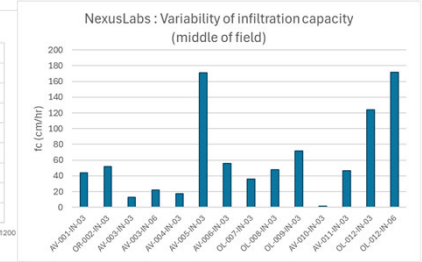
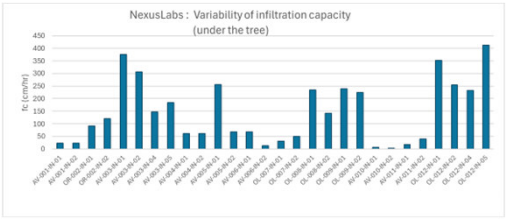
Infiltration experiments

Infiltration Experiments
and Field Variability

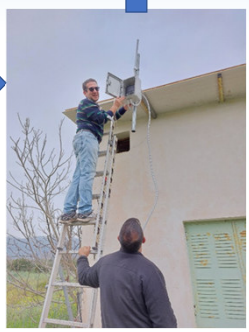


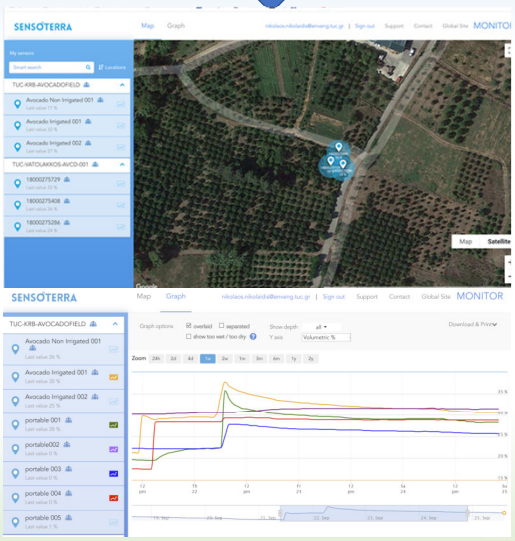




8

Optimize Irrigation





9

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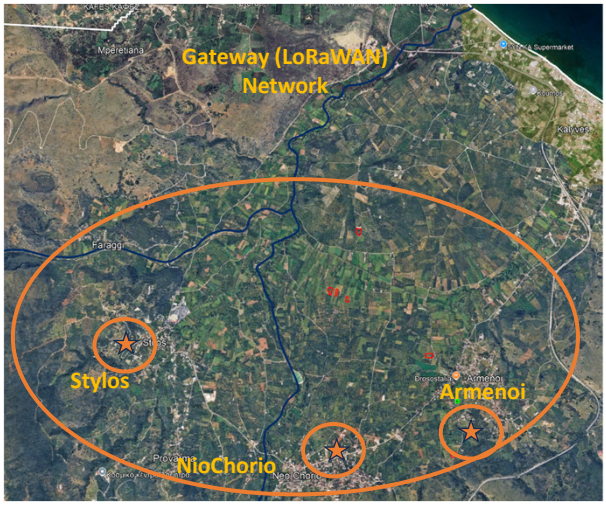
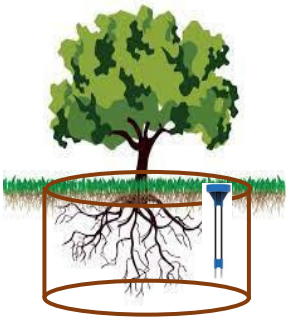
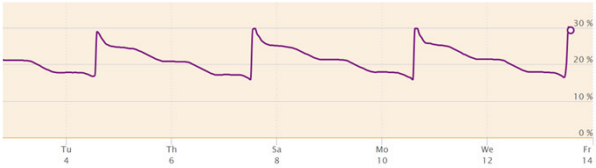
Soil Moisture



"water the tree and not the field"





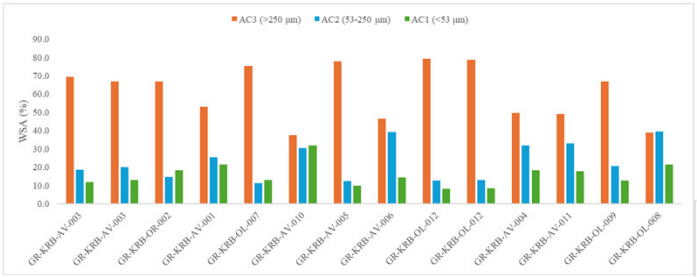
Organic carbon, water stable aggregates, and soil fertility

11

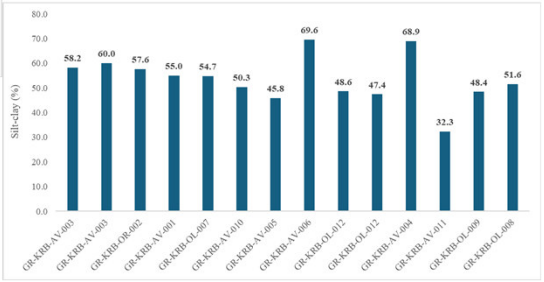
Living Lab Koiliaris CZO

Soil Structure and Water Stable Aggregates

Water Stable Aggregate Fractionation

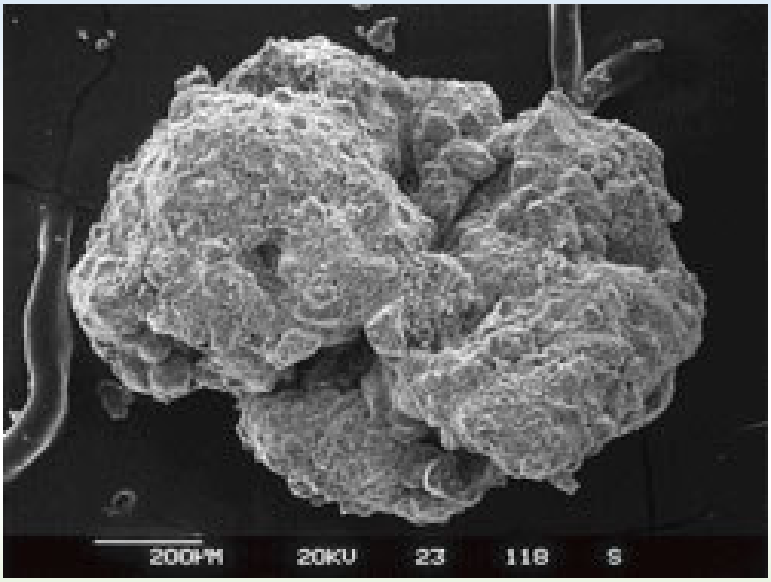


Silt-Clay Content



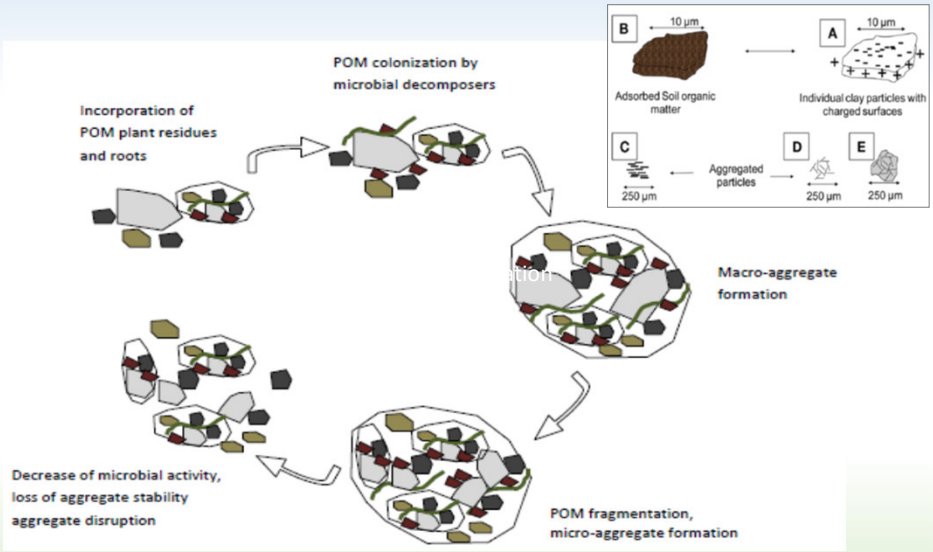
12

The "Golden Aggregate"



13

Conceptual model of aggregate formation



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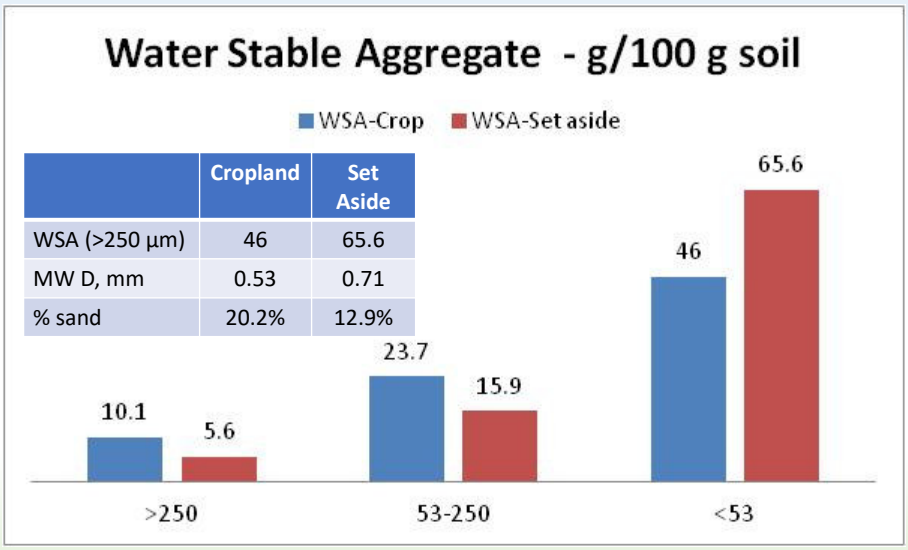
Water Stable Aggregate Formation



	Cropland	Set Aside
WSA (>250 µm)	46	65.6
MW D, mm	0.53	0.71
% sand	20.2%	12.9%

Stamati et al., 2011

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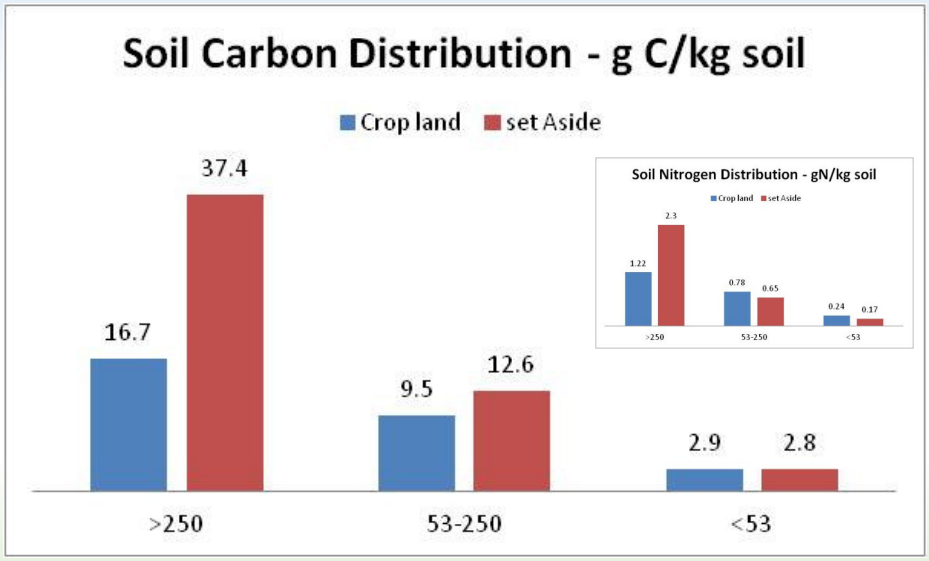
Water Stable Aggregate Formation



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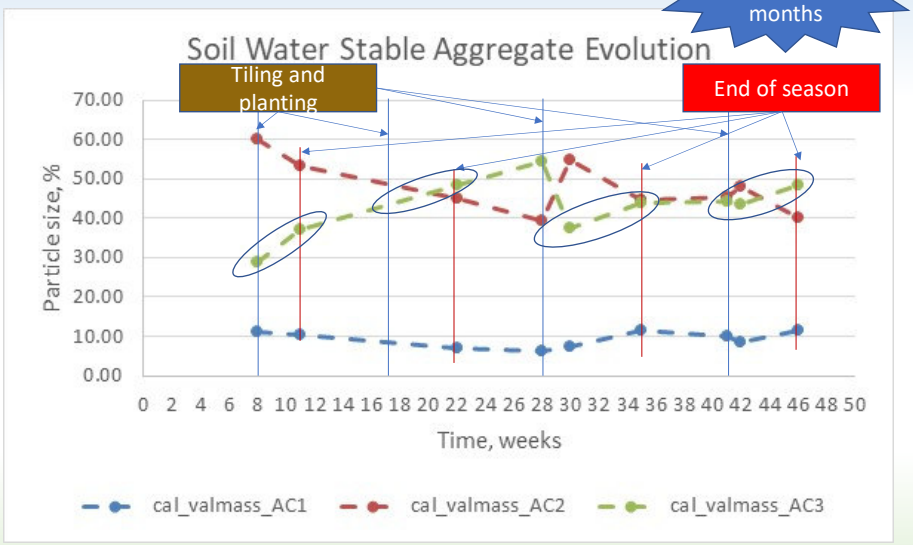
How fast is aggregation happening?

Very fast – weeks to months



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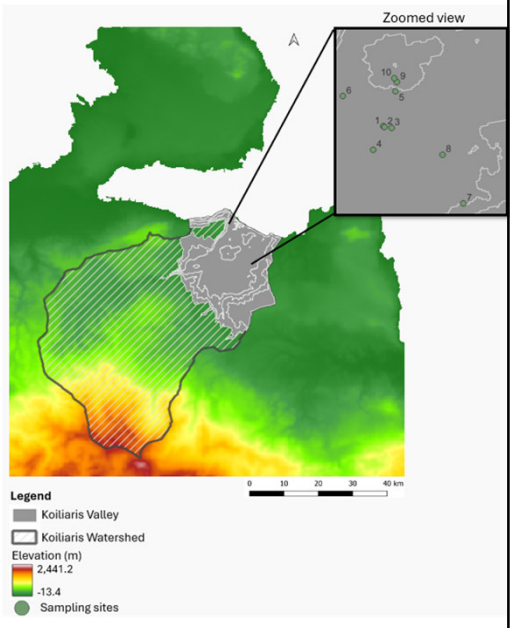
Activities

- **Key progress and activities**:
  - Analysis of soil samples (12 fields)
  - Soil infiltration (3X/field)
  - Porosity, bulk density, Soil Organic carbon and nitrogen
  - Water stable aggregate fractionation
  - Cations and heavy metals
  - Water retention capacity using pedotransfer functions



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Soil chemistry

ΑΝΑΛΥΣΗ ΦΥΣΙΚΟΧΗΜΙΚΩΝ & ΥΔΡΟΛΟΓΙΚΩΝ ΙΔΙΟΤΗΤΩΝ ΕΔΑΦΟΥΣ

Αγροτεμάχιο # GR-KRB-AV-004- Έκθεση Μετρήσεων Εδάφους

Εκπονήθηκε από: Πολυτεχνείο Κρήτης (TUC) – H.E.R.S. LAB

Χρηματοδότηση: Το έργο χρηματοδοτείται από το πρόγραμμα PRIMA της Ε.Ε.

Ιδιοκτήτης Αγροτεμαχίου: Καραγιαννάκης Παντελής

Είδος Καλλιέργειας: Αβοκάντο

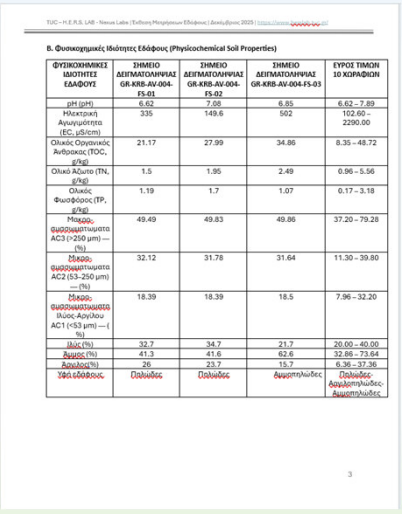
Ημερομηνία: Φεβρουάριος 2025

ΕΚΤΑΣΗ ΑΓΡΟΤΕΜΑΧΙΟΥ : 1244 m²

ΗΜΕΡΟΜΗΝΙΑ ΣΥΛΛΟΓΗΣ ΔΕΙΓΜΑΤΩΝ : Ιανουάριος 2026

Α. Στοιχεία Δειγματοληψίας (Sampling Information)

Κωδικός δείγματος	Γεωγραφικό πλάτος	Γεωγραφικό μήκος
GR-KRB-AV-004-FS-01	35.436530	24.144630
GR-KRB-AV-004-FS-02	35.436445	24.144666
GR-KRB-AV-004-FS-03	35.436271	24.144700



Β. Φυσικοχημικές Ιδιότητες Εδάφους (Physicochemical Soil Properties)

ΦΥΣΙΚΟΧΗΜΙΚΕΣ ΙΔΙΟΤΗΤΕΣ ΕΔΑΦΟΥΣ	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-01	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-02	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-03	ΕΥΡΟΣ ΤΙΜΩΝ 10 ΧΩΡΑΦΙΩΝ
pH (pH)	6.62	7.08	6.85	6.62 – 7.89
Ηλεκτρική Αγωγιμότητα (EC, μS/cm)	335	149.6	502	102.60 – 2290.00
Ολικός Οργανικός Άνθρακας (TOC, g/kg)	21.17	27.99	34.86	8.35 – 48.72
Ολικό Άζωτο (TN, g/kg)	1.5	1.95	2.49	0.96 – 5.56
Ολικός Φωσφόρος (TP, g/kg)	1.19	1.7	1.07	0.17 – 3.18
Μακρο-συσσωματώματα AC3 (>250 μm) — (%)	49.49	49.83	49.86	37.20 – 79.28
Μακρο-συσσωματώματα AC2 (53–250 μm) — (%)	32.12	31.78	31.64	11.30 – 39.80
Μακρο-συσσωματώματα Ιλυώς Αργίλου AC1 (<53 μm) — (%)	18.39	18.39	18.5	7.96 – 32.20
Ιλύς (%)	32.7	34.7	21.7	20.00 – 40.00
Άμμος (%)	41.3	41.6	62.6	32.86 – 73.64
Άργιλος (%)	26	23.7	15.7	6.36 – 37.36
Υφή εδάφους	Πηλώδες	Πηλώδες	Αμμοπηλώδες	Πηλώδες-Αργιλοπηλώδες-Αμμοπηλώδες

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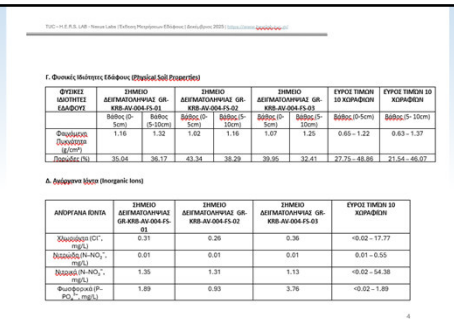
Soil chemistry

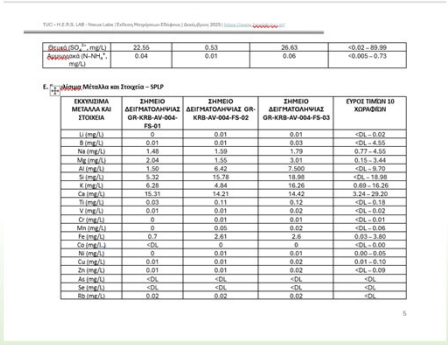


Γ. Φυσικές Ιδιότητες Εδάφους (Physical Soil Properties)

ΦΥΣΙΚΕΣ ΙΔΙΟΤΗΤΕΣ ΕΔΑΦΟΥΣ	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-01		ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-02		ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-03		ΕΥΡΟΣ ΤΙΜΩΝ 10 ΧΩΡΑΦΙΩΝ	ΕΥΡΟΣ ΤΙΜΩΝ 10 ΧΩΡΑΦΙΩΝ
	Βάθος (0-5cm)	Βάθος (5-10cm)	Βάθος (0-5cm)	Βάθος (5-10cm)	Βάθος (0-5cm)	Βάθος (5-10cm)	Βάθος (0-5cm)	Βάθος (5-10cm)
Φαινόμενη Πυκνότητα (g/cm³)	1.16	1.32	1.02	1.16	1.07	1.25	0.65 – 1.22	0.63 – 1.37
Πορώδες (%)	35.04	36.17	43.34	38.29	39.95	32.41	27.75 – 48.86	21.54 – 46.07

Δ. Ανόργανα Ιόντα (Inorganic Ions)

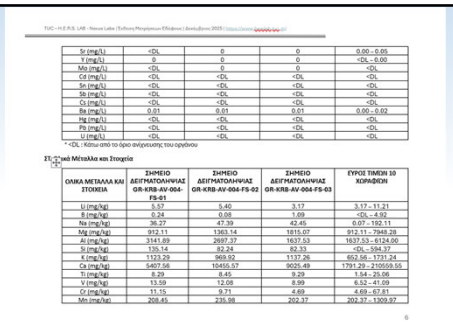
ΑΝΟΡΓΑΝΑ ΙΟΝΤΑ	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-01	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-02	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-03	ΕΥΡΟΣ ΤΙΜΩΝ 10 ΧΩΡΑΦΙΩΝ
Χλωρίωση (Cl^-, mg/L)	0.31	0.26	0.36	<0.02 – 17.77
Νιτρώδη ($N\text{-}NO_2^-$, mg/L)	0.01	0.01	0.01	0.01 – 0.55
Νιτρικά ($N\text{-}NO_3^-$, mg/L)	1.35	1.31	1.13	<0.02 – 54.38
Φωσφορικά ($P\text{-}PO_4^{3-}$, mg/L)	1.89	0.93	3.76	<0.02 – 1.89



Θειικά (SO_4^{2-}, mg/L)	22.55	0.53	26.63	<0.02 – 89.99
Αμμωνιακά ($N\text{-}NH_4^+$, mg/L)	0.04	0.01	0.06	<0.005 – 0.73

Ε. Συνολικά Μέταλλα και Στοιχεία – SPLP

ΕΚΧΥΛΙΣΙΜΑ ΜΕΤΑΛΛΑ ΚΑΙ ΣΤΟΙΧΕΙΑ	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-01	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-02	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-03	ΕΥΡΟΣ ΤΙΜΩΝ 10 ΧΩΡΑΦΙΩΝ
Li (mg/L)	0	0.01	0.01	<DL – 0.02
B (mg/L)	0.01	0.01	0.03	<DL – 4.55
Na (mg/L)	1.48	1.59	1.79	0.77 – 4.55
Mg (mg/L)	2.04	1.55	3.01	0.15 – 3.44
Al (mg/L)	1.56	6.42	7.500	<DL – 9.70
Si (mg/L)	5.32	15.78	18.98	<DL – 18.98
K (mg/L)	6.28	4.84	16.26	0.69 – 16.26
Ca (mg/L)	15.31	14.21	14.42	3.24 – 29.20
Ti (mg/L)	0.03	0.11	0.12	<DL – 0.18
V (mg/L)	0.01	0.01	0.02	<DL – 0.02
Cr (mg/L)	0	0.01	0.01	<DL – 0.01
Mn (mg/L)	0	0.05	0.02	<DL – 0.06
Fe (mg/L)	0.7	2.61	2.6	0.03 – 3.80
Co (mg/L)	<DL	0	0	<DL – 0.00
Ni (mg/L)	0	0.01	0.01	0.00 – 0.05
Cu (mg/L)	0.01	0.01	0.02	0.01 – 0.10
Zn (mg/L)	0.01	0.01	0.02	<DL – 0.09
As (mg/L)	<DL	<DL	<DL	<DL
Se (mg/L)	<DL	<DL	<DL	<DL
Rb (mg/L)	0.02	0.02	0.02	<DL

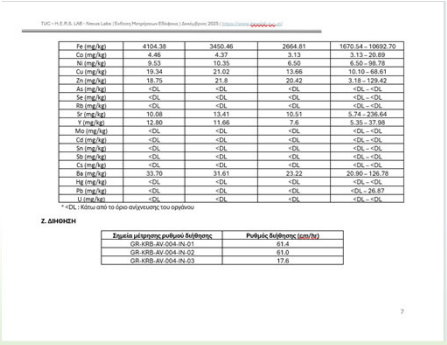


Sr (mg/L)	<DL	0	0	0.00 – 0.05
Y (mg/L)	0	0	0	<DL – 0.00
Mo (mg/L)	<DL	0	0	<DL
Cd (mg/L)	<DL	<DL	<DL	<DL
Sn (mg/L)	<DL	<DL	<DL	<DL
Sb (mg/L)	<DL	<DL	<DL	<DL
Cs (mg/L)	<DL	<DL	<DL	<DL
Ba (mg/L)	0.01	0.01	0.01	0.00 – 0.02
Hg (mg/L)	<DL	<DL	<DL	<DL
Pb (mg/L)	<DL	<DL	<DL	<DL
U (mg/L)	<DL	<DL	<DL	<DL

* <DL - Κάτω από το όριο ανίχνευσης του οργάνου

ΣΤ. Συνολικά Μέταλλα και Στοιχεία

ΟΛΙΚΑ ΜΕΤΑΛΛΑ ΚΑΙ ΣΤΟΙΧΕΙΑ	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-01	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-02	ΣΗΜΕΙΟ ΔΕΙΓΜΑΤΟΛΗΨΙΑΣ GR-KRB-AV-004-FS-03	ΕΥΡΟΣ ΤΙΜΩΝ 10 ΧΩΡΑΦΙΩΝ
Li (mg/kg)	5.57	5.46	3.17	3.17 – 11.21
B (mg/kg)	0.24	0.08	1.09	<DL – 4.92
Na (mg/kg)	36.27	47.39	42.45	0.07 – 192.11
Mg (mg/kg)	912.11	1363.14	1815.07	912.11 – 7948.28
Al (mg/kg)	3141.89	2697.37	1637.53	1637.53 – 6124.00
Si (mg/kg)	135.14	92.24	82.33	<DL – 594.37
K (mg/kg)	1323.29	969.92	1137.26	652.56 – 1731.24
Ca (mg/kg)	5407.56	10455.57	9025.49	1791.29 – 210559.55
Ti (mg/kg)	8.29	8.45	9.29	1.54 – 25.06
V (mg/kg)	13.59	12.08	8.99	6.52 – 41.09
Cr (mg/kg)	11.15	9.71	4.69	4.69 – 67.81
Mn (mg/kg)	208.45	235.98	202.37	202.37 – 1309.97



Fe (mg/kg)	4104.38	3450.46	2664.81	1670.54 – 10692.70
Co (mg/kg)	4.46	4.37	3.13	3.13 – 20.89
Ni (mg/kg)	9.53	10.35	6.50	6.50 – 98.78
Cu (mg/kg)	19.34	21.02	13.66	10.19 – 68.61
Zn (mg/kg)	18.75	21.8	20.42	3.18 – 129.42
As (mg/kg)	<DL	<DL	<DL	<DL – <DL
Se (mg/kg)	<DL	<DL	<DL	<DL – <DL
Rb (mg/kg)	<DL	<DL	<DL	<DL – <DL
Sr (mg/kg)	10.68	13.41	10.51	5.74 – 236.64
Y (mg/kg)	12.80	11.66	7.6	5.35 – 37.98
Mo (mg/kg)	<DL	<DL	<DL	<DL – <DL
Cd (mg/kg)	<DL	<DL	<DL	<DL – <DL
Sn (mg/kg)	<DL	<DL	<DL	<DL – <DL
Sb (mg/kg)	<DL	<DL	<DL	<DL – <DL
Cs (mg/kg)	<DL	<DL	<DL	<DL – <DL
Ba (mg/kg)	33.79	31.61	23.22	20.90 – 126.78
Hg (mg/kg)	<DL	<DL	<DL	<DL – <DL
Pb (mg/kg)	<DL	<DL	<DL	<DL – 26.87
U (mg/kg)	<DL	<DL	<DL	<DL – <DL

* <DL - Κάτω από το όριο ανίχνευσης του οργάνου

Ζ. ΔΙΗΘΗΣΗ

Σημεία μέτρησης ρυθμού διήθησης	Ρυθμός διήθησης (cm/hr)
GR-KRB-AV-004-IN-01	61.4
GR-KRB-AV-004-IN-02	61.0
GR-KRB-AV-004-IN-03	17.6

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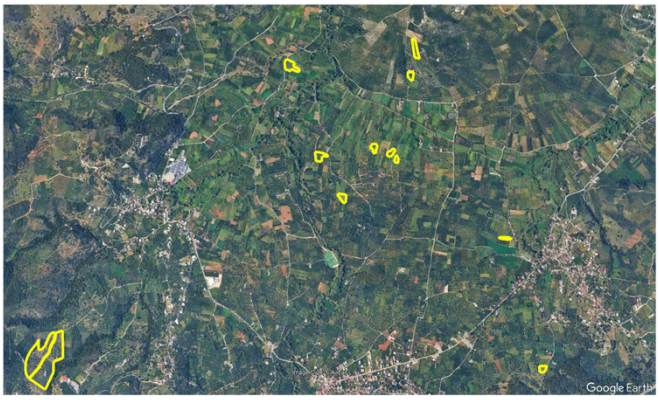
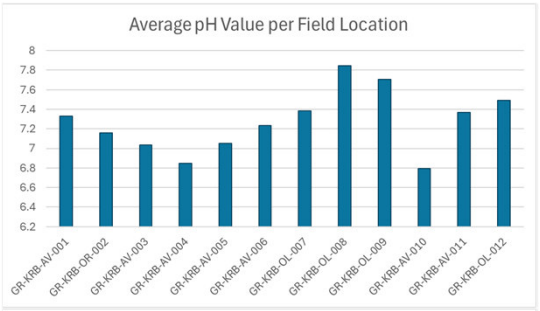
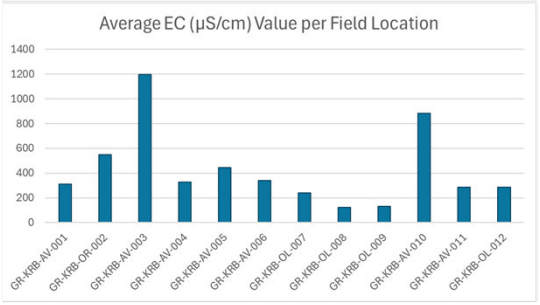
Soil chemistry







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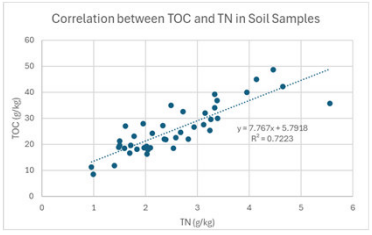
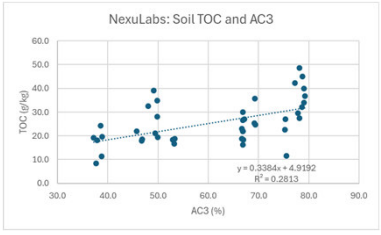
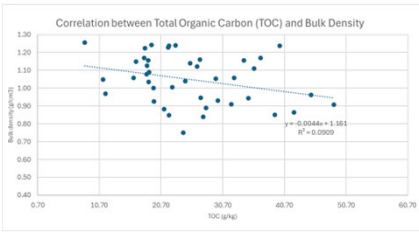
Soil Fertility



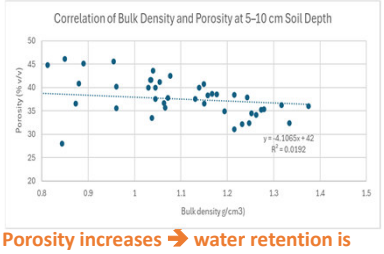
Organic matter increase soil TN and TOC



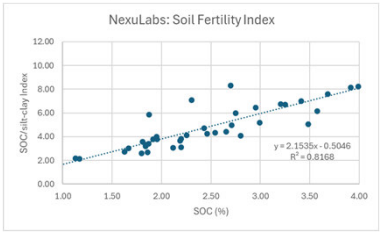
Microorganisms are being activated and create water stable aggregates and soil structure



Soil bulk density decreases ➔ the soil becomes lighter



Porosity increases ➔ water retention is increasing ➔ soil structure is improving



Soil fertility is increasing

Agro-ecological practices improve the Water-Fertility-Biodiversity of the soil

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Soil carbon and available water content

Check for updates

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Soil Science Society of America Journal

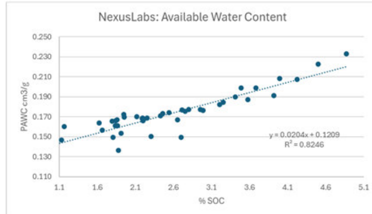
SOIL PHYSICS & HYDROLOGY

Carbon-sensitive pedotransfer functions for plant available water

Dianna K. Bagnall[1] | Cristine L. S. Morgan[1] | Michael Cope[1] | Gregory M. Bean[1] | Shannon Cappellazzi[1] | Kelsey Greub[1] | Daniel Liptzin[1] | Charlotte L. Norris[1] | Elizabeth Rieke[1] | Paul Tracy[1] | Ezra Aberle[2] | Amanda Ashworth[3] | Oscar Bañuelos Tavarez[4] | Andy Bary[5] | R. Louis Baumhardt[6] | Alberto Borbón Gracia[7] | Daniel Brainard[8] | Jameson Brennan[9] |

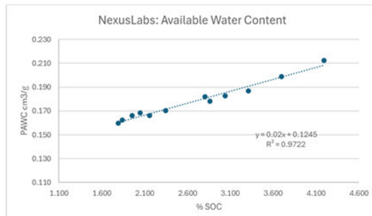
$$\theta_{PWP,calc} = 7.907 + 0.236Clay - 0.082Sand + 0.441SOC + 0.002\,(Clay \times Sand) \quad (3)$$

$$\theta_{FC,calc} = 33.351 + 0.020Clay - 0.446Sand + 1.398SOC + 0.052\,(Sand \times SOC) - 0.077\,(Clay \times SOC) + 0.011\,(Clay \times Sand) \quad (4)$$



Using USA Pedo-transfer Functions

1% increase in SOC ➔ 0.016 cm3/g of soil moisture ➔ increase in soil moisture by 35 m3/ha



If we exclude fields 6 and 12 with the lowest PAWC ➔ "perfect" straight line

1% increase in SOC ➔ 0.02 cm3/g of soil moisture ➔ increase in soil moisture by 44 m3/ha

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PRIMA

23

Cost benefit analysis

Ανάλυση κόστους–οφέλους

Ιδιοκτήτης Αγροτεμαχίου: Καραγιαννάκης Παντελής

Είδος Καλλιέργειας: Αβοκάντο

Κόστη

Έξοδα για ηλεκτρισμό:

Αντλία: 500 W * 44 ποτίσματα * 3 ώρες ανά πότισμα= 66 kWh * 0.15€/kWh= **9.9 €**

Έξοδα για καύσιμο (πετρέλαιο κίνησης)

Απόσταση 5 χλμ.* 2 φορές * 44 ποτίσματα= 440 χλμ.

Η μέση κατανάλωση πετρελαίου κίνησης είναι 0.8 L/χλμ. και η τιμή του καυσίμου είναι περίπου 1.6€/L.

440 χλμ. * 0.8L/χλμ. * 1.6€/L = **563.2 €**

Έξοδα για λιπάσματα και κοπριά

3/2/25	132 kg of 12-13-18: 198€ 175 kg of SO3: 224€
28/5/25	10 kg of Ca(NO3)2: 12€
1/6/25	5 kg of ENTEC (NH4+Fe+Zn): 3.5€
9/6/25	10 kg of Ca(NO3)2: 12€ 0.3 kg of Zn-EDTA: 4.5€ 1 kg of Theoboron 8% B: 16€
21/6/25	10 kg of Ca(NO3)2: 12€
28/6/25	0.6 kg ElemFe: 9€ 0.25 kg ElemMix: 9€ 0.2 kg STRONG: 2€ 3 L Aminoton: 27€
10/7/25	0.6 kg ElemFe: 9€ 0.25 kg ElemMix: 9€ 3 L Aminoton: 27€
18/7/25	8 kg ENTEC: 5.6€
27/7/25	4 L Aminoton: 36€ 0.2 kg STRONG: 2€
12/8/25	7 kg of 13-0-46: 14€
29/8/25	10 kg of 13-0-46: 20€
11/9/2025	9 kg of 13-0-46: 18€ 3 kg of ENTEC: 2.1€
30/9/25	4 kg of 12-61-0: 8.4€ 3 L Aminoton: 27€ Κόστος λιπασμάτων: **707.1 €**

Κόστος κοπριάς: 66 δέντρα * 1 τσουβάλι ανά δέντρο * 5€/τσουβάλι = **330 €**

Συνολικά: **1,037.1 €**

Κόστος για νερό άρδευσης

182 m³ νερού από τον ΟΑΚ (29/8/25–5/11/25) με κόστος 0.3€/m³

Συνολικά: **54.6 €**

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Κόστος για ανθρώπινη εργασία

- 44 ποτίσματα * 1 ώρα ανά πότισμα = 44 ώρες για πότισμα
- 8 ώρες για συγκομιδή
- 16 ώρες για κλάδεμα δέντρων
- 4 φορές * 3 ώρες για κόψιμο χόρτων
- 16 ώρες για εφαρμογή λιπασμάτων και κοπριάς

44 + 8 + 16 + 12 + 16= 96 ώρες

Το μεροκάματο είναι 60 € οπότε $\frac{96}{8}$ * 60€ = **720 €**

Οφέλη

Όφελος από πώληση αβοκάντο

Για το έτος 2024: **2,690 €**

(Ποικιλία Zutano – 1,482 €, Ποικιλία Fuerte – 708 €, Ποικιλία Hass – 500 €)

Η τιμή καθορίστηκε βάσει ποιότητας αβοκάντο:

Πρώτη ποιότητα – 2.2€/kg

Δεύτερη ποιότητα – 1.4€/kg

Σκάρτα – 1.0€/kg

Συνολικό κόστος: 9.9€ + 563.2€ + 1037.1€ + 54.6€ + 720€= 2,384.8€

Όφελος από την πώληση αβοκάντο: 2,690 €

Άρα τελικό όφελος: 2,690€−2,384.8€ = 305.2€

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Ιδιοκτήτης Αγροτεμαχίου: Καραγιαννάκης Παντελής

Είδος Καλλιέργειας: Ελιές

Κόστη

Έξοδα για καύσιμο (πετρέλαιο κίνησης)

Απόσταση 5 χλμ.* 2 φορές * 13 ποτίσματα= 130 χλμ.

Η μέση κατανάλωση πετρελαίου κίνησης είναι 0.8 L/χλμ. και η τιμή του καυσίμου είναι περίπου 1.6€/L.

130 χλμ. * 0.8L/χλμ. * 1.6€/L = **166.4 €**

Έξοδα για λιπάσματα

183 kg of 20-6-16: 146€

48.8 kg of 13-0-46: 98€

Κόστος λιπασμάτων: **244€**

Κόστος για νερό άρδευσης

526 m³ νερού από τον ΟΑΚ με κόστος 0.3€/m³

Συνολικά: **157.8 €**

Κόστος για ανθρώπινη εργασία

- 13 ποτίσματα * 1 ώρα ανά πότισμα = 13 ώρες για πότισμα
- 48 ώρες για συγκομιδή
- 3 φορές * 5 ώρες για κόψιμο χόρτων

13 + 48 + 15= 76 ώρες

Το μεροκάματο είναι 65 € οπότε $\frac{76}{8}$ * 65€ = 617.5 € + 61 δέντρα * 5 € κλάδεμα ανά δέντρο = **922.5 €**

Οφέλη

Όφελος από πώληση ελαιόλαδου

Νοέμβριος 2025: 1,141 kg ελιές παρήγαγαν 271 kg ελαιόλαδου με οξύτητα 0.4.

Τιμή παραγωγού: 5€ ανά kg ελαιόλαδου άρα, 271 kg ελαιόλαδο * 5€ ανά kg ελαιόλαδου= **1,355 €**

Συνολικό κόστος: 166.4€ + 244€ + 157.8€ + 922.5€= **1,490.7€**

Όφελος από την πώληση ελαιόλαδου: **1,355 €**

Άρα 1,355€−1,490.7€= **-135.7€ (ζημία)**

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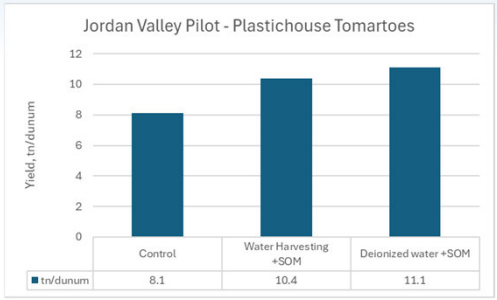
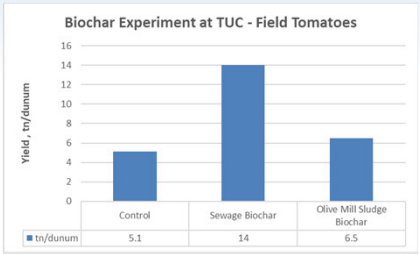
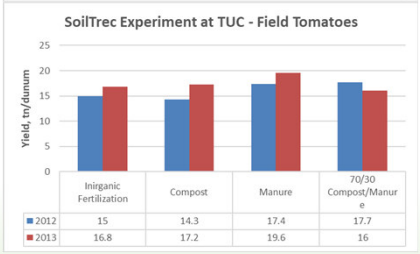
PRIMA

24

Soil carbon and tomato production







	% Soil Carbon	Max tomato yield, tn/dunum
Jordanian Pilot	0.8	8.1-11.1
Biochar Pilot	1.5	14
SoilTrec Pilot	2.5	19.6

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Next steps

- Installation of gateways (data transmission network)
- Installation of flow meters and soil moisture meters
- Drip irrigation pipes around the trees
- Demonstrate/train on use of instrumentation – how to irrigate
- Data collection for Farm Audit (EROI and Cost-Benefit analysis)
- Start data collection of 2026 irrigation season

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Koiliaris-CZO Publications

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