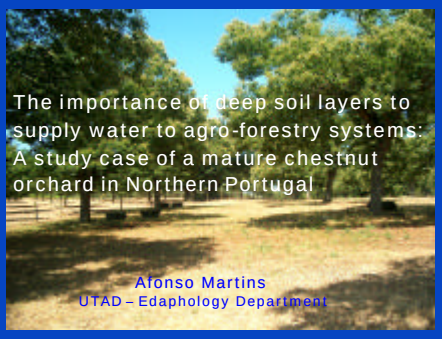


The importance of deep soil layers to supply water to agro-forestry systems: A study case of a mature chestnut orchard in Northern Portugal

Afonso Martins
UTAD – Edaphology Department

Research Team

UTAD

Edaphology Dept	Afonso Martins
	Fernando Raimundo
	Isabel Linhares
	Jorge Pinheiro (Auxiliar)
Crop Production & Rural Engineering Dept	
	Vicente Sousa
	Fernando Santos
Biology Dept	José Laranjo
	João P. Coutinho
DRATM	Olga Borges
ISA – Env. Sci. Dept	Manuel Madeira

Financial support:
EC – 5th Framework-Programme - MANCHEST project,
AGRO Program – Project No 19, OFLORINT

Background

Traditional soil management on chestnut orchards

Surface soil tillage with tine cultivator 3-4 times a year

Tine cultivator - Tillage depth - 15-20 cm

Reasons invocated to the annual soil tillage

- ✓ **Weed control to save water to the main crop**
  As it will be shown, the obtained results do not confirm this
- ✓ **Soil surface regularization to improve the fruit harvest**
  The obtained experience don't prove that and does not adapt to the mechanical harvesting, which must be envisaged in the future
- ✓ **Destroying surface crust after raining for soil respiration**
  It's a vicious circle, because the soil crust formation only occur on mobilised soils
- ✓ **Others (traditional weight and associated myths)**
  The most difficult to pass over

Effects of tine cultivator tillage on the ecosystem

- Decreasing OM amount and biodiversity
- Destruction and damage of root system
- Spread of diseases
- Increasing of soil compaction on sub subsurface soil layers
- Increasing erosion hazard
- Causing crust surface formation
- Increasing costs

Examples of tillage effects

Soil erosion

- ✓Decreasing soil depth
- ✓Loss of most active soil components and nutrients
- ✓Soil fertility decreasing

Surface soil crust

- ✓ Decreasing soil respiration
- ✓ Increasing CO_2 level, unfavourable conditions for biologic activity and pathogenic risks

[Keeping in mind that weed control for saving water to the chestnut trees is the main reason to the annual soil tillage operations]

Objectives of the present communication:

1. To report a synthesis of obtained results related to soil moisture regime, leaf water potential and fruit production from 1997 to 2001, for different soil management practices on adult chestnut orchards
2. To report the obtained results about the importance of deep soil layers to supply water for trees, also using different soil management practices on the same systems

Localization of the Research Area

Localization - Northern Portugal (41 ° 36 ´ N; 6 ° 56´ W)
Altitude - 760 m
Mean annual temperature - 12 °C
Mean annual rainfal - 650 l m^{-2}
Lithology - Schists
Soils - Dystric Regosols (FAO, 1998)

1st Experimental device (1997-2001)

Soil management practices:

TS (A) – Traditional tillage system, with tine cultivator three or four times a year

DH (B) – Reduced tillage with disk harrow ploughing twice a year

NT (C) – No tillage with natural grass cover

SP (D) – No tillage with seeded pasture under canopy

Experimental field consists of a set of 16 plots, (4 replications), with about 1200 m^2 and 12 to 15 trees each one, with 50 years old.

Disk harrow ploughing

Tillage depth (» 10 cm), less than with tine cultivator (15-20 cm)

Rainfeed Seeded pasture under tree canopy

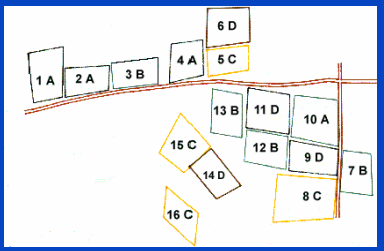
Advantages

- ✓ Increasing OM and N
- ✓ Increasing soil conservation
- ✓ Increasing biodiversity
- ✓ Improving soil physical properties

Possible inconvenient (?)

- ✓ Competition with trees to the water
- ✓ Unbalance of nutrients

1st Experimental device Distribution of the plots in the field



Methods

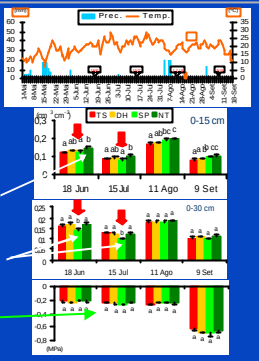
Soil moisture content (SMC) - Time Domain Reflectrometry device
(measured at 015 cm and 030 cm depth, from June to September)

Leaf water potential (Ψw, predawn values) - Pressure Chamber (PMS instrument), also measured from June to September

Fruit production – Harvesting the fruits produced by two trees of each plot

RESULTS

Pattern of SMC and Ψw, according the different treatments (May to Sept 1999)



Comments

- Generally higher values of SMC on NT plots, at soil surface, when compared with TS plots
- Lower values of SMC on SP plots until the middle of July
- No differences on Ψw

Average values for fruit production (DM) (g m-2 CA) from 1997 to 2001 (n=8)

Year / Treatments	1997	1998	1999	2000	2001
TS	104,3 a	249,5 a	118,7 a	132,2 a	130,7 a
DH	130,8 ab	323,1 a	136,6 a	146,2 a	143,3 a
SP	–	295,3 a	99,5 a	196,1 a	145,6 a
NT	158,1 b	329,6 a	154,5 a	183,8 a	170,1 a

CA – canopy area; **DM** Dry matter – (≈ 50% fresh fruit)
Ex. For an adult tree with 100 m² CA, 150 g/m2 represents 30 kg fresh fruit/tree

In all the years fruit production was higher in NT plots than in tilled plots (TS & DH)

Conclusions from the studies between 1997 to 2001

- ✓ Traditional management with tine cultivator tillage shows no efficiency on soil water conservation and its availability to the trees
- ✓ The use of natural grass cover or seeded pasture suggests the grazing or the cut on late spring, or the use of irrigation, in order to avoid the uptake of water by grasses and competition with trees
- ✓ Water supplying shows not dependent on surface layers which suggests that deep layers are very important on that process
- ✓ Fruit production, however not significantly different among treatments, is higher on NT plots, which shows no advantages of soil tillage on these systems, respecting to productivity

Questions that remain to be clarified

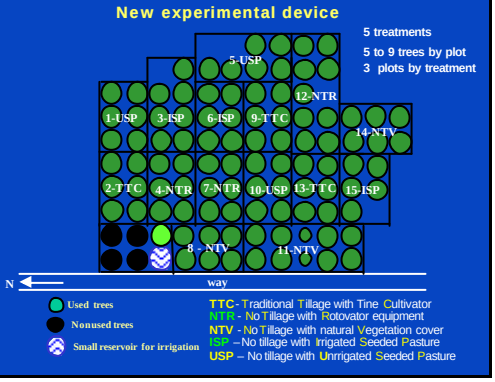
Related to this study

- ✓ Effect of deep layers to supply water to the trees
- ✓ Effect of irrigation on orchard productivity

Others

- ✓ Effect of other management practices (use of destroying equipment, use of herbicides,...)
- ✓ Effect of management practices on fruit quality

New experimental device



TTC - Traditional Tillage with Tine Cultivator
NTR - NoTillage with Rotovator equipment
NTV - NoTillage with natural Vegetation cover
ISP – No tillage with Irrigated Seeded Pasture
USP – No tillage with Unrrigated Seeded Pasture

Alternative solutions to the soil management related to the traditional system

Destroying the leaves, burs, twigs and vegetation and keep them at the soil surface (NTR treatment)

Advantages

- ✓ Weed control
- ✓ Organic matter and nutrient cycle conservation

Alternative solutions to the soil management related to the traditional system

Use of irrigation - (ISP treatment)

Possible advantages (??)

- ✓ Increasing fruit production and quality (caliber)
- ✓ Increasing productivity (fruit and pasture)

Irrigation information

2 sprinklers by tree
3 irrigated trees by plot
(9 in total)

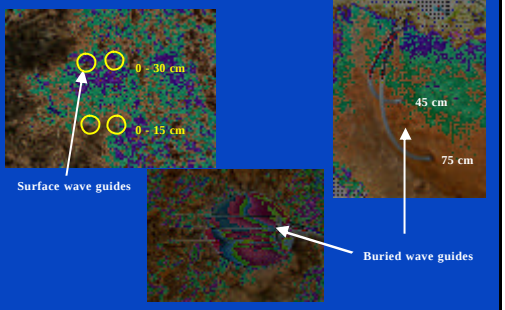
Number, dates and volume of irrigations

Irrigation No	date	time h:min	time min	water vol l/sprinkler *	water vol l/tree	water vol l m^{-2} **
1ª	Jun-09	3:00	180	1038.60	**2077.2**	13.5
2ª	Jun-18	3:25	205	1182.85	**2365.7**	15.4
3ª	Jun-27	3:20	200	1154.00	**2308.0**	15.0
4ª	Jul-09	3:50	230	1327.10	**2654.2**	17.3
5ª	Jul-22	3:15	195	1125.15	**2250.3**	14.6
6ª	Jul-30	3:20	200	1154.00	**2308.0**	15.0
7ª	Aug-06	3:15	195	1125.15	**2250.3**	14.6
8ª	Aug-13	2:45	165	952.05	**1904.1**	12.4
9ª	Aug-20	4:20	260	1500.20	**3000.4**	19.5
10ª	Aug-27	4:00	240	1384.80	**2769.6**	18.0
11ª	Sep-04	3:00	180	1038.60	**2077.2**	13.5
12ª	Sep-11	3:35	215	1240.55	**2481.1**	16.1
13ª	Sep-19	3:25	205	1182.85	**2365.7**	15.4
14ª	Sep-26	3:42	222	1280.94	**2561.9**	16.7
Total						216.9

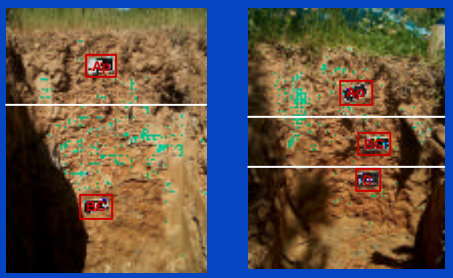
* 5.77 l/min

** 153.86 m³/tree

New devices for soil moisture control at different depths



Representative soils of the experimental field



Dystric Regosols from schists

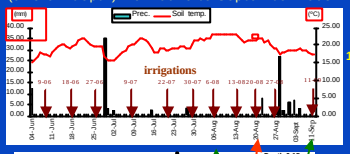
Soil characterization
Physical properties

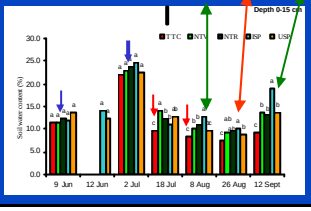
soil profile	depth cm	% water (KPa) 10.0	50	1500	bulk density	coarse sand	fine sand	silt	clay
1	0-22	26,2	18,3	13,0	1,29	30,8	42,7	21,0	5,5
	30-50	24,8	16,2	12,2	1,22	30,6	49,5	8,1	11,9
2	0-20	26,1	19,1	14,9	1,19	22,5	46,3	10,2	20,9
	25-40	26,5	20,9	12,8	1,31	25,0	60,5	3,3	11,2
	50-70	27,5	19,1	11,8	1,24	34,6	36,4	23,1	5,9
3	0-15	27,7	17,5	10,5	1,34	36,9	45,0	14,3	3,9
	30-45	26,9	19,1	11,4	1,36	34,3	53,3	3,2	9,2
	45-65	25,8	19,6	11,7	1,40	30,2	47,9	13,4	8,4
4	0-20	28,1	18,5	11,7	1,26	36,6	36,2	24,4	2,9
	40-60	22,5	16,2	11,6	1,25	23,8	53,9	14,2	8,2
6	0-15	27,6	17,6	10,9	1,31	34,0	46,6	13,4	6,0
	25-35	25,2	17,7	12,0	1,26	27,7	48,1	11,9	12,2
	40-55	21,7	16,5	12,8	1,22	37,3	22,1	19,2	21,5
7	0-20	26,4	19,4	10,6	1,32	27,1	35,9	29,1	7,9
	50-75	22,4	17,9	12,1	1,28	34,1	25,1	28,2	12,5
	80-110	24,2	19,1	14,8	1,16	32,8	23,7	22,1	21,4
8	0-20	30,2	21,2	12,0	1,22	34,7	46,7	10,4	8,2
	35-60	26,4	20,7	10,6	1,31	28,0	33,8	28,5	9,6
	60-90	25,1	18,9	10,7	1,25	23,8	35,6	29,8	10,9

Main properties

- Medium to coarse texture
- WP: average value - 12.0 ± 1.3 % (W %)

Rainfall, soil temperature and soil moisture (0-15 cm depth) from June to September 2003

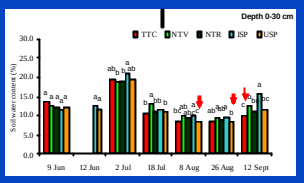




Comments

1. High daily temperatures during summer (25-35 ºC)
2. Similar values of SM among treatments until Jul-18
3. Lower values of SM on TTC plots after that date
4. Higher values of SM on ISP plots during the next days after irrigation
5. Decreasing of the irrigation effect a week after that

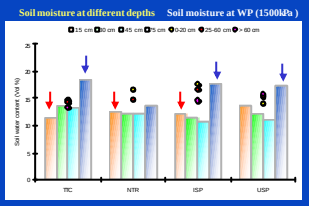
Soil moisture content during the measuring period 0 -30 cm depth



1. Lower differences than at 0-15 cm among treatments
2. After 18 July TTC and partly USP plots shows de lower values

Soil moisture content on June-09 according soil depth and compared with WP

Before the rainfall and the irrigation

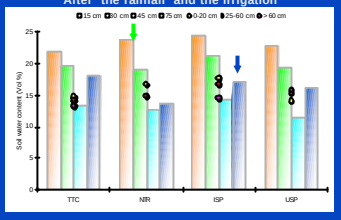


Comments

1. At soil surface layers moisture is generally lower than WP
2. In soil depth moisture is generally higher than WP

Soil moisture content on July-02 according soil depth and compared with WP

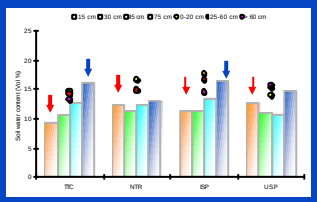
After the rainfall and the irrigation



Comments

- At soil surface layers, moisture is much higher than WP
- In soil depth, moisture continues generally higher than WP

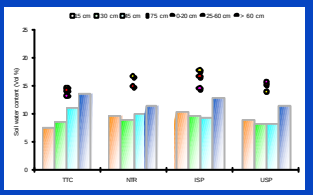
Soil moisture content on July-18 according soil depth and compared with WP



Comments

- At soil surface layers, moisture is lower than WP independently of the treatment
- In soil depth, moisture is generally near the WP

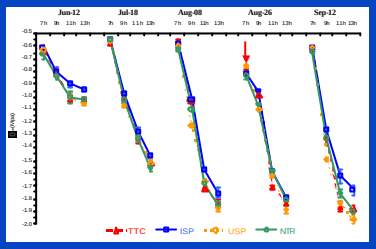
Soil moisture content on August 02 according soil depth and compared with WP



Comments

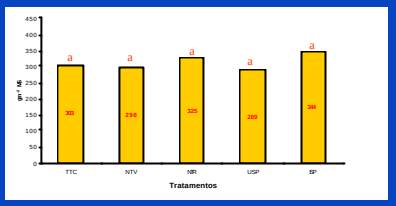
At soil surface and in deep layers moisture is generally lower than the WP

Average values for leaf water potential (y_w) during the period according the treatments (n=12)



- Until de end of August trees re-establish the water level during night
- After that date the y_w values decrease sharply

Average values for fruit production on 2003 (g/m² MS) (n=12)



Comments

- No significative differences among treatments
- Higher productions on NTR e IST
- The effect of irrigation on fruit production is not clear

Conclusions

(especially for Mediterranean climatic conditions)

- ✓ Soil moisture at surface layers on chestnut orchards is lower than WP since the beginning of dry season independently of the soil manag ement practices, which question the advantage of tillage and emphasizes the importance of deep layers to supply water to the trees
- ✓ Irrigation effect was not clear on fruit production of adult trees, which seems related to the observed re-establishment of water level by trees during the night showing enough water in the soil for chestnut require ments
- ✓ Soil moisture at 75 cm depth keeps higher that the WP until the middle of the dry season, and LWP (Y w) sharply decrease after that (August), which seems to show the importance of deep layers to supply water for trees
- ✓ The obtained results emphasises the importance of rooting depth on agro-forestry systems, which requires a natural sufficient soil depth or an adequate soil preparation before plantation