IRRIGATION AND DRAINAGE IN THE LIGHT OF CLIMATE CHANGE

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OLIVE GROWING IN MONTENEGRO: WATER AND SOIL REQUIREMENTS

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Introduction

- The olives *(Olea europaea L.)* are cultivated worldwide on nearly 11 million ha, with more than 90% of that area in the Mediterranean Basin, characterized by cold, wet winters and hot, dry summers *(Zipori et al., 2020)*.
- About 70% of the olive orchards are traditional and marginal with a medium to very low productivity due to the lack of appropriate orchard management.
- The rest are mainly new orchards (drip-irrigated, fertirrigated and planted with quick-growing young olive plantings) with suitable productivity but higher environmental impacts *(Gargouri et al., 2006; Zipori et al., 2020).*
- Soil fertility is often not taken into consideration during farm management causing over or under-application of fertilizers, leading to economic losses and environmental pollution and unsatisfactory yields.

Olive growing in Montenegro

- *South-eastern Mediterranean country with total area of 13 812 km^2 and coastline 293.5 km long ; Total population around 650 000 people.*

- *Olive orchards cover about 3200 ha or 1/3 of the total surface under fruit trees in MNE;*
- *Hilly olive growing area (85%), on the slopes of mountain massifs - Orjen, Lovćen and Rumija;*
- *Two olive sub-areas at Montenegrin coast: Bar sub-area (Ulcinj, Bar, Budva) and Boka-Kotorska sub-area (Tivat, Kotor, Herceg Novi);*
- *In Bar sub-area Žutica olive variety is predominantly grown; while in Boka-Kotorska sub-area also varieties Crnica, Lumbardeška, Sitnica, Šarulja etc- are present as well;*
- *Foreign varieties Picholine, Leccino, Coratina, Itrana, Ascolana tenera are present at about 3% in olive orchards.*

- *Predominantly traditional olive growing – average tree age from 150 to 200 years old;*
- *Average tree height 7 -10 -15 meters – need for rigorous pruning and height lowering;*
- *Average yield from 4 to 8 kg/tree or about 1 litre oil/tree – not sufficient to cover national consumption needs; 400-500 tons of oil yearly;*
- *Olive groves with size between 0.2 ha and 2.0 ha (Luštica 20 000 trees and Valdanos 80 000 trees);*
- *Plantings are mainly produced by rooting, mist propagation, but there are recent requests for grafted Žutica in windy areas;*
- *Main issues: pest Bactrocera oleae - Prays oleae and pathogen Spilocaea oleaginea.*

Olive requirements for soil properties

- Olives prefer deep loam texture soils, well-drained and aerated soils with moderately fine texture (from sandy to silty clay, loamy soils);
- Olives require soil pH ranging from 6.5 to 8.6 and are tolerant to mild saline conditions *(Gargouri et al., 2006; Toscano et al., 2015);*
- Olive trees are very tolerant towards soil carbonates – excellent yield and vegetative growth is observed in both soils with low content of carbonates and where this parameter is between 50 and 76% *(Gargouri et al., 2006)*;
- Soil organic matter that enhances both olive tree productivity through improvement of soil structure, soil water retention capacity as well as availability of some nutrients are considered suitable to be more than 1% for successful olive growth *(Soyergin et al., 2002).*

Olive requirements for soil properties

- The available fraction of P depends on adsorption by various minerals, mostly by carbonates and may be influenced by several factors like the pH and soil organic matter *(Topalović et al., 2006).*
- The available K content in the soil is correlated to clay content. The olive trees can compensate, partially, the lack of soil P and K due to uptake of these nutrients from huge soil volume *(Gargouri et al., 2006).*
- *Tubeileh et al. (2014)* found that available soil potassium amount and soil depth explained together 77% of the yield variability.
- Microelements such as *Fe, Zn, Mn,* and *Cu* are required in small or very small amounts. Due to fact that most olive orchards are grown on calcareous soils their availability may be limited.

Olive growing in MNE: Water and Soil requirements Recent scientific achievements

1. Impact of climate change on olive growth suitability, water requirements and yield in Montenegro *(Knežević et al., 2017)*;
2. Impact of soil properties on soil moisture mapping and irrigation requirements in Montenegro: The case of ancient olive groves in the coastal Mediterranean region *(Markoč M., 2019)*;
3. Comparative analysis of macro and micro elements in soil and olive leaves from the area of the municipality of Tivat *(Olea europaea L.)* *(Lekić D., 2015);*

Impact of soil properties on soil moisture mapping and irrigation requirements in Montenegro: The case of ancient olive groves in the coastal Mediterranean region (Markoč M., 2019)

Mean temperatures
Tavg 17.9°C
Tmin 2.1°C (January)
Tmax 30.3°C (June)

Extreme temperatures
Tmin -0.1°C (January)
Tmax 36.2°C (June)

Precipitation
Sum 605.5 mm
May 188.2 mm
June 8.3 mm
July 29th 50.6 mm

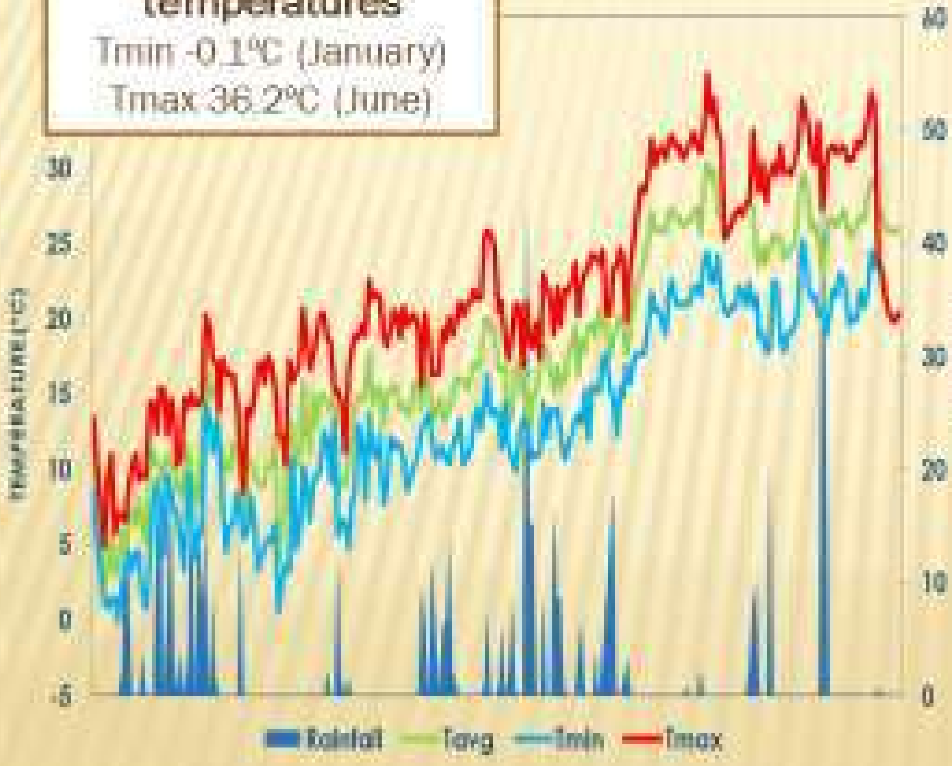
Relative humidity
ranged from 23% (June and July) to 91% (April)
Rh_{avg} 56.8%

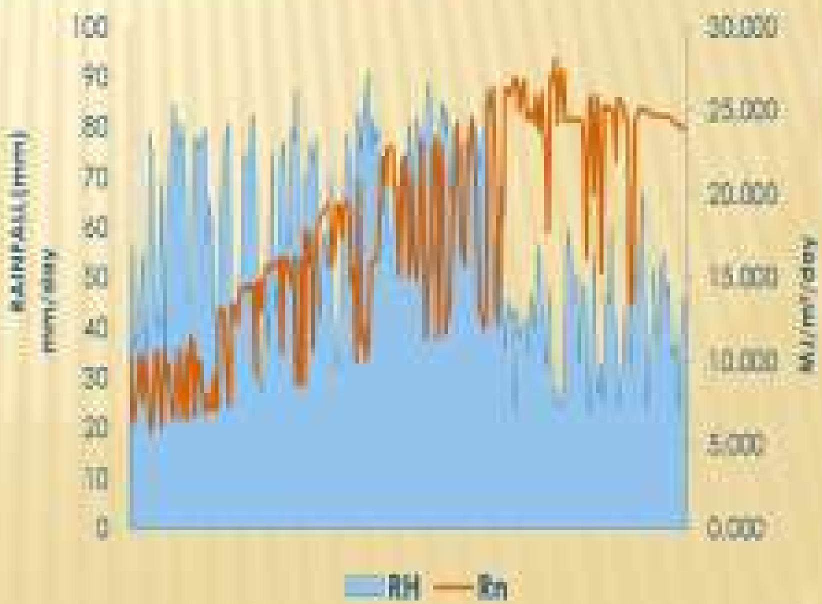
Net radiation
Rn_{avg} 17.87 MJ/m²/day

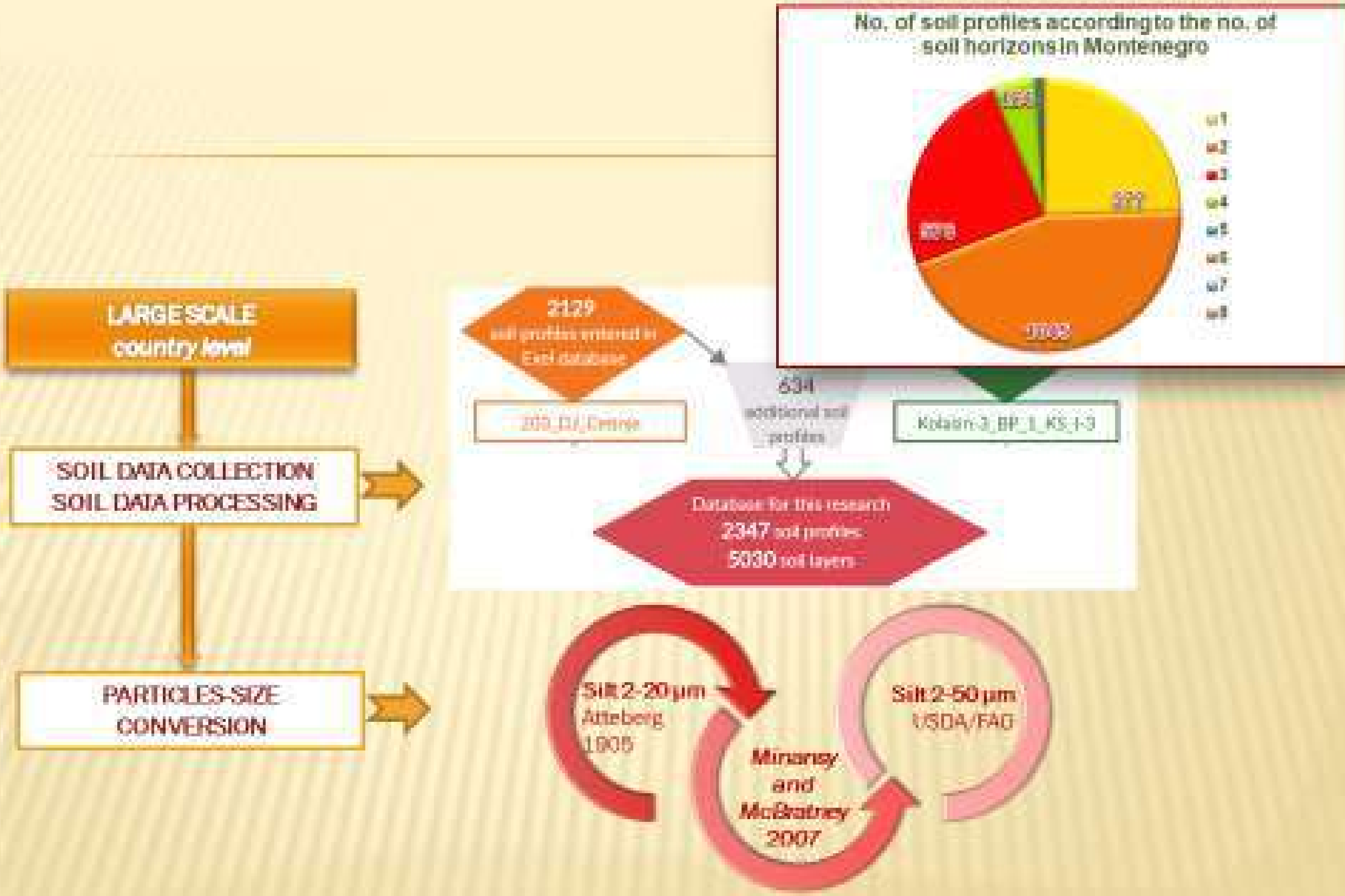
Sunshine duration
June 27th 14.3 hours

Wind
Average wind speed 1.1 m/s

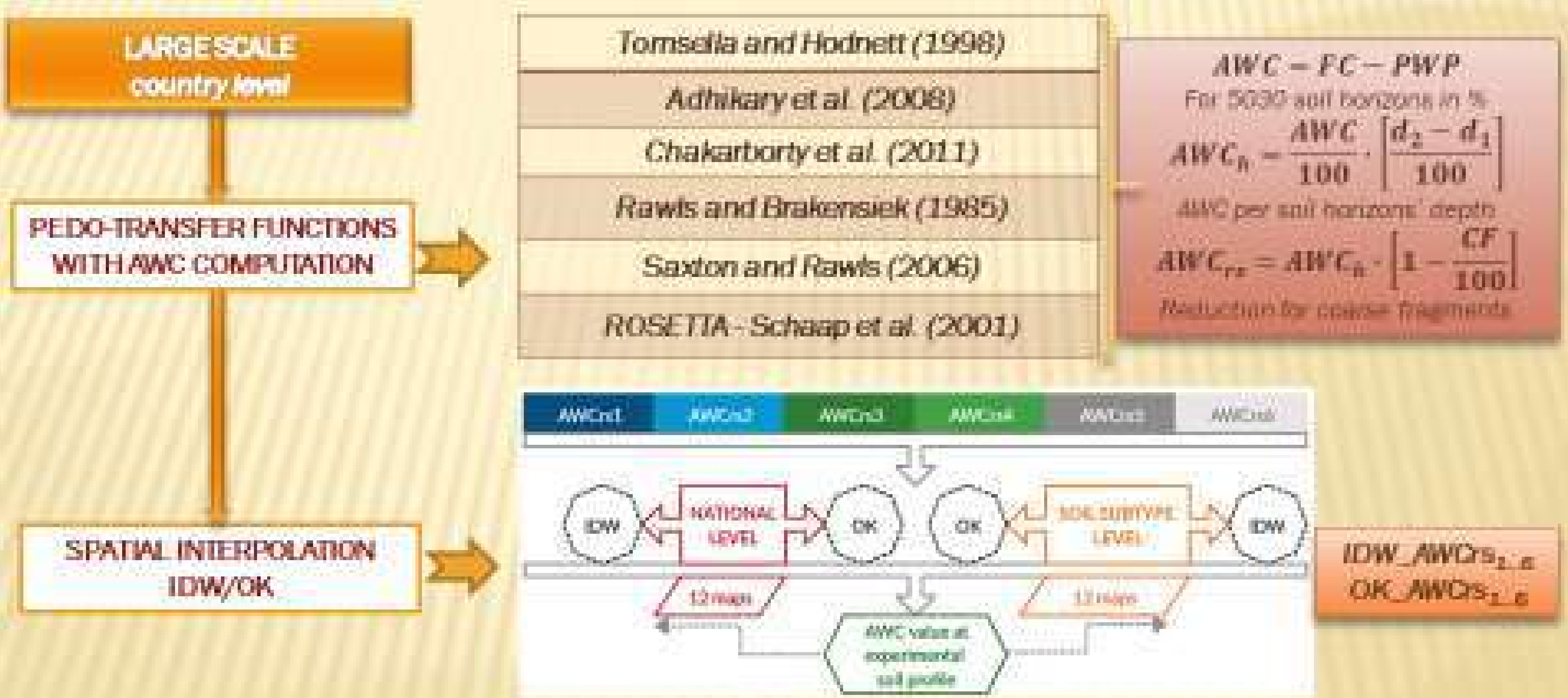
Evapotranspiration
ETоavg 6.44 mm/day
ETcavg 3.74 mm/day







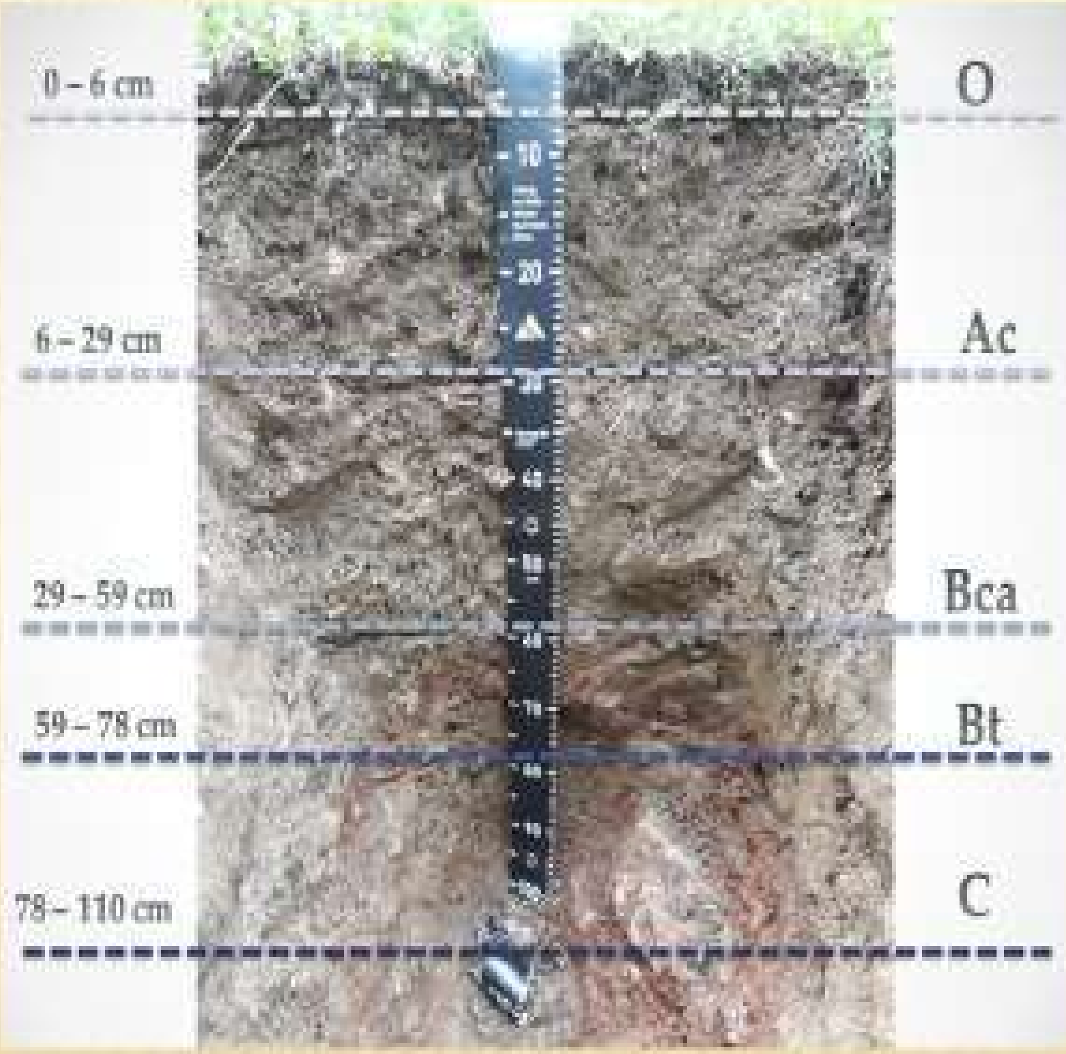
LARGE SCALE
country level
SOIL DATA COLLECTION
SOIL DATA PROCESSING
PARTICLES-SIZE
CONVERSION
2129
soil profiles entered in
Excel database
634
additional soil
profiles
Kolasin 3_BP_1_KS_I-3
Database for this research
2347 soil profiles
5030 soil layers
No. of soil profiles according to the no. of
soil horizons in Montenegro
1
2
3
4
5
6
7
8
Silt 2-20 µm
Atteberg
1905
Minansy
and
McBratney
2007
Silt 2-50 µm
USDA/FAO


LARGE SCALE
country level
PEDO-TRANSFER FUNCTIONS
WITH AWC COMPUTATION
SPATIAL INTERPOLATION
IDW/OK
Tomsella and Hodnett (1998)
Adhikary et al. (2008)
Chakarborty et al. (2011)
Rawls and Brakensiek (1985)
Saxton and Rawls (2006)
ROSETTA - Schaap et al. (2001)
$AWC = FC - PWP$
For 5030 soil horizons in %
$AWC_h = \frac{AWC}{100} \cdot \left[\frac{d_2 - d_1}{100}\right]$
AWC per soil horizons' depth
$AWC_{rs} = AWC_h \cdot \left[1 - \frac{CF}{100}\right]$
Reduction for coarse fragments
IDW
NATIONAL
LEVEL
OK
OK
LEVEL
IDW
12 maps
12 maps
$IDW\_AWCrs_{1\_6}$
$OK\_AWCrs_{1\_6}$

Eutric Cambisol on phlich

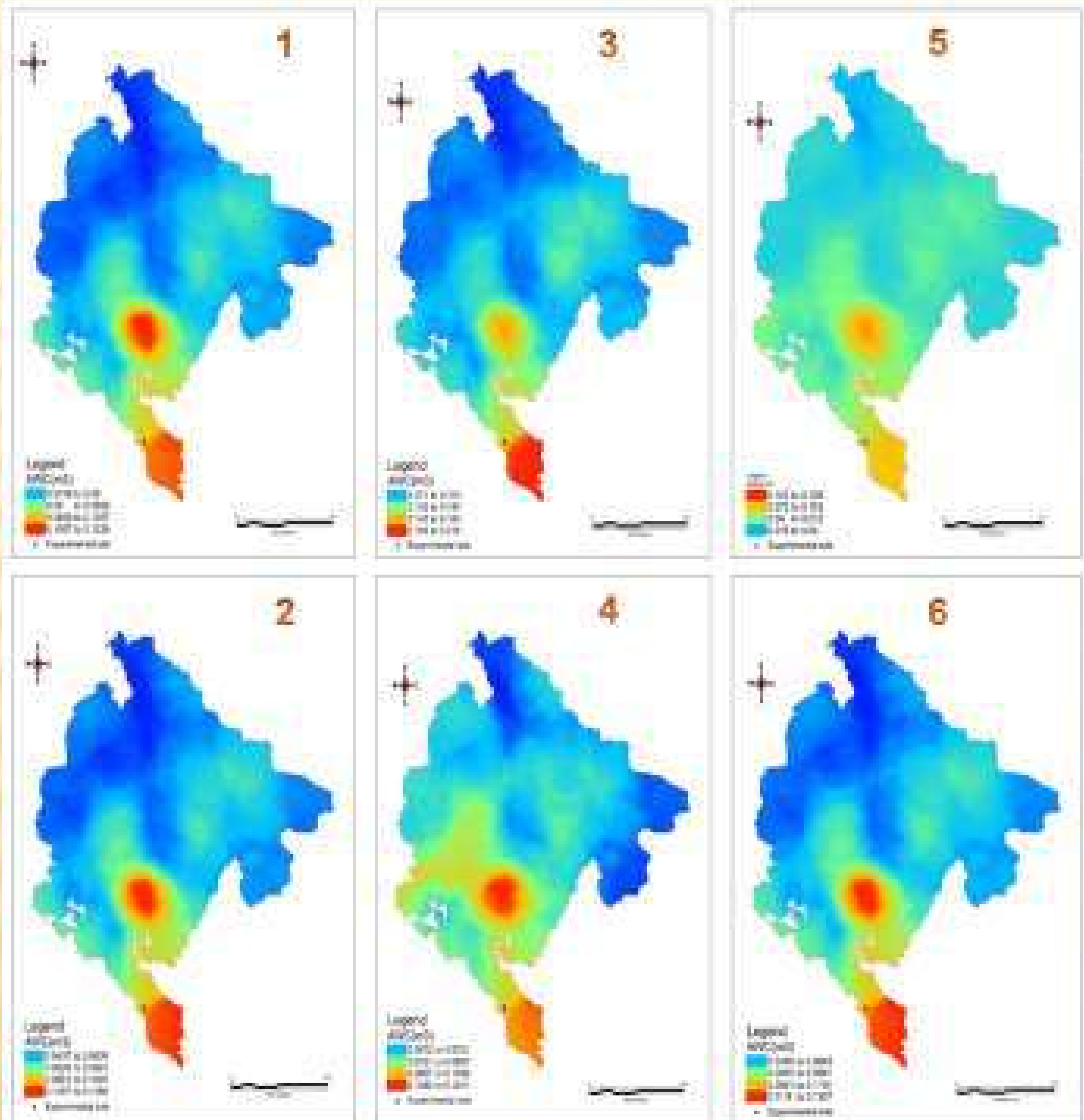
Soil classification system of Montenegro

(Fuštić and Đuretić, 2000)



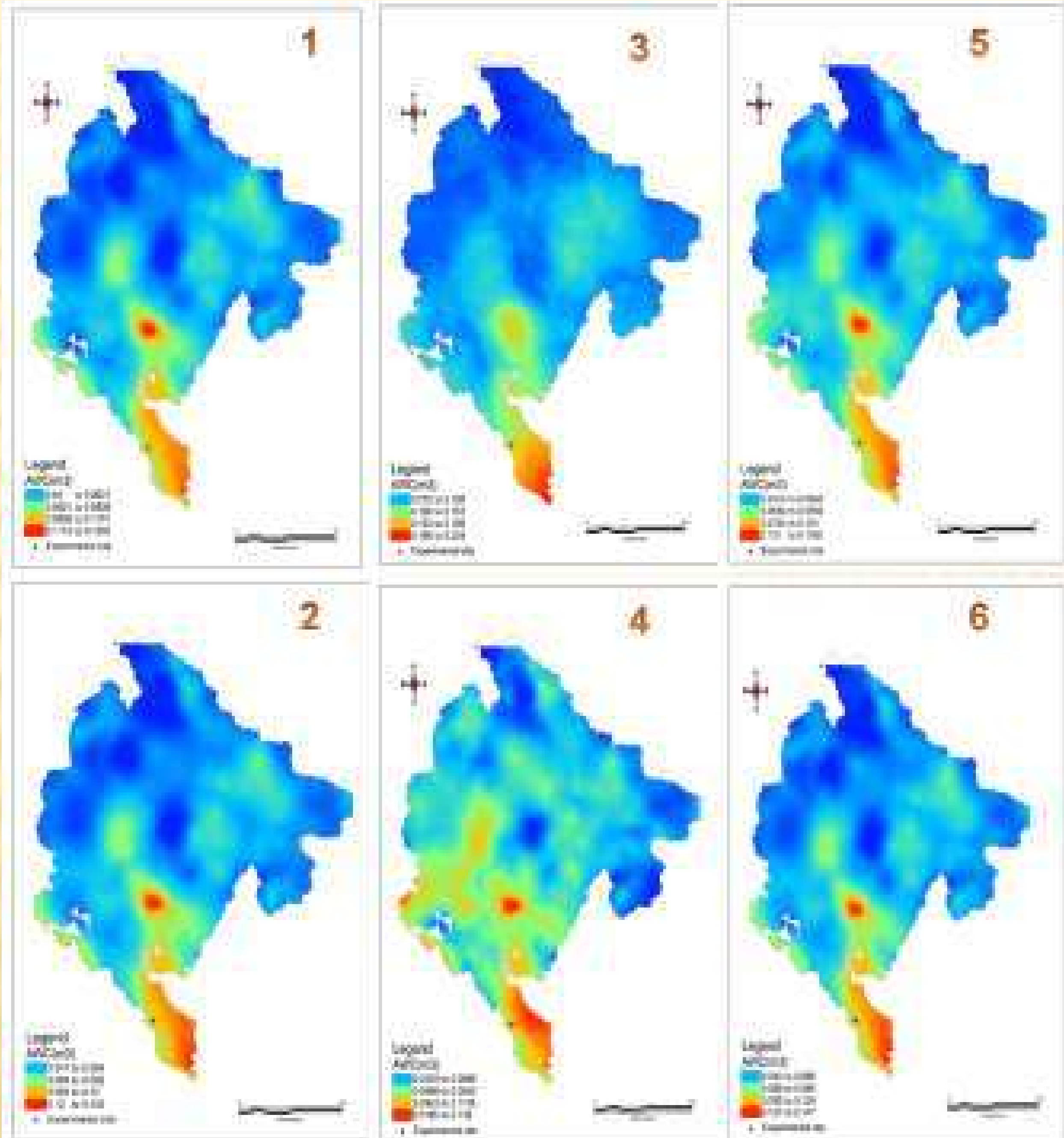
- Soil moisture declines with depth
- Significant increment of SWC at different matric potentials within Bt horizon
- FC ↑ 38.80%
- AWC = 28.45% or **0.090152 m³**

- P205 and K20 contents decrease with depth
- P205 57.6 ↓ 1.2 / K20 39.1 ↓ 8.2 mg/100 gr
- Seldom and shallow fertilizers application
- Injecting essential nutrients and foliar feeding with micro-elements



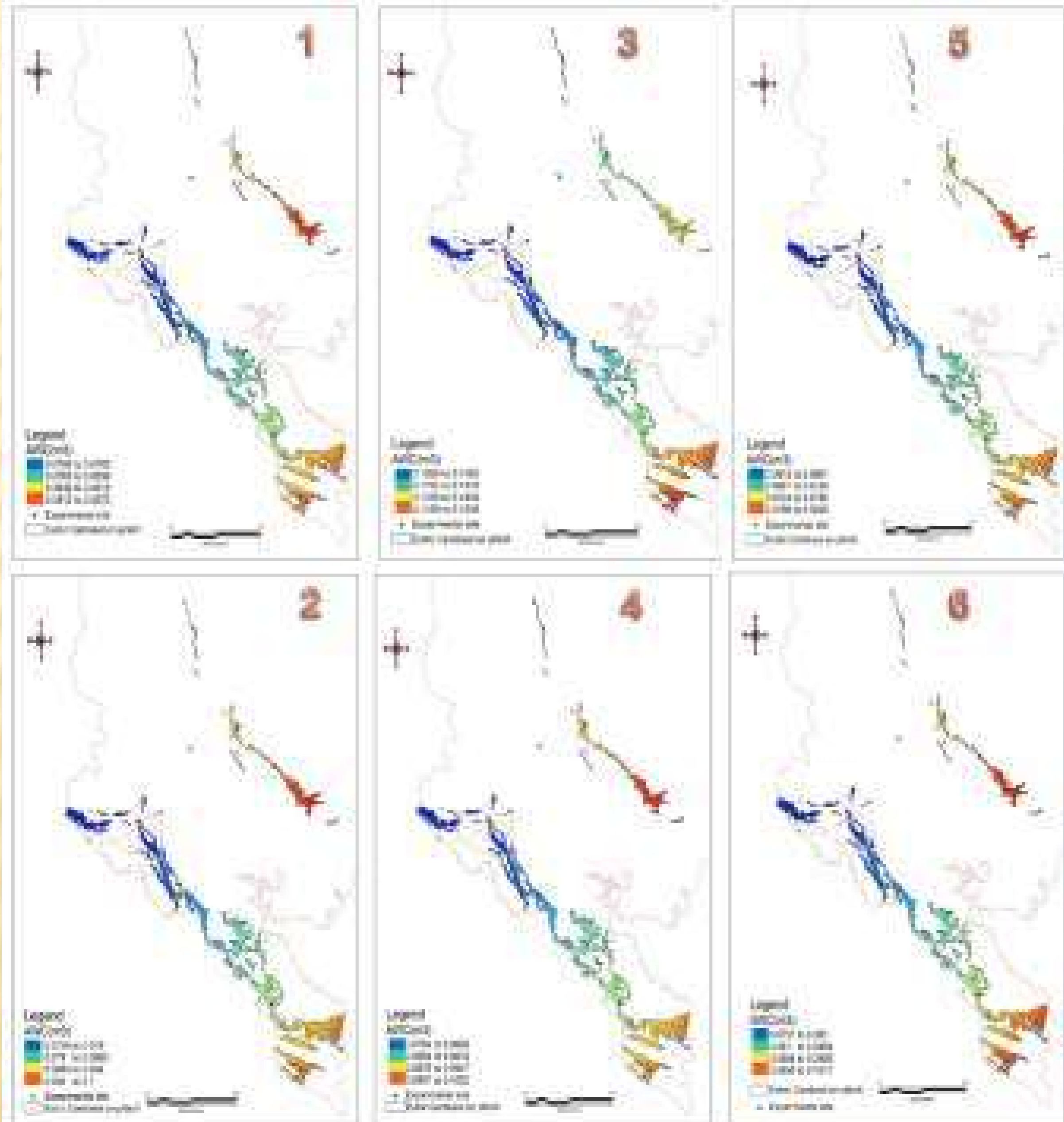
Soil moisture maps of Montenegro $IDW\_AWC_{rs.1-6}$

2347 AWC input data



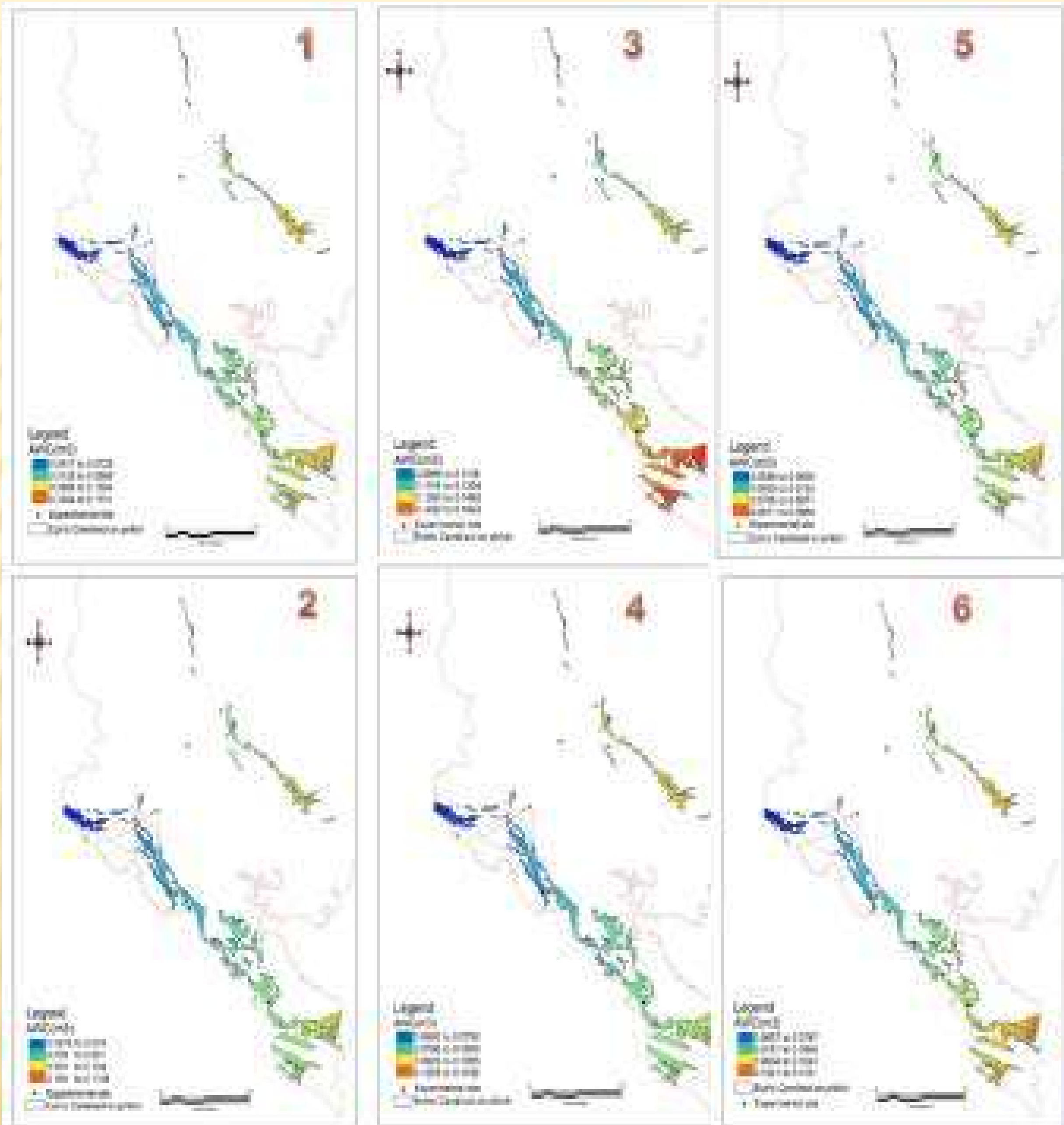
Soil moisture maps of Montenegro *OK_AWC*$_{rs1\text{-}6}$

2347 AWC input data



Soil moisture maps of *Eutric cambisol* on *philch* IDW_AWC_{n1-6}

97 AWC input data



Soil moisture maps of *Eutric cambisol on phlich* $OK\_AWC_{rs1\text{-}6}$

97 AWC input data

METHOD	AWC (m^3)	|ΔA| (m^3)	|RE| (unitless)	MAE (m^3)	RMSE (m^3)
IDW_AWC$_1$_MNE	0.10203	0.011878	0.131755258		
IDW_AWC$_2$_MNE	0.10729	0.017138	0.190101162		
IDW_AWC$_3$_MNE	**0.17108**	0.080918	0.897572988		
IDW_AWC$_4$_MNE	0.1049	0.014748	0.163590381	0.0244	0.0872
IDW_AWC$_5$_MNE	**0.08831**	0.001842	0.020432159		
IDW_AWC$_6$_MNE	0.11024	0.020088	0.222823676		
OK_AWC$_1$_MNE	0.10852	0.018368	0.203744787		
OK_AWC$_2$_MNE	0.1125	0.022348	0.247892448		
OK_AWC$_3$_MNE	**0.17202**	0.081868	0.908110746		
OK_AWC$_4$_MNE	0.11748	0.027328	0.303132487	0.0297	0.0946
OK_AWC$_5$_MNE	**0.09243**	0.002278	0.025268436		
OK_AWC$_6$_MNE	0.11596	0.025808	0.286272074		
IDW_AWC$_1$_EC	0.08889	0.001262	0.01399858		
IDW_AWC$_2$_EC	0.08983	0.000322	0.003571745		
IDW_AWC$_3$_EC	**0.14599**	0.055838	0.619376165		
IDW_AWC$_4$_EC	**0.09013**	2.2E-05	0.000244032	0.0127	0.0577
IDW_AWC$_5$_EC	0.07647	0.013682	0.151765906		
IDW_AWC$_6$_EC	0.09565	0.005498	0.06098589		
OK_AWC$_1$_EC	0.08541	0.004742	0.052600053		
OK_AWC$_2$_EC	0.08823	0.001922	0.021319549		
OK_AWC$_3$_EC	**0.13393**	0.043778	0.485602094		
OK_AWC$_4$_EC	0.08934	0.000812	0.00900701	0.0114	0.0469
OK_AWC$_5$_EC	0.07399	0.016162	0.179275002		
OK_AWC$_6$_EC	**0.09126**	0.001108	0.012290354		

IDW
97.96% MNE
99.98% EC
OK
99.02% MNE
99.7% EC

Saxton and Rawls (2006)
Rawls and Brakensiek (1985)
~~Chakarborty et al. (2011)~~

Comparative analysis of macro and micro elements in soil and olive leaves from the area of the municipality of Tivat (Olea europapaea L.) (Lekić D., 2015)

- Great variability in soil properties – fertile soils with weakly acidic to neutral reaction, optimal to very high humus content and total carbonates up to 27%;
- Indication of the high effect of fertilization on soil properties – high to very high concentration of nutrients in topsoil and underlying soil layer;
- Texture classes – mostly clay loam and light clay (in the underlying layer); sandy loam at one location.

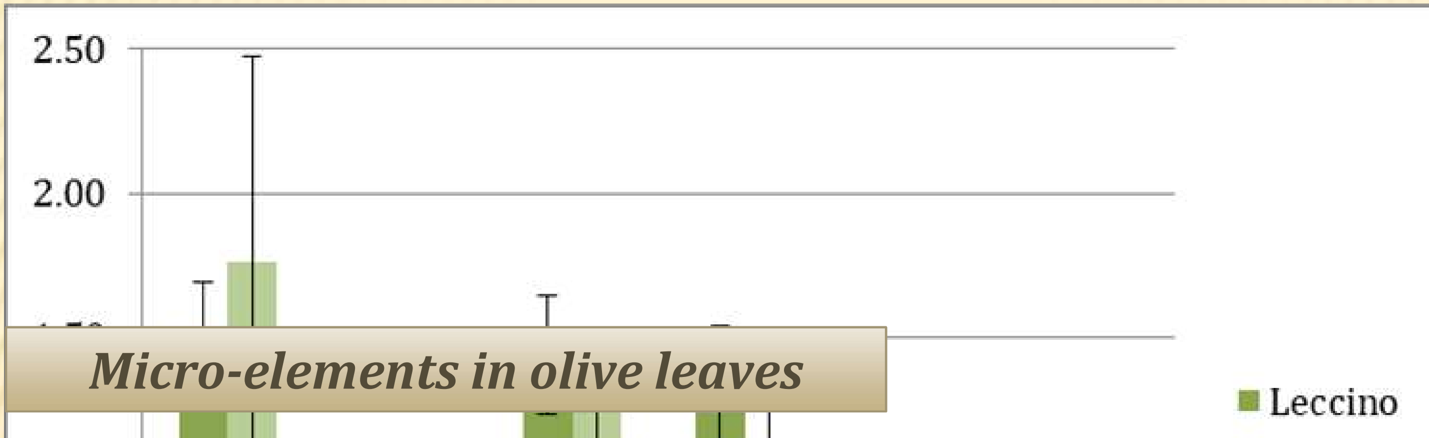
Descriptive statistics for soil parameters
Topsoil samples from olive orchards in the municipality of Tivat

Soil layer (0-30 cm) in olive orchard	*Leccino*	*Žutica*
	Mean±sd	Mean±sd
pH(H_2O)	6.92 ± 0.67	7.02 ± 0.60
pH(KCl)	6.38 ± 0.72	6.41 ± 0.62
Total carbonates (%$CaCO_3$)	17.90 ± 31.00	9.83 ± 13.48
Humus (%)	6.11 ± 0.47	6.28 ± 1.07
Available P (mg P_2O_5/100 g)	40.00 ± 28.52	14.23 ± 5.12
Available K (mg K_2O/100 g)	56.10 ± 52.41	60.37 ± 46.20
Electrical conductivity (microS/cm)	114.10 ± 35.95	116.53 ± 39.97
Exchangeable Ca (mg/100 g)	905.00 ± 1131.98	923.00 ± 1023.58
Exchangeable Mg (mg/100 g)	18.23 ± 9.02	24.67 ± 7.92
Available Fe (mg/kg)	25.57 ± 12.71	19.83 ± 3.86
Available Mn (mg/kg)	54.53 ± 45.51	48.47 ± 39.72
Available Cu (mg/kg)	19.62 ± 9.93	12.80 ± 12.94
Available Zn (mg/kg)	5.60 ± 3.32	4.87 ± 4.98
Coarse sand (%)	14.28 ± 10.86	7.84 ± 10.72
Fine sand (%)	41.84 ± 4.49	37.37 ± 12.13
Silt (%)	27.01 ± 4.49	32.89 ± 7.91
Clay (%)	16.88 ± 6.64	21.90 ± 5.37
Total sand (%)	56.12 ± 9.85	45.21 ± 2.64
Total clay (%)	43.88 ± 9.85	54.79 ± 2.64

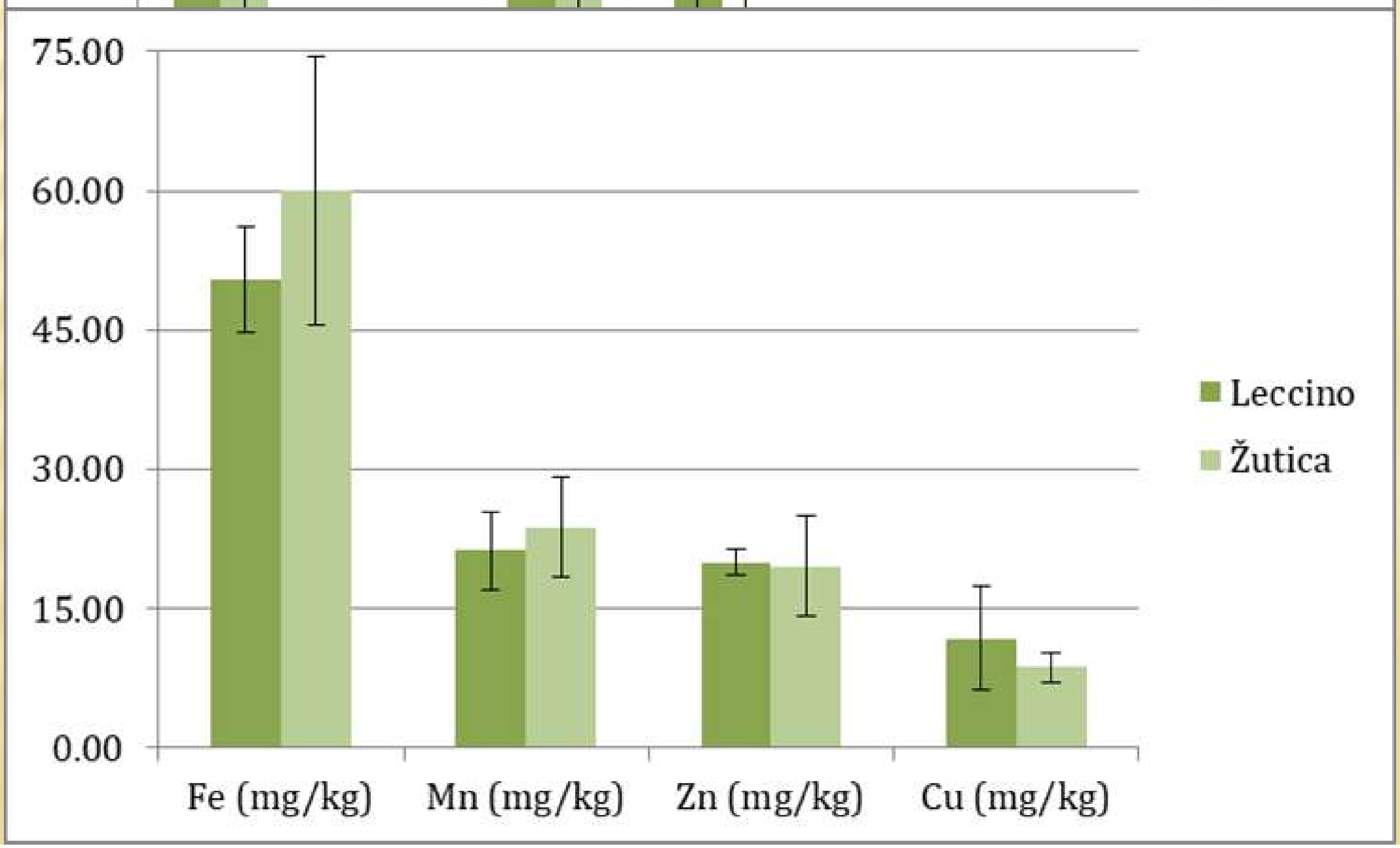
Descriptive statistics for soil parameters
Samples of underlying soil layer from olive orchards in the municipality of Tivat

Soil layer (30-60 cm) in olive orchard	*Leccino*	*Žutica*
	Mean±sd	Mean±sd
pH(H_2O)	7.41 ± 0.41	7.03 ± 0.72
pH(KCl)	6.81 ± 0.46	6.47 ± 0.74
Total carbonates (%$CaCO_3$)	22.03 ± 32.94	11.40 ± 13.16
Humus (%)	3.91 ± 0.81	5.11 ± 1.60
Available P (mg P_2O_5/100 g)	9.33 ± 4.79	6.40 ± 9.47
Available K (mg K_2O/100 g)	23.13 ± 17.64	21.27 ± 3.51
Electrical conductivity (microS/cm)	137.77 ± 63.78	106.63 ± 51.81
Exchangable Ca (mg/100 g)	968.00 ± 1060.93	869.00 ± 1051.72
Exchangable Mg (mg/100 g)	17.37 ± 11.99	24.70 ± 10.91
Available Fe (mg/kg)	15.57 ± 8.40	16.80 ± 5.72
Available Mn (mg/kg)	29.93 ± 19.72	29.53 ± 9.96
Available Cu (mg/kg)	12.85 ± 14.38	6.31 ± 3.65
Available Zn (mg/kg)	1.99 ± 1.45	2.30 ± 1.10
Coarse sand (%)	18.62 ± 9.54	7.14 ± 10.39
Fine sand (%)	35.41 ± 5.03	34.45 ± 14.94
Silt (%)	24.03 ± 2.92	30.71 ± 8.13
Clay (%)	21.93 ± 11.60	27.70 ± 7.56
Total sand (%)	54.04 ± 13.78	41.59 ± 11.16
Total clay (%)	45.96 ± 13.78	58.41 ± 11.17

Macro- and meso-elements in olive leaves

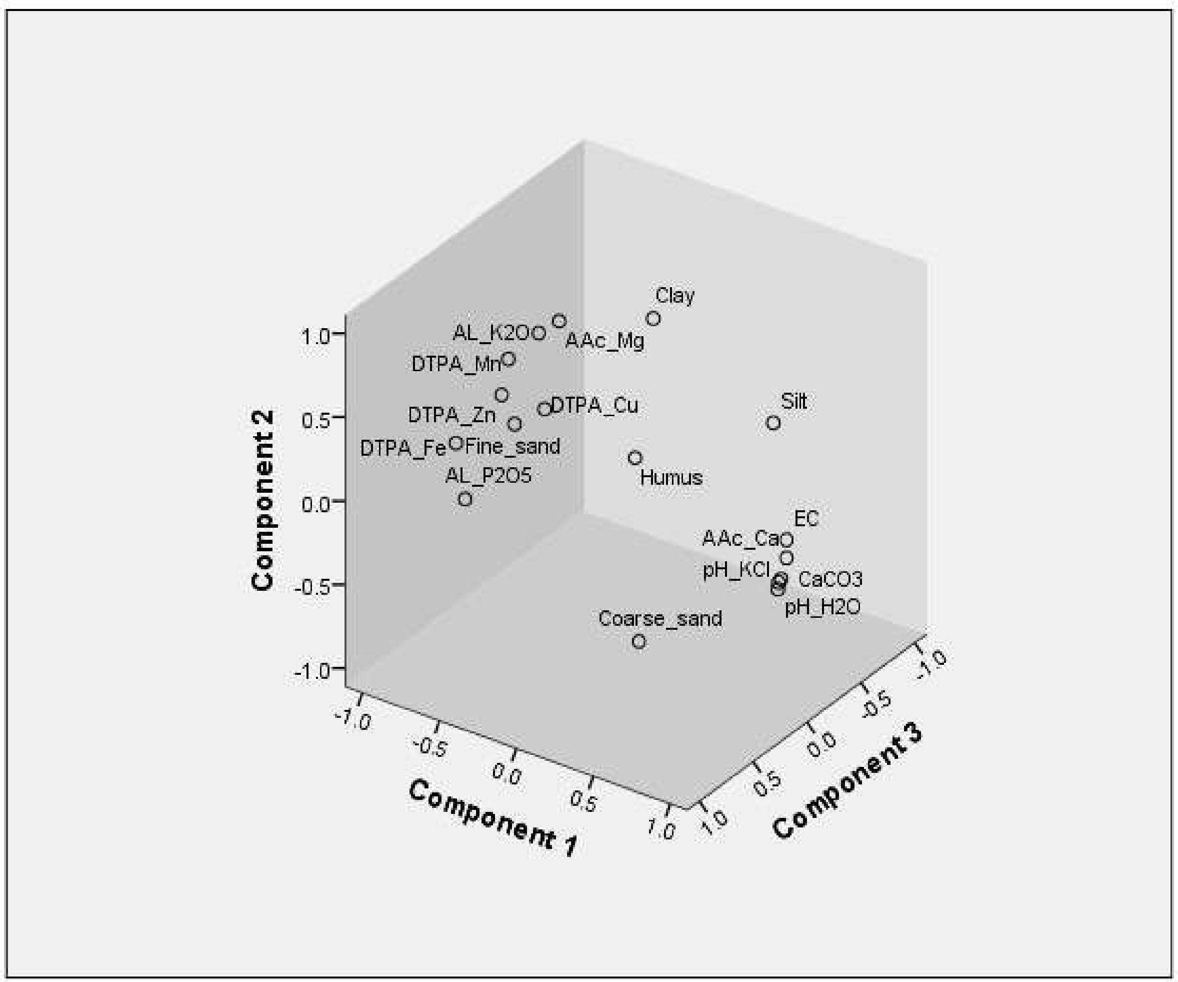


Micro-elements in olive leaves



- N – deficiency was recorded in some orchards
- Fe – below optimal in both cultivars
- Mg – mainly below or at the lower limit of optimal
- Ca – at the lower limit of optimal content in *Žutica*
- K - above the optimal value in both cultivars
- Cu - above the optimal value in *Leccino*

Component Plot in rotated space (PCA with Varimax rotation)



Component 1 – *Carbonate*
Component 2 – *Clay*
Component 3 – *Silt (negative)*
Component 4 – *Humus*

The bivariate correlation analysis between the scores of soil parameters and the content of leaf elements

- Negative relationship of clay component with Cu ($p=0.055$)
- Negative relationships between silt component and P ($p=0.053$)
- Positive relationship between humus component with Zn ($p=0.055$)

Conclusions and Recommendations

- Non fertilization and fertilization non according to soil and leaf analysis are one of the highest concerns regarding optimal management of olive groves in Montenegro. Foliar fertilization is highly advisable, especially for Fe and Mg content increase.
- Intensive agri-technical measures regarding revitalization of ancient olive trees (rigorous pruning, tillage, drip irrigation, inner cropping, terraces adaptation etc.) would better soil moisture status in Montenegrin olive groves.
- The rainfed cultivation of olives could remain one of the viable solutions in the future; however it could represent an occasion and challenge to promote the sustainable olive growing and olive cultivation in more northern parts of the country.
- According to the fact that the olive groves are mostly located far from the shore and local meteorological stations, it is highly advisable to set and agri-meteorological station within the groves for further experimental purposes.

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THANK
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