Introduction of new oLIVE crop management practices focused on CLIMAte change mitigation and adaptation

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Preliminary report on CO_2 balance in olive ecosystem

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Table of contents

1. Summary

The present report summarise the terminology widely adopted within scientific literature for carbon (C) cycling in ecosystems and related framework to be used in the deliverables. In addition to C fluxes occurring between the atmosphere and the orchard, it has been focussed the need for accounting of “lateral” fluxes of C. That lateral transport of C refers to some (anthropogenic) aspect of orchard management such as fruit removal with harvest, C supply through organic fertilisers. All these fluxes have been combined in the Net Ecosystem Carbon Balance (NECB) which would be considered as the reference, therefore NECB >0 indicates the ability of the orchard to sequester C while NECB <0 indicates that the orchard release C.

In this report the simulations (RothC model) of the changes in soil organic carbon level as affected mainly by management practices and water supply method (irrigated/rainfed) are reported.

2. Introduction

The atmospheric concentrations of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have all increased in past decades, in 2011 their concentrations exceeded the pre-industrial levels by about 40%, 150%, and 20%, respectively and CO_2 was indicted as the strongest driver of climate change as measured through the total radiative forcing (IPCC, 2013). Systematic measurements of atmospheric CO_2 concentration are carried out at many sites and networks all over the world (Liu et al., 2015) showing that global atmospheric CO_2 concentration has been regularly increasing at a rate of approx. 2 parts per million (ppm) per year and in places passed 400 ppm in May 2013 (Monastersky, 2013; Liu et al., 2015) (Fig. 1). Carbon dioxide concentrations have increased primarily from fossil fuel emissions and secondarily from net land use change emissions. The ocean has absorbed about 30% of the emitted anthropogenic CO_2, causing ocean acidification which will in turn reduce future ocean capability to trap CO_2 (IPCC, 2013) adding further constraints to the climate change issue.

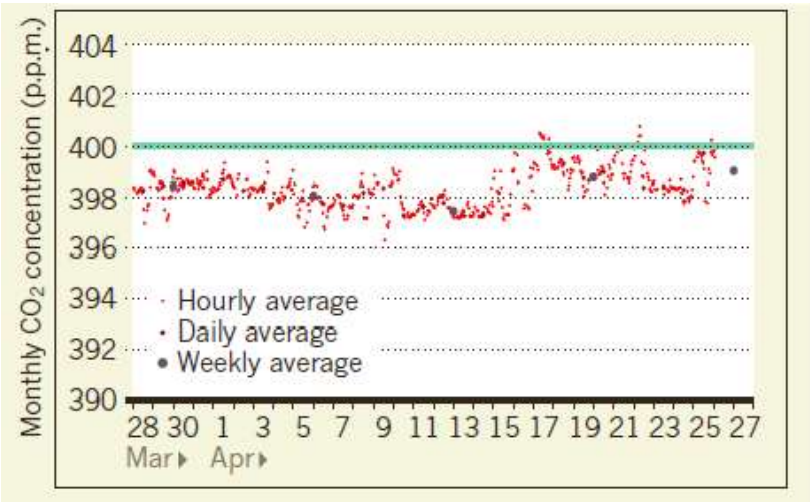


Figure 1 - Records of monthly atmospheric CO_2 concentration during some months in the 2013 at Mauna Loa, Hawaii. (Redrawn from Monastersky, 2013).

A recent review of trends in global GHG emissions reports that agriculture, forestry and other land uses (AFOLU) share approx. 22% of global GHG anthropogenic emissions and that agriculture sector (crop and livestock production) accounts for ~50% of AFOLU emissions (Toniello et al., 2015). The two main anthropogenic sources of GHG emission from agriculture are (i) the energy use (e.g. manufacture, use of external inputs and farm machinery) and (ii) the management of cultivated land. However, the agriculture sector has a great atmospheric CO_2 mitigation potential mainly because of the huge amount of carbon (C) storable in the soil which has been identified has one of the main options for GHG mitigation by the IPCC. Since the breaking of agricultural land in most regions, the soil C stocks have been depleted to such an extent, that soil now represents a potential sink for CO_2 removal from the atmosphere (Hutchinson et al., 2007). However, whether a cultivated land/ecosystem act as sink or source of CO_2 depends on the practices adopted at field scale. For example, appropriate practices promoting CO_2 capture into soil are rotations with high-biomass crops, shifting from annual to perennial crops, reducing or avoiding biomass or crop residues burning, reducing tillage, *in situ* mulching of crop residue management, optimal nutrient and water management, use of organic fertilizers, no-tillage, use of cover crops (Montanaro et al., 2010 and 2012; Petersen et al., 2013).

Proper estimate of the potential for CO_2 sequestration in agricultural ecosystems would be beneficial for identification of best-practices and for a wider recognition of agriculture as key sector for atmospheric CO_2 mitigation. In addition, a consistent approach to account for agricultural emissions/sequestration would minimise disagreement as to whether an ecosystem act as sink or source. However, a more comprehensive understanding of tree growth and C partitioning and its interaction with the environment (soil, atmosphere) is needed to predict C budgets and fluxes in a scenario of future climatic change.

The turnover of the soil organic matter as combined with human management/disturbance of agro-ecosystems is significant for the contribution of agriculture to greenhouse gas (GHG) emissions to the extent that the increase of 4‰ per year of the SOC may significantly help to curb GHG as debated at the last COP21 in December 2015 (Lal, 2016). In addition, there is a renewed interest in modelling the changes of soil C pool as good practice for the optimization of frameworks for national measuring and accounting of GHG (IPCC, 2014; Petersen, 2013). Therefore, through field, management and environmental data collected within the Actions B1, B2, C1, C2, C3 at Peza, Miranbello and Nileas, a Roth-C based 30-year simulations of carbon turnover in relation to environment, soil and management options is reported.

3. Ecosystem carbon balance

Assessing an ecosystem's C balance may help deeper understanding of ecosystem functioning and in turn could be beneficial for the C cycle at global scale. In addition, understanding of C dynamics in olive grove using an ecosystem C balance approach may support development of new environmental friendly policy for olive industry.

Analysis of C mass exchanges between the atmosphere and an ecosystem based on micrometeorological measurements (eddy covariance, EC) has been introduced mainly for forest ecosystems (Baldocchi et al., 1988) and it is increasingly used also in fruit tree crops (e.g. apple, Zanotelli et al., 2014) including olive grove (Nardino et al., 2013). The EC based methodology for C balance has several advantages being non-destructive, providing long-term detailed records at ecosystem scale, however the EC methodology has several constraints: it operates accurately in flat and relatively large area, it provides only data on net ecosystem exchange while information on gross primary production, soil respiration and C stock variation remain to be inferred (Luyssaert et al., 2009). In addition, the financial cost of the equipment may further limit a wide use of EC particularly in hill, non-flat areas. Therefore, in order to have a more affordable C accounting methodology, this report will preliminarily focus on ecosystem C balance based on field measurements that accounts for changes in C sequestration, emissions and net C flux with time.

3.1 Definitions and framework

Gross Primary Production (GPP)

The GPP is the total amount of carbon fixed by plants (including cover crops) through photosynthesis in an ecosystem.

Net Primary Production (NPP)

The NPP is the net production of organic carbon by plants in an ecosystem occurring over a time period (usually one year or more). It is the GPP minus the amount of carbon respired by plants themselves in autotrophic respiration (Ra):

$$NPP = GPP - Ra \qquad (1)$$

The NPP accounts for new leaf (deciduous species), new shoot, fruit, new roots, flowers residuals, biomass increment of coarse roots and shoots, eventually the biomass consumed by herbivores. In addition, amounts related to the short-lived biomass (e.g. fruit drop or thinned, shoots removed through summer pruning) should be accounted, too. The same apply to cover crops if the NPP for the ecosystem is to be determined. Schematic summary for the above/below ground NPP components is reported in the Tab. 1. Importantly, only the amount of carbon produced and lost in the year for which NPP is being calculated is counted, not what was produced in an earlier year and lost in the current year (Kirschbaum et al., 2001).

ECOSYSTEM (ORCHARD) NPP	TREE	Aboveground	Fruit
			Summer pruning
			Leaves
			Dropped fruit
			1-year shoot
			Δwood
			flower rsiduals
		Belowground	$Root_{FINE}$
			$\Delta Root_{COARSE}$
	COVER CROPS	Aboveground	mowed biomass
		Belowground	Root

Table 1 – Tree and cover crops above and belowground components to be accounted for the NPP determination. Note that “dropped fruit” includes thinned fruit; Δwood and Δroot is the biomass increment in > 1-year branches, trunk and coarse root respectively.

Autotrophic respiration (Ra)

Because of internal plant metabolisms, part of the carbon fixed through photosynthesis is lost again in atmosphere by autotrophic respiration (Ra). Usually amount of Ra reaches ~ 50% of GPP and it refers the carbon lost by both the above and belowground plant biomass.

Heterotrophic respiration (Rh)

Apart from Ra, soil is a source of carbon (and other gases) because of heterotrophic respiration from soil organisms, and eventually from litter decomposition and from organic matter oxidation. Hence “soil CO_2 efflux” includes Ra and Rh as schematized in Fig. 2.

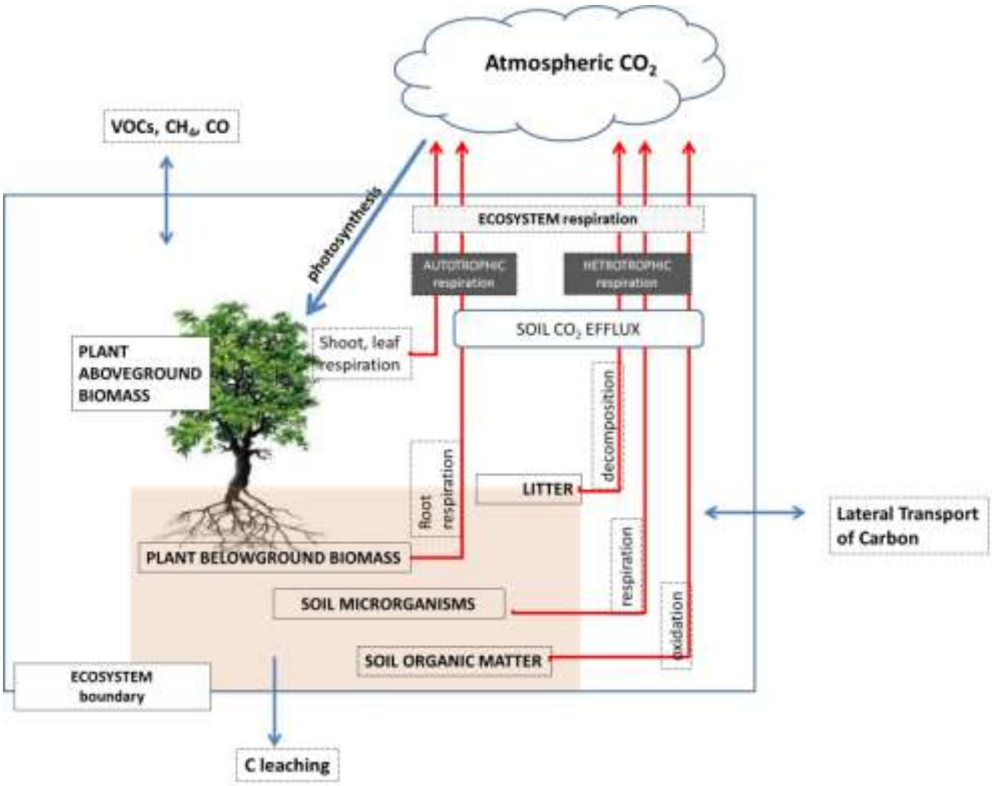


Figure 2 – Schematic representation of the main carbon fluxes in an ecosystem.

Net Ecosystem Production (NEP)

The NEP has been defined as the difference between the ecosystem photosynthetic gain of C (i.e. the gross primary production, GPP) and the ecosystem (plant, microbial, animal) respiratory loss of C (i.e. the ecosystem respiration, Re) (Chapin III et al., 2006) (Fig. 2)

$$NEP = GPP - Re \qquad (2)$$

Considering that Re is the sum of Ra and Rh, and that NPP = GPP-Ra the eq. 2 becomes:

$$NEP = NPP - Rh \qquad (3)$$

hence NEP refers to the net primary production (NPP) minus carbon loss due to heterotrophic respiration. Note that the term NEP equals the NEE (net ecosystem exchange) when fluxes are determined using atmospheric-based measurements (eddy covariance) over time scales of hours. The NEP is more used when C fluxes measurements are based on ecosystem-carbon stock changes.

3.2 Carbon accumulation in ecosystems

Based on eq. (3), it appears that an ecosystem accumulates C when GPP is greater than Re (i.e. GPP/Re >1) whilst an ecosystem lose C when ecosystem respiration exceeds GPP (i.e. GPP/Re <1) thus they can be defined as autotrophic and heterotrophic ecosystems, respectively (Lovett et al., 2006).

Farming can play a major role in climate regulation, both by limiting emissions of GHGs and by sequestering carbon in plants and soil, depending on their management, therefore farms should be considered as “managed ecosystem” (Swinton, 2008). In this context, the total C imports and exports including the anthropogenic sources (or removal) of C should be accounted when determining the ecosystem C balance at orchard scale. According to Chapin III et al., (2006) it is suggested to use the Net Ecosystem Carbon Balance (NECB) in order to include that anthropogenic components and others C sources and sinks identifying “lateral” C fluxes and non-CO_2 fluxes with a positive (absorption) or negative (emission, consumption) sign.

Among the components of the lateral C fluxes are the inorganic/organic dissolved C in soil solution (DIC, DOC), volatile organic compounds (VOC), organic fertilisers (OF), fruit harvest (FH), pruning material (PM) when burned, monoxide C (CO), methane (CH_4), soil exudate, C exported to mycorrhizas, C leaching below the root zone (see Tab. 2 and Fig. 2).

Table 2 – lists the main lateral transport C (LTC) components to be accounted for the NECB determination (adapted from Lovett et al., 2006 and Chapin III et al., 2006), note that pruning material is accounted only when burned.

"Lateral" transport of C (LTC)	MANAGEMENT, SOIL FEATURES and INTERACTIONS	*negative sign*	Yield
		positive sign	compost/manure
		negative sign	pruning material
		negative sign	Erosion
		negative/positive sign	VOC, CH_4, CO,
		positive sign	C export to mycorrhizas
		positive sign	Exudates
		negative sign	C leaching

Considering that most of these LTC components are relatively small and very difficult to assess, the NECB could be simplified as:

NECB = GPP - Re +OF –FH (5)

which equals the following eq. assuming that pruning material is mulched in loco:

NECB = NPP -Rh +OF –FH (6)

Considering that the ecosystem (orchard) is the reference, NECB >0 indicates the ability of the orchard to sequester C while NECB <0 indicates that the orchard release C. An Excel spreadsheet as been assembled to collectively report all components of C ecosystem balance (Tab. 3).

Table 3 – List of components for NECB and other indexes determination

					dry mass $t\ ha^{-1}\ DM\ year^{-1}$	Carbon $t\ C\ ha^{-1}\ year^{-1}$
Comment	**ECOSYSTEM (ORCHARD) NPP**	TREE	Aboveground	Fruit		
				Summer pruning		
				Leaves		
includes thinned fruit				Dropped fruit		
				1-year shoot		
increment in > 1-year branches and trunk				Δwood		
				flower rsiduals		
			Belowground	$Root_{FINE}$		
increment in coarse roots				$\Delta Root_{COARSE}$		
		COVER CROPS	Aboveground	mowed biomass		
			Belowground	Root		
					total NPP $g\ C\ m^{-2}\ year^{-1}$	**0**
	"Lateral" transport of C (LTC)	MANAGEMENT, SOIL FEATURES and INTERACTIONS	*negative sign*	Yield		
			positive sign	compost/manure		
it is intend only if the prunings are removed from orchard			*negative sign*	pruning material		
accounting C in eroded soil: important in not-flat soil			*negative sign*	Erosion		
			negative/positive sign	VOC, CH_4, CO,		
			positive sign	C export to mycorrhizas		
remaining within the soil volume explored by root			*positive sign*	Exudates		
dissolved, non-dissolved C leaching below root zone			*negative sign*	C leaching		
					Net LTC $g\ C\ m^{-2}\ year^{-1}$	**0**
	RESPIRATION	SOIL Carbon EMISSIONS R_{eco}	R_a	R_a Autotrophic (root) resp.		
			R_h	Heterotrophic resp.		
				Organic matter oxidation		
				litter decomposition		
					total R_h $g\ C\ m^{-2}\ year^{-1}$	**0**
					NEP Net Ecosystem Production $g\ C\ m^{-2}\ year^{-1}$	**0**
				NECB > 0, sink **NECB <0, source**	**NECB Net Ecosystem C Balance $g\ C\ m^{-2}\ year^{-1}$**	**0**
			GPP=NEP+Reco;	CUE = NPP/GPP	**CUE Carbon Use Efficiency**	**#DIV/0!**
				NPP_{fruit}/NPP	**HI harvest index**	**#DIV/0!**
					NSCB Net Soil Carbon Balance	
	NPP minus fruit, standing biomass, 5% fine root,			+compost, + pruning material	**INPUT** $g\ C\ m^{-2}\ year^{-1}$	0
				corresponds to R_h	**OUTPUT** $g\ C\ m^{-2}\ year^{-1}$	0
					$g\ C\ m^{-2}\ year^{-1}$	**0**

4. Long-term soil organic carbon dynamics

The 109 experimental olive plots involved in the projects OLIVECLIMA have been divided into the following 12 clusters, based on their total soil carbon (TOC) content, water supply (irrigated/rainfed) and application of sustainable management practices for carbon storage in soil (treated/control). The “treated” fields are those managed according with the suggestions provided in the Project and aimed at increase the soil carbon content. The following Table summarize these practices adopted at each of location considered:

	Nileas	Miranbello	Peza
Mulching of pruning residues	YES	YES	YES
Cover crops	YES	YES	YES
Addition of compost	YES	YES	YES
Addition of olive mill wastewater	NO	NO	YES
No soil tillage	YES	YES	YES

From the combination of the various managements and TOC level, the following 12 typologies of field were analysed:

1. Treated irrigated very low TOC
2. Treated irrigated low TOC
3. Treated irrigated medium TOC
4. Treated rainfed very low TOC
5. Treated rainfed low TOC
6. Treated rainfed medium TOC

7. Control irrigated very low TOC
8. Control irrigated low TOC
9. Control irrigated medium TOC
10. Control rainfed very low TOC
11. Control rainfed low TOC
12. Control rainfed medium TOC

The thresholds to define the categories of carbon content in soil have been retrieved from the European Soil Data Center (http://esdac.jrc.ec.europa.eu/content/ptrdb-attributes): OC_TOP = Topsoil organic carbon content:

H = High (> 6 %)
M = Medium (2 - 6 %)
L = Low (1 - 2 %)
V = Very low (< 1 %)

For each defined cluster, composed of different numbers of plots, have been calculated the average data necessary to perform the simulation: soil carbon content, number of trees per hectare, soil texture, yield and amount of water irrigated (from data of 2013-2014).
The soil bulk density have been calculated from soil texture (soil calculator of century website https://www.nrel.colostate.edu/projects/century/) and a default soil scheleton of 3% has been assumed.
The ratio between Decomposable Plant Material and Resistant Plant Material (DPM/RPM) used in the Roth C simulation has been fixed equal to 0.25 for treated plots (0.2/0.8), and to 4 for control plots (0.8/0.2).
The 109 plots are located in three different areas of Greece showed in the map below: Messinia, Peza, Mirabello. The average of last 10 years climate data for each area have been used to perform the Roth C simulations:

Location	Month	Avg Temp [°C]	Avg Rainfall [mm]	Avg Eto [mm]
Merambelos - Agios Nikolaos	January	6,4	184,6	38,6
	February	6,5	173,0	35,0
	March	8,4	71,5	41,0
	April	10,9	58,0	40,5
	May	15,2	34,7	44,4
	June	18,4	5,9	48,8
	July	19,8	0,4	61,7
	August	20,1	0,7	68,3
	September	17,5	31,2	66,0
	October	14,3	130,2	57,5
	November	10,9	99,5	45,3
	December	7,8	188,5	39,7
Nileas-Kalamata	January	9,1	128,5	42,9
	February	9,9	104,0	39,8
	March	12,7	60,1	47,7
	April	15,4	44,1	46,9
	May	20,1	25,9	51,0
	June	24,1	18,0	56,4
	July	27,1	4,0	73,8
	August	27,3	9,3	81,3
	September	22,9	41,4	76,1
	October	18,1	93,0	64,3
	November	13,8	88,0	49,9
	December	10,8	112,4	44,3
Peza-Iraklio	January	12,3	78,9	48,1
	February	12,2	76,7	43,3
	March	14,2	31,9	49,9
	April	16,6	21,3	48,6
	May	20,3	12,0	51,2
	June	24,0	1,1	56,3
	July	26,4	0,0	72,6
	August	26,4	0,1	79,8
	September	23,7	14,7	77,5
	October	19,8	73,4	67,4
	November	16,7	48,7	54,5
	December	14,0	88,8	49,2

The carbon input to soil used in simulation have been retrieved from different sources:

- Pruning residues, seed mixture and weed residues, compost and olive mill waste water data have been provided from field per each of the three pilot area examined;

- Weeds and seed mixture data provided have been increased of 20% to take into account the belowground part of weeds (Celano et al., 2003).
- Leaves' turnover per tree estimated based on Ĉermák et al. (2007) e Connor e Fereres (2005), multiplied per the average tree density of the cluster.

Month of C input: November (harvesting and rainfall induce fall of senescent leaves)
Avg leaf mass: 85 mg
Leaves live for 2 to 3 years so ca.
40% of the canopy is lost (and replaced) each year.
145000 leaves average (Ĉermák et al. 2007)
58.000 senescent leaves every year => *4,93 kg senescent leaves · tree^{-1}· year^{-1}*
Specific leaf mass = 205 g m^{-2} (Connor e Fereres 2005)
Mean leaf area = 45-94 m^2 (Cermak et al 2007) => *14,24 kg senescent leaves · tree^{-1}· year^{-1}*
Average = ***9,59 kg kg senescent leaves · tree^{-1}· year^{-1}***
It was assumed 30% moisture of leaves ad 50% carbon content of dry mass

- Fine roots' turnover estimated as 50% of aboveground trees' organs turnover (leaves turnover+pruning residues+yield) (Cannell, 1985). Months of carbon input to soil (Palese et al 2000): March for rainfed systems (winter-spring), July for irrigated systems (summer).

In the following pages are reported the results of Roth C simulations for the 26 clusters identified in the three experimental areas of OLIVECLIMA project. The simulations have been implemented for a time horizon of 30 years, assuming that before this period all plots were managed with conventional practices (as control plots), for the initialization of soil carbon pools in the Roth C model.
The version of Roth C 10_N adapted to region with semi-arid climatic conditions (Farina et al 2013) have been used, in the excel based format.

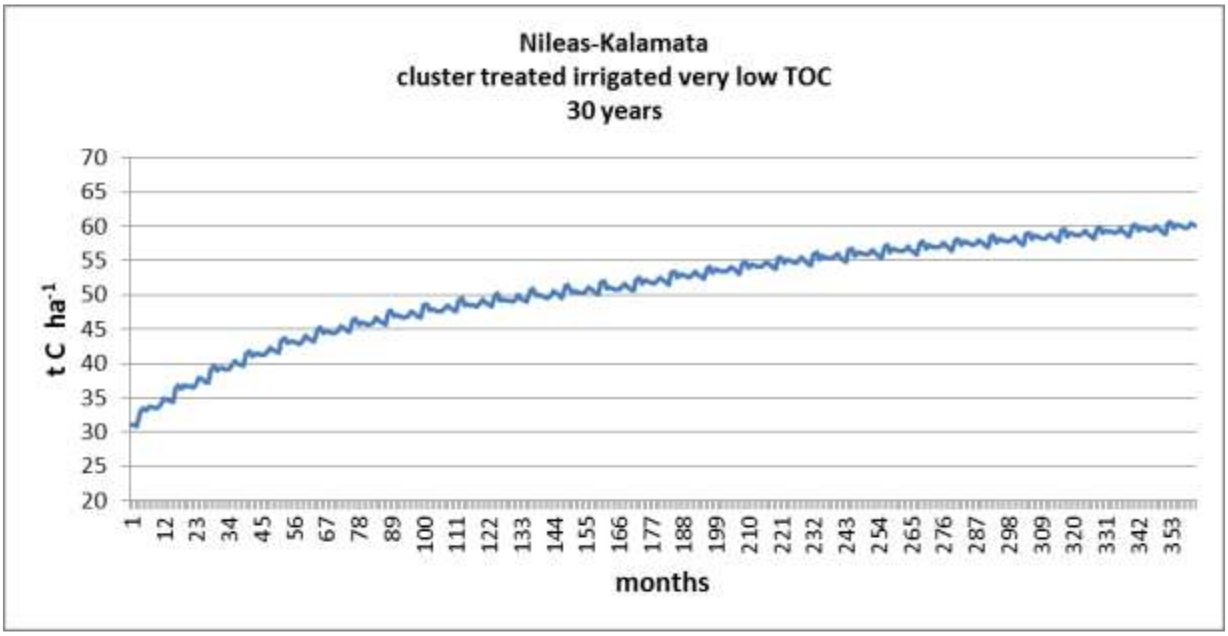
NILEAS (10 simulations)

1. Treated irrigated very low TOC

4 plots: 12.01 55.03 59.01 8.03

Sand= 42,1% Silt= 31,0% Clay= 26,9%
Avg n. trees ha^{-1}= 194

Soil Organic C from 0,85% to 1,64% in 30 years → storage of 0,97 t C ha^{-1} year^{-1} in soil = 3,6 t CO_2 ha^{-1} year^{-1} removed from atmosphere



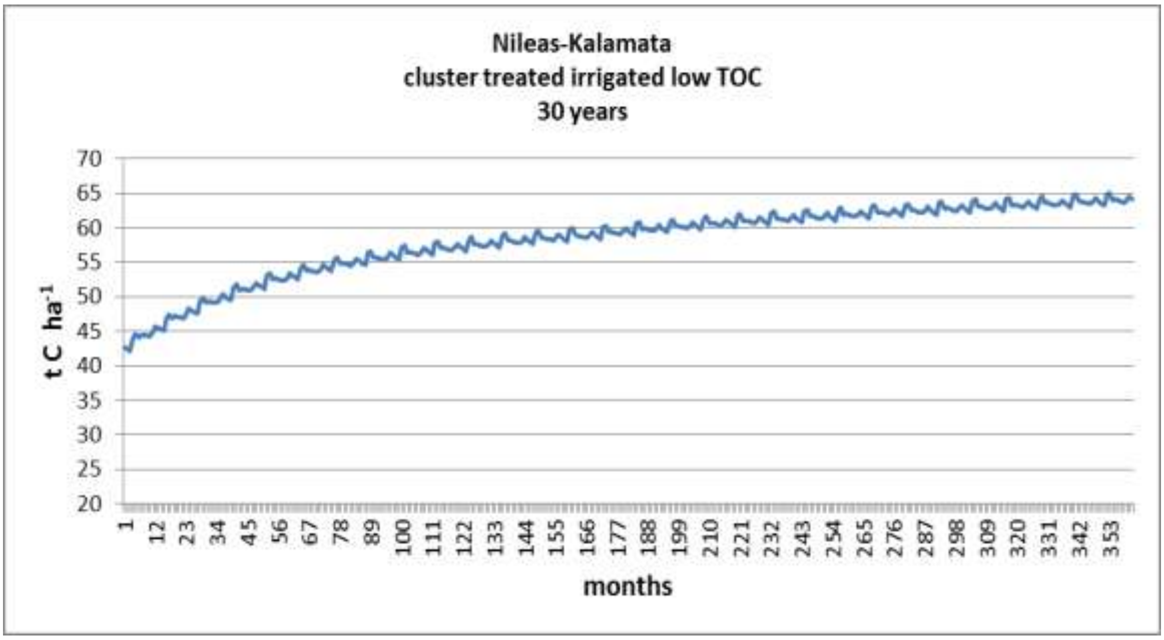
2. Treated irrigated low TOC

4 plots: 10.03   17.04 27.04 180.08

Sand =34,1%   Silt=35,9%   Clay=30,1%

Avg n. trees ha^{-1}= 167

Soil Organic C from 1,2% to 1,79% in 30 years → storage of 0,7 t C ha^{-1} $year^{-1}$ in soil = 2,6 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



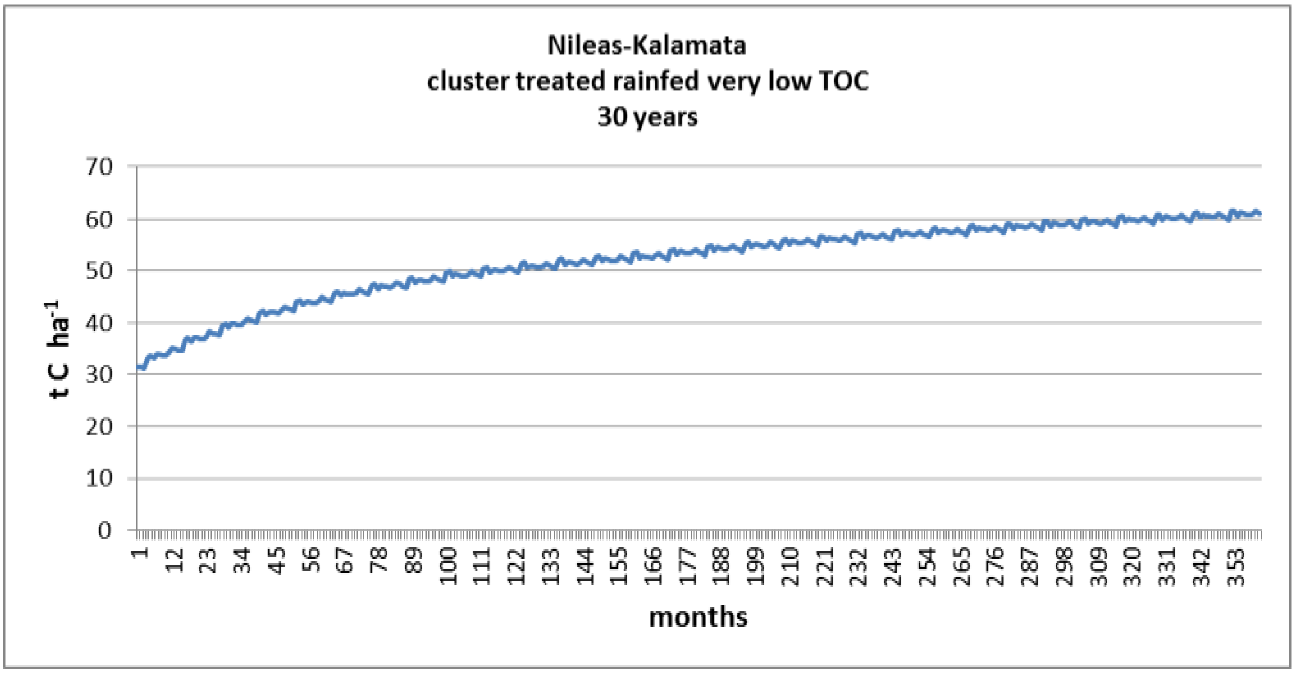
3. Treated rainfed very low TOC

2 plots: 30.04   73.02

Sand= 36,0%   Silt=37,5%   Clay=26,5%

Avg n. trees ha^{-1}= 195

Soil Organic C from 0,87% to 1,68% in 30 years → storage of 0,98 t C ha^{-1} $year^{-1}$ in soil= 3,6 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



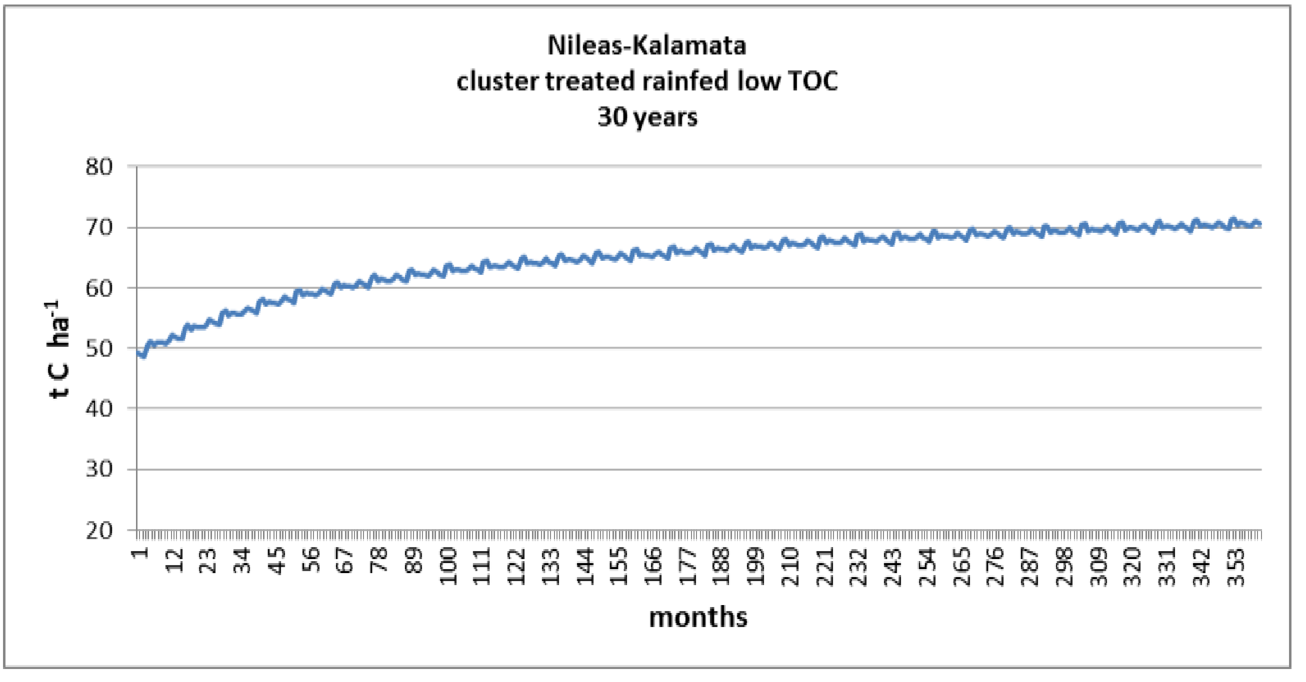
4. Treated rainfed low TOC

8 plots: 10.04 200.01 21.01 40.04 41.03 44.01 58.01 8.01

Sand= 34,7% Silt=39,7% Clay= 25,7%

Avg n. trees ha^{-1}= 187

Soil Organic C from 1,35% to 1,94% in 30 years → storage of 0,71 t C ha^{-1} $year^{-1}$ in soil = 2,6 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



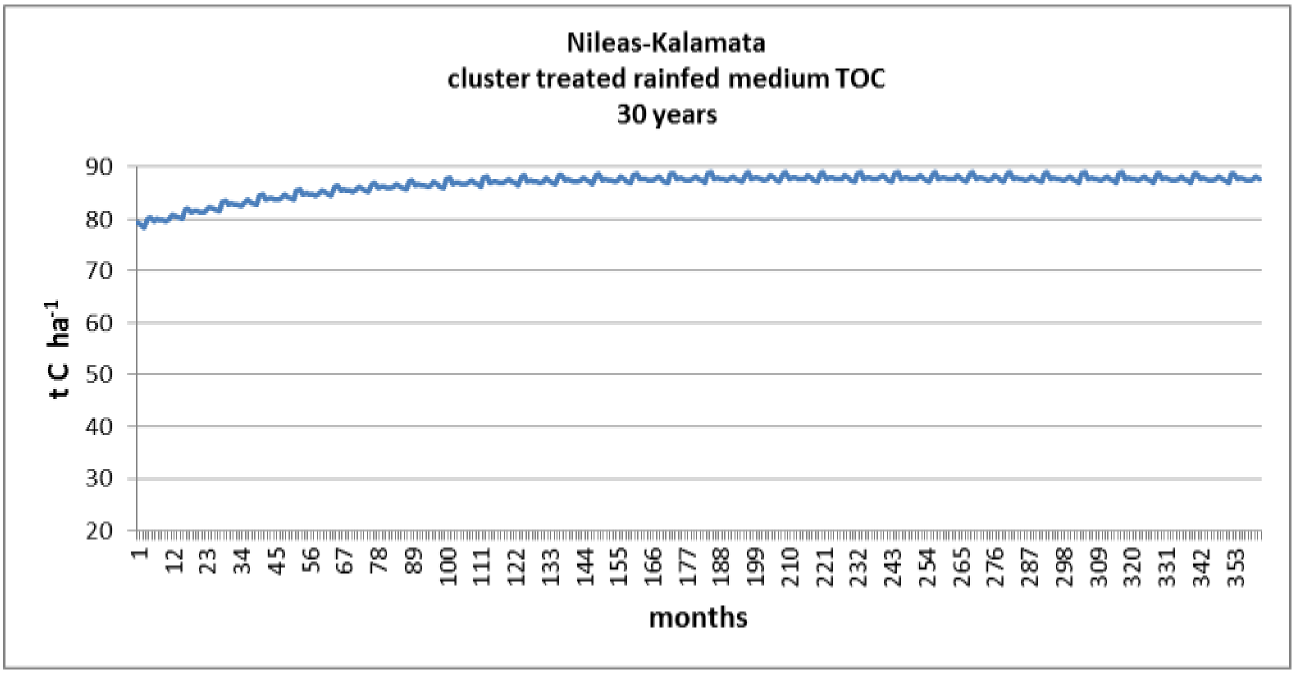
5. Treated rainfed medium TOC

1 plot: 180.10

Sand= 55,2%   Clay= 20,8%   Silt=24,0%

Avg n. trees ha^{-1}= 288

Soil Organic C from 2,11% to 2,32% in 30 years → storage of 0,28 t C ha^{-1} $year^{-1}$ in soil = 1,03 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



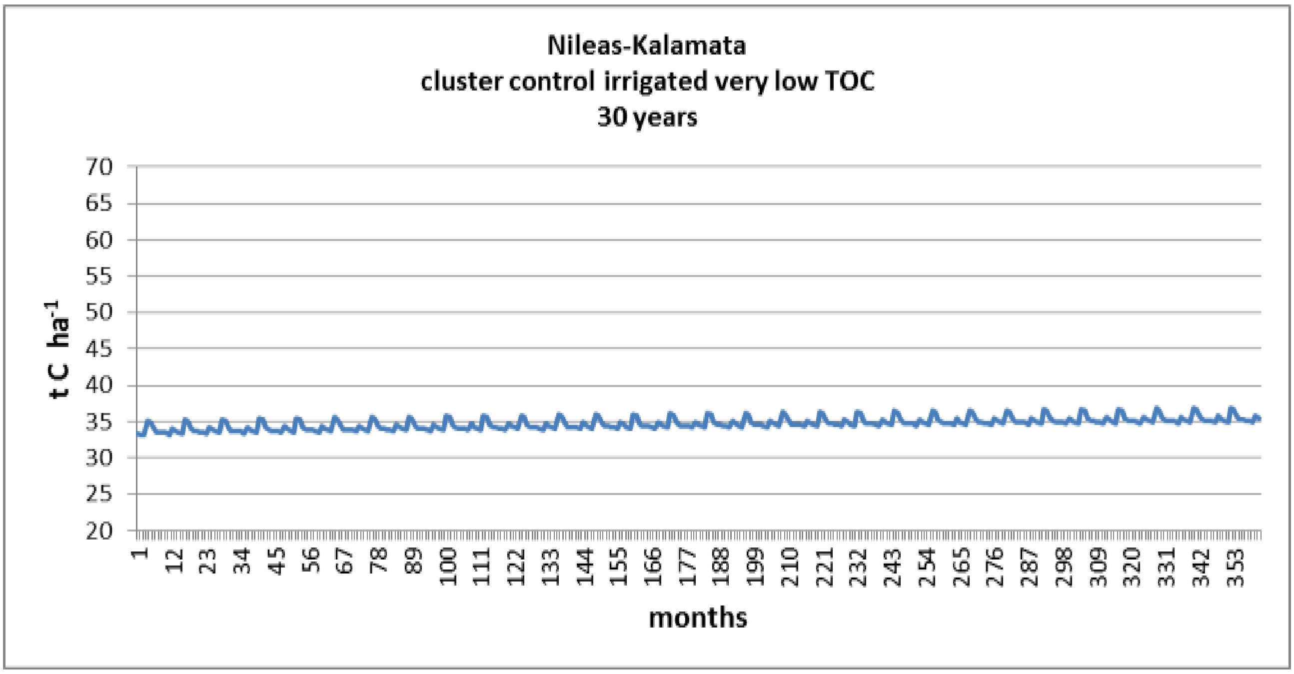
6. Control irrigated very low TOC

2 plots: 17.10   27.03

Sand= 55,2%   Silt= 28,2%   Clay=16,6%

Avg n. trees ha^{-1}= 219

Soil Organic C from 0,85% to 0,9% in 30 years → storage of 0,07 t C ha^{-1} $year^{-1}$ in soil= 0,26 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



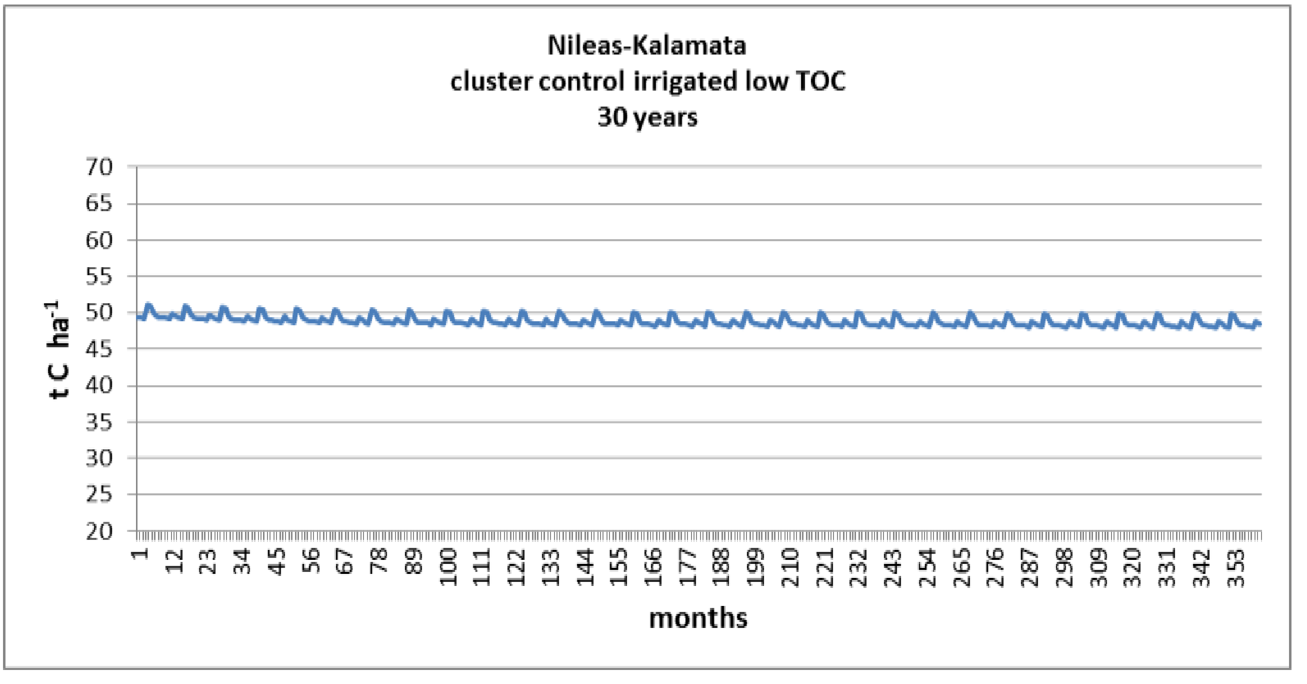
7. Control irrigated low TOC

6 plots: 8.04   10.02   10.05   17.07   59.05   98.02

Sand=31,0%   Silt=39,2%   Clay=29,7%

Avg n. trees ha^{-1}= 217

Soil Organic C from 1,37% to 1,35% in 30 years → decrease of 0,035 t C ha^{-1} $year^{-1}$ in soil = 0,13 t CO_2 ha^{-1} $year^{-1}$ emitted in atmosphere



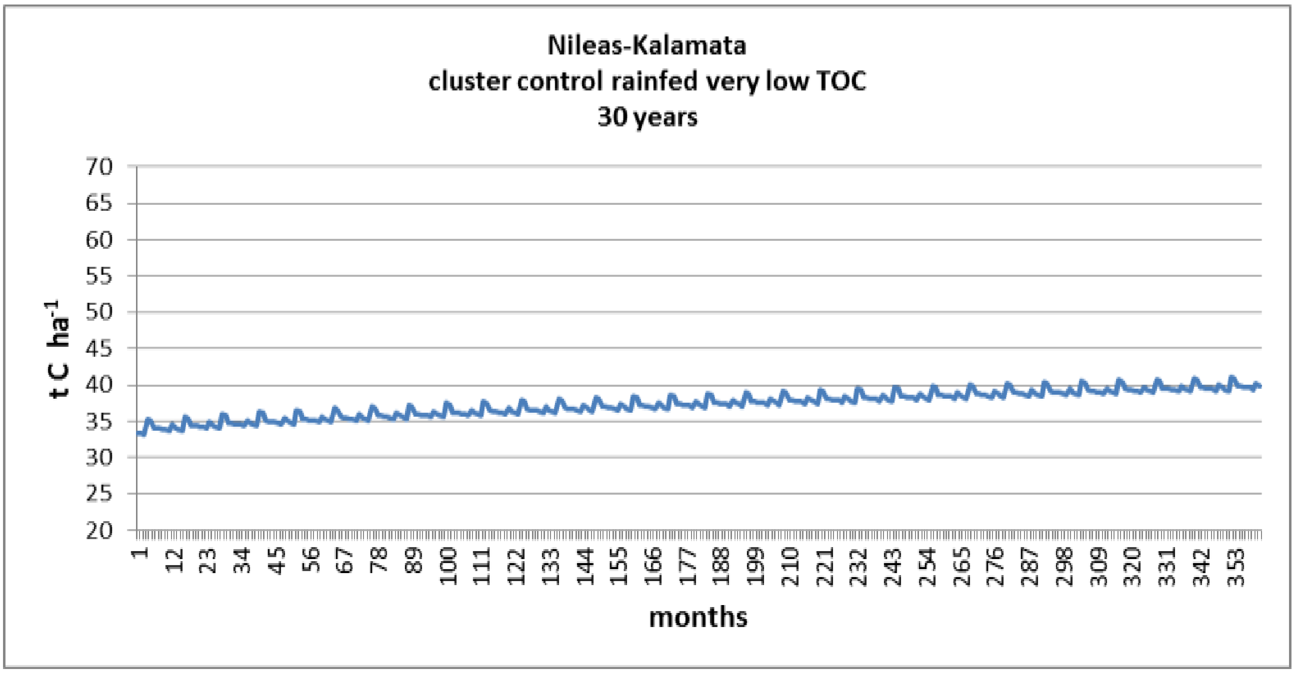
8. Control rainfed very low TOC

1 plot: 17.03

Sand= 23,6%   Silt=47,6%   Clay=28,8%

Avg n. trees ha^{-1}= 172

Soil Organic C from 0,91% to 1,12% in 30 years → storage of 0,21 t C ha^{-1} $year^{-1}$ in soil = 0,78 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



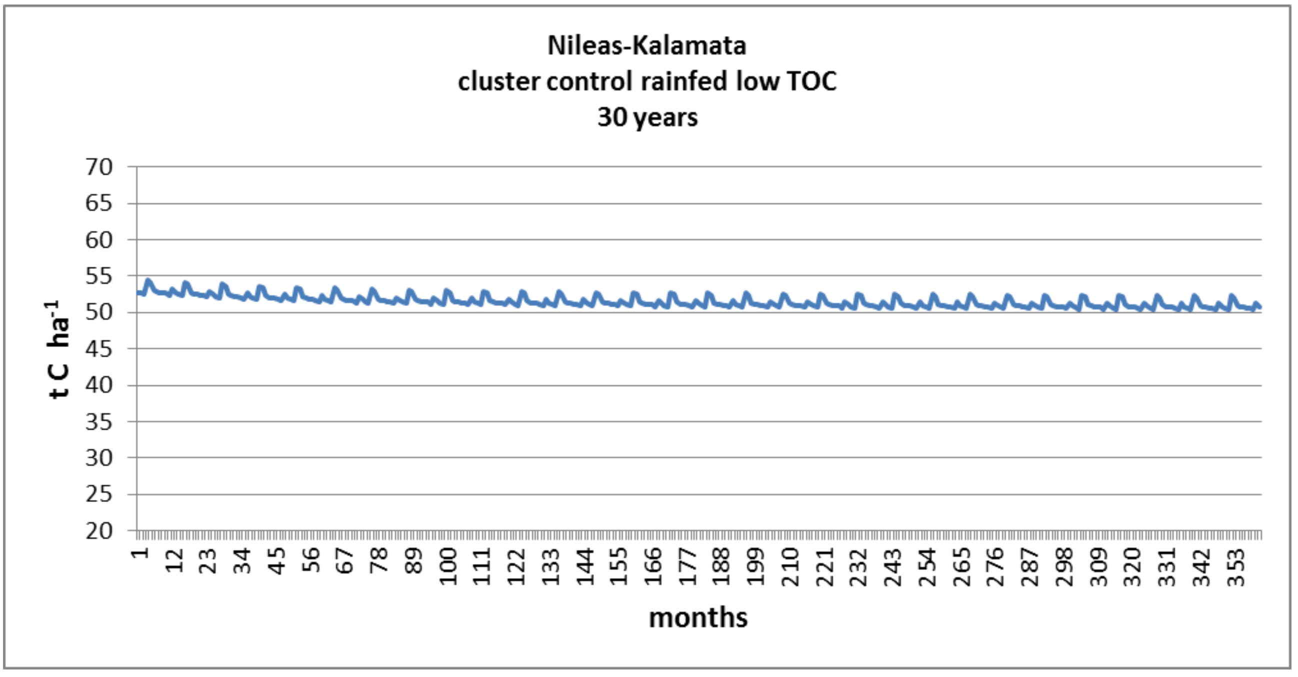
9. Control rainfed low TOC

9 plots: 180.06 20.02 23.01 23.02 41.04 43.02 48.01 55.05 8.02

Sand=41,7% Silt=34,6% Clay=23,6%

Avg n. trees ha^{-1}= 180

Soil Organic C from 1,41% to 1,36% in 30 years → decrease of 0,065 t C ha^{-1} $year^{-1}$ in soil = 0,24 t CO_2 ha^{-1} $year^{-1}$ emitted in atmosphere



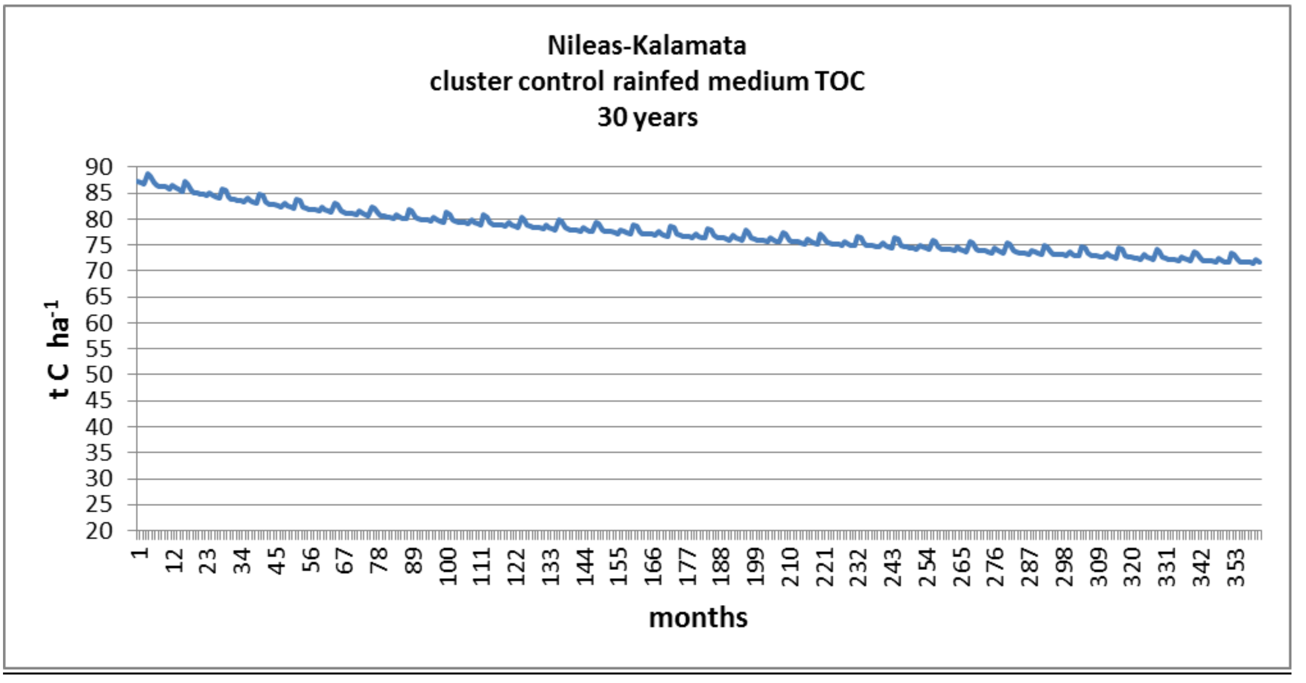
10. Control rainfed medium TOC

1 plot: 180.11

Sand=56,4% Silt=19,6% Clay= 24,0%

Avg n. trees ha^{-1}= 140

Soil Organic C from 2,3% to 1,9% in 30 years → decrease of 0,5 t C ha^{-1} $year^{-1}$ in soil = 1,89 t CO_2 ha^{-1} $year^{-1}$ emitted in atmosphere



MIRABELLO (8 simulations)

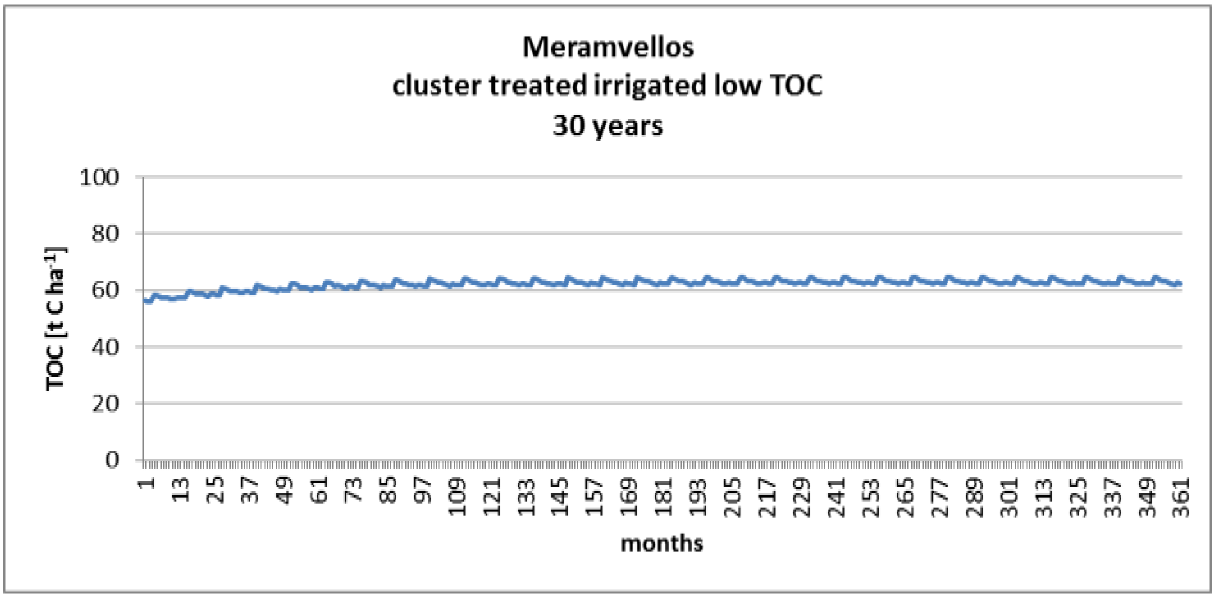
1. Treated irrigated low TOC

4 plots: MΣME0041 MΣME0043 MΣME0863 MΣME0870

Sand= 44% Silt=26,8% Clay=29,2%

Avg n. trees ha^{-1}= 258

Soil Organic C from 1,55% to 1,72% in 30 years → storage of 0,2 t C ha^{-1} $year^{-1}$ in soil = 0,73 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



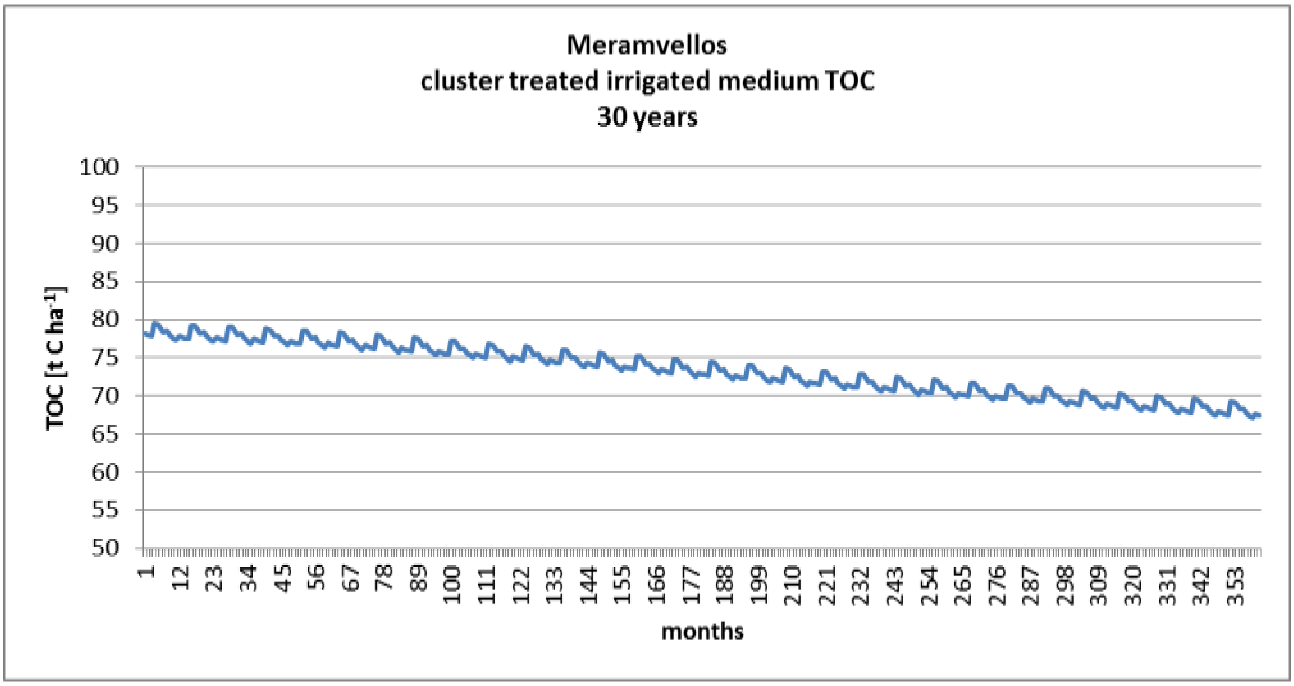
2. Treated irrigated medium TOC

4 plots: AAME1065 MΣME0042 MΣME0044 MΣME0452

Sand= 28,6% Silt= 22,8% Clay=48,6%

Avg n. trees ha^{-1}= 217

Soil Organic C from 2,34% to 2,01% in 30 years → decrease of 0,36 t C ha^{-1} year^{-1} in soil = 1,32 t CO_2 ha^{-1} year^{-1} emitted to atmosphere



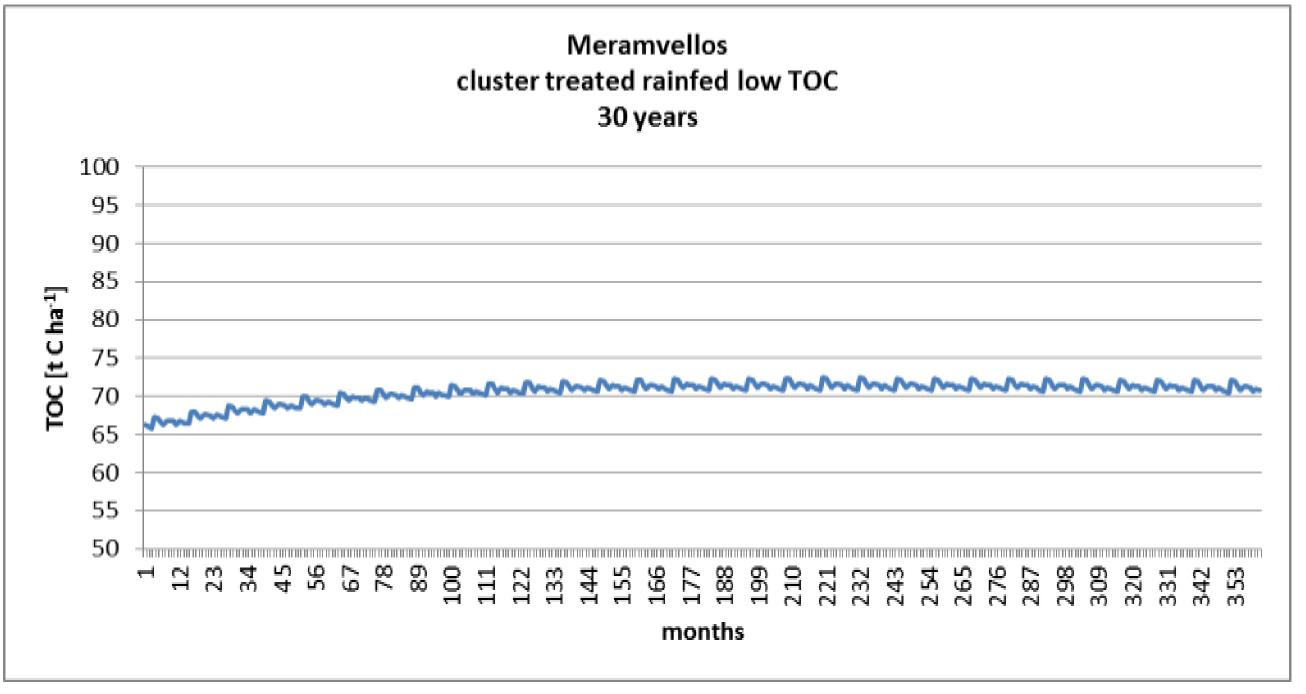
3. Treated rainfed low TOC

4 plots: AAME0435 ΜΣΜΕ0225 ΜΣΜΕ0475 ΜΣΜΕ0864

Sand=39,1% Silt=36,4% Clay=24,5%

Avg n. trees ha^{-1}= 195

Soil Organic C from 1,80% to 1,92% in 30 years → storage of 0,15 t C ha^{-1} year^{-1} in soil = 0,55 t CO_2 ha^{-1} year^{-1} removed from atmosphere



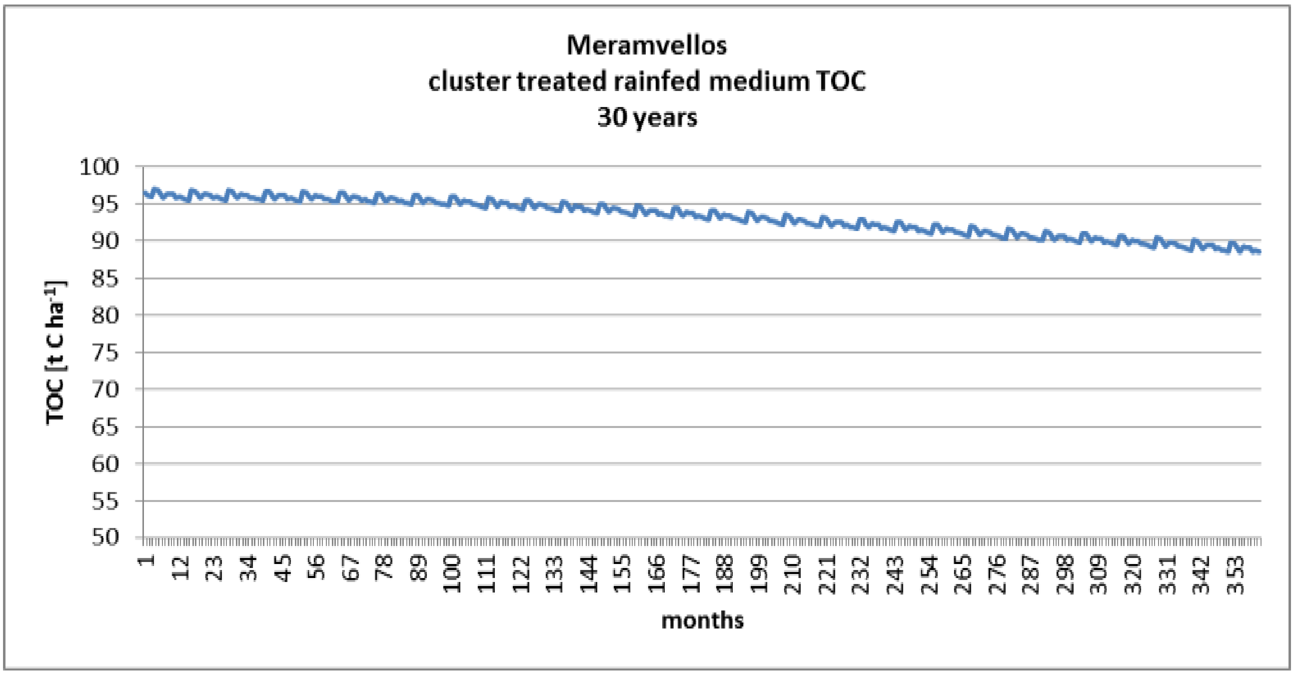
4. Treated rainfed medium TOC

6 plots: AAME0865 MΣME0282 MΣME0464 MΣME0467 MΣME0469 MΣME0546

Sand =25,87% Silt= 33,73% Clay=40,4%

Avg n. trees ha^{-1}= 107

Soil Organic C from 2,84% to 2,60% in 30 years → decrease of 0,27 t C ha^{-1} year^{-1} in soil = 0,99 t CO_2 ha^{-1} year^{-1} emitted to atmosphere



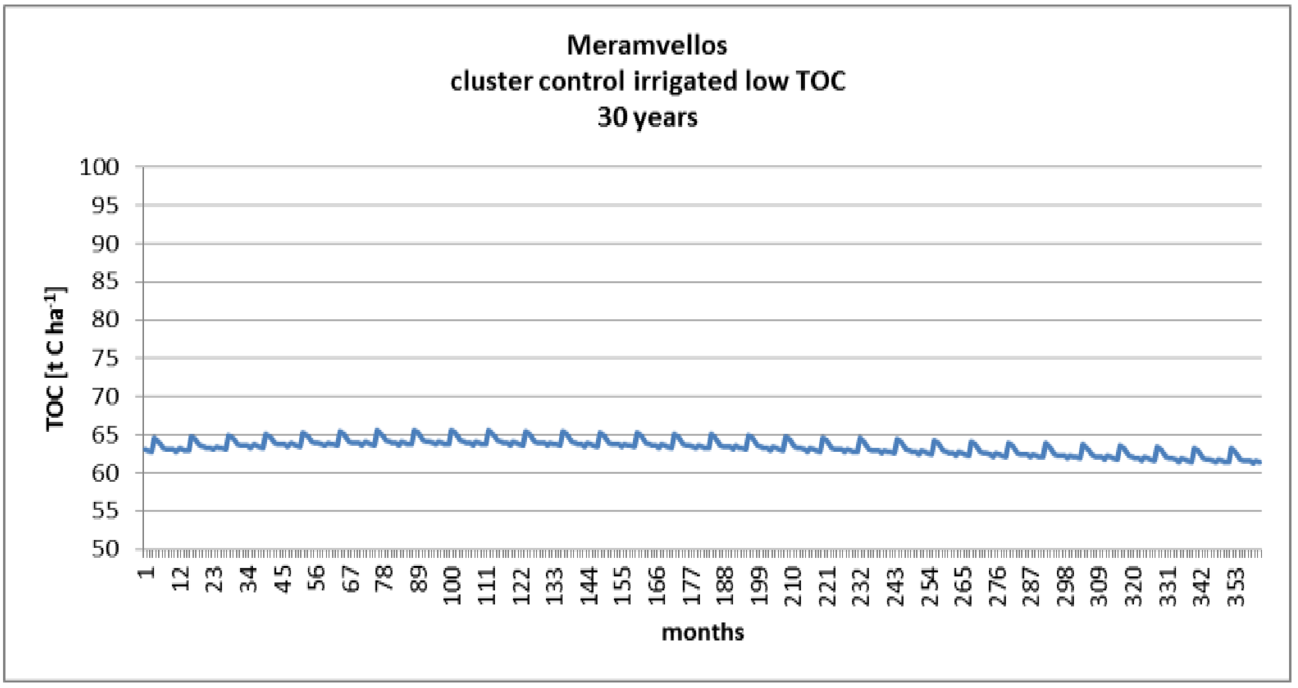
5. Control irrigated low TOC

4 plots: MΣME0037 MΣME0845 MΣME0423 MΣME0860

Sand=34,6% Silt=35% Clay=30,4%

Avg n. trees ha^{-1}= 193

Soil Organic C from 1,76% to 1,72% in 30 years → decrease of 0,05 t C ha^{-1} $year^{-1}$ in soil = + 0,18 t CO_2 ha^{-1} $year^{-1}$ emitted to atmosphere



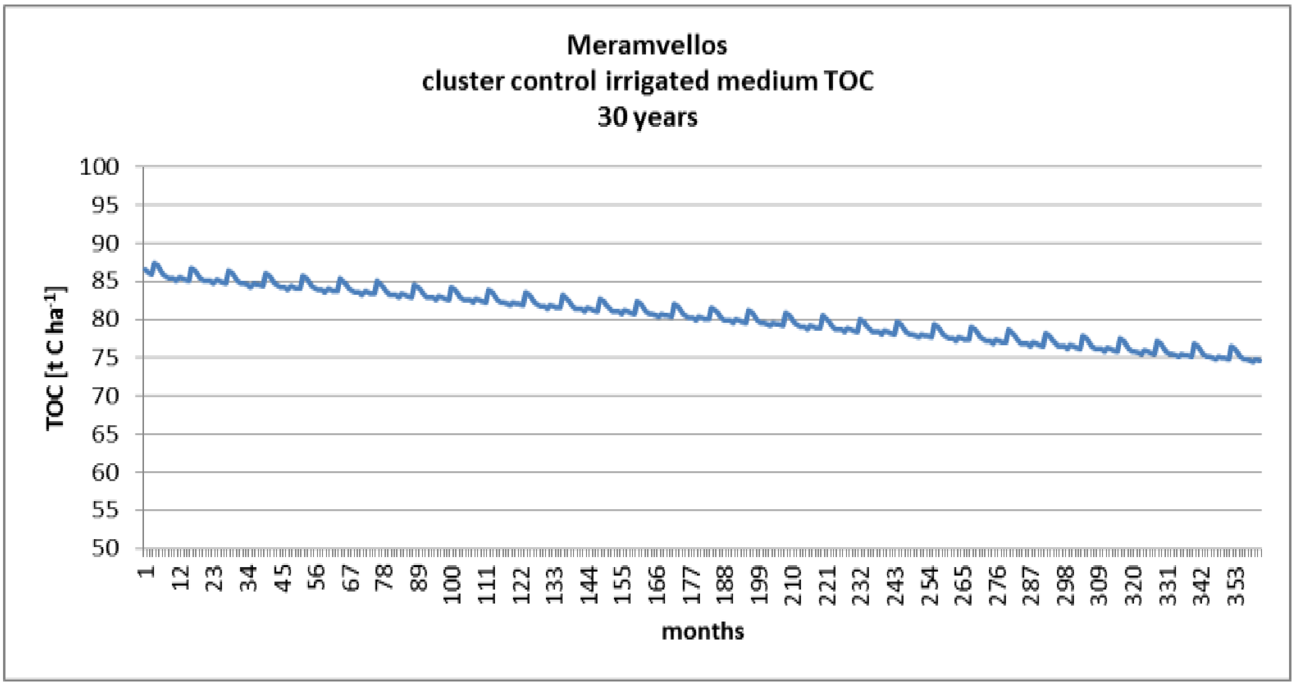
6. Control irrigated medium TOC

5 plots: AAME0027 MΣME0038 MΣME0429 MΣME0451 MΣME0453

Sand=32,88% Silt=27,28% Clay=39,84%

Avg n. trees ha^{-1}= 207

Soil Organic C from 2,52% to 2,18% in 30 years → decrease of 0,39 t C ha^{-1} year^{-1} in soil = 1,43 t CO_2 ha^{-1} year^{-1} emitted in atmosphere



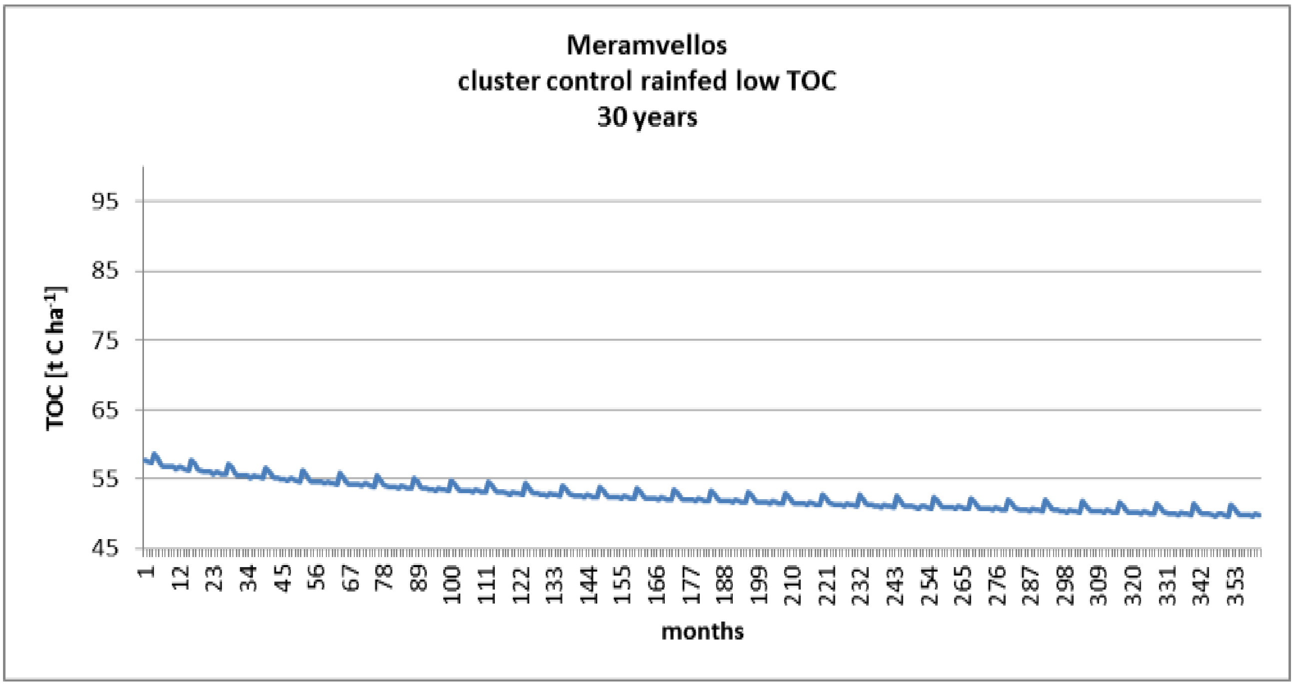
7. Control rainfed low TOC

7 plots: AAME0436 AAME0341 AAME0343 AAME0347 ΜΣΜΕ0279 ΜΣΜΕ0283 ΜΣΜΕ0479

Sand=34,74% Silt=38,23% Clay=27,03%

Avg n. trees ha^{-1}= 145

Soil Organic C from 1,7% to 1,46% in 30 years → decrease of 0,27 t C ha^{-1} $year^{-1}$ in soil = 0,99 t CO_2 ha^{-1} $year^{-1}$ emitted to atmosphere

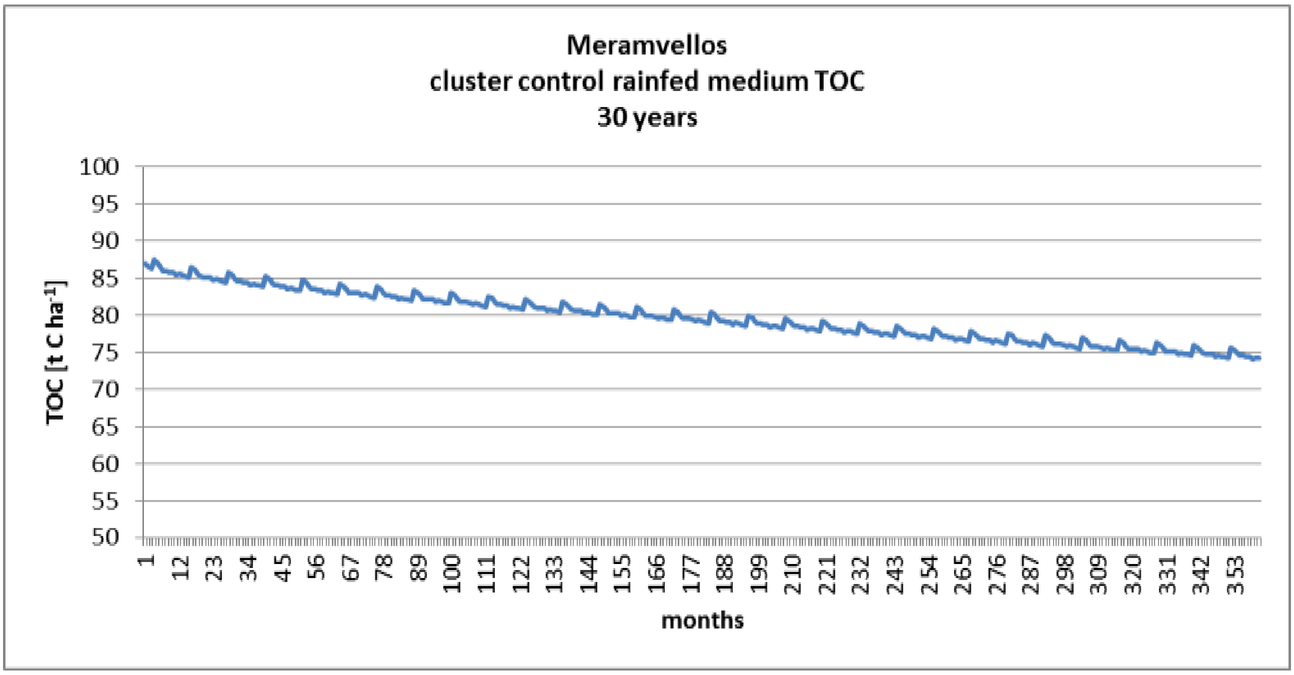


8. Control rainfed medium TOC

4 plots: ΜΣΜΕ0226 ΜΣΜΕ0457 ΜΣΜΕ0483 ΜΣΜΕ0542
Sand=37,4% Silt=27,7% Clay=34,9%

Avg n. trees ha^{-1}= 116

Soil Organic C from 2,47% to 2,11% in 30 years → decrease of 0,43 t C ha^{-1} $year^{-1}$ in soil = 1,57 t CO_2 ha^{-1} $year^{-1}$ emitted to atmosphere



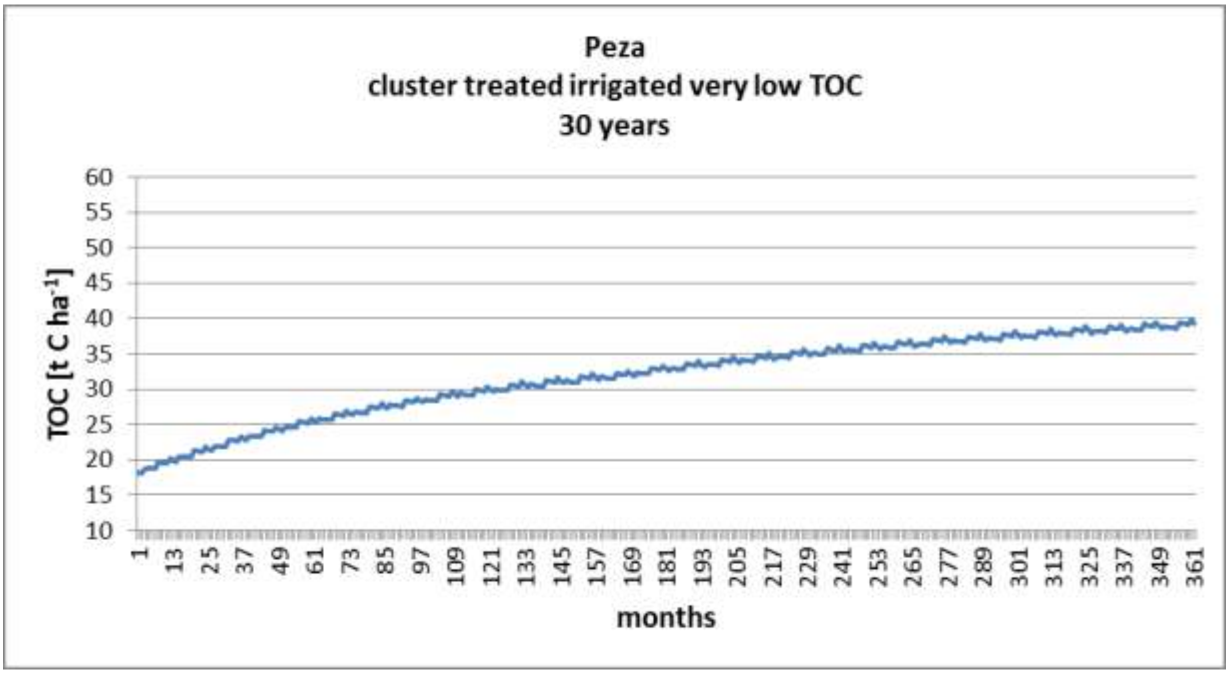
PEZA (8 simulations)

1. Treated irrigated very low TOC

3 plots: 103004   17302   17303 (old code)
Sand= 47,5% Silt= 25,3%   Clay= 27,2%

Avg n. trees ha^{-1}= 213

Soil Organic C from 0,5% to 1,06% in 30 years → storage of 0,7 t C ha^{-1} $year^{-1}$ in soil = 2,57 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere

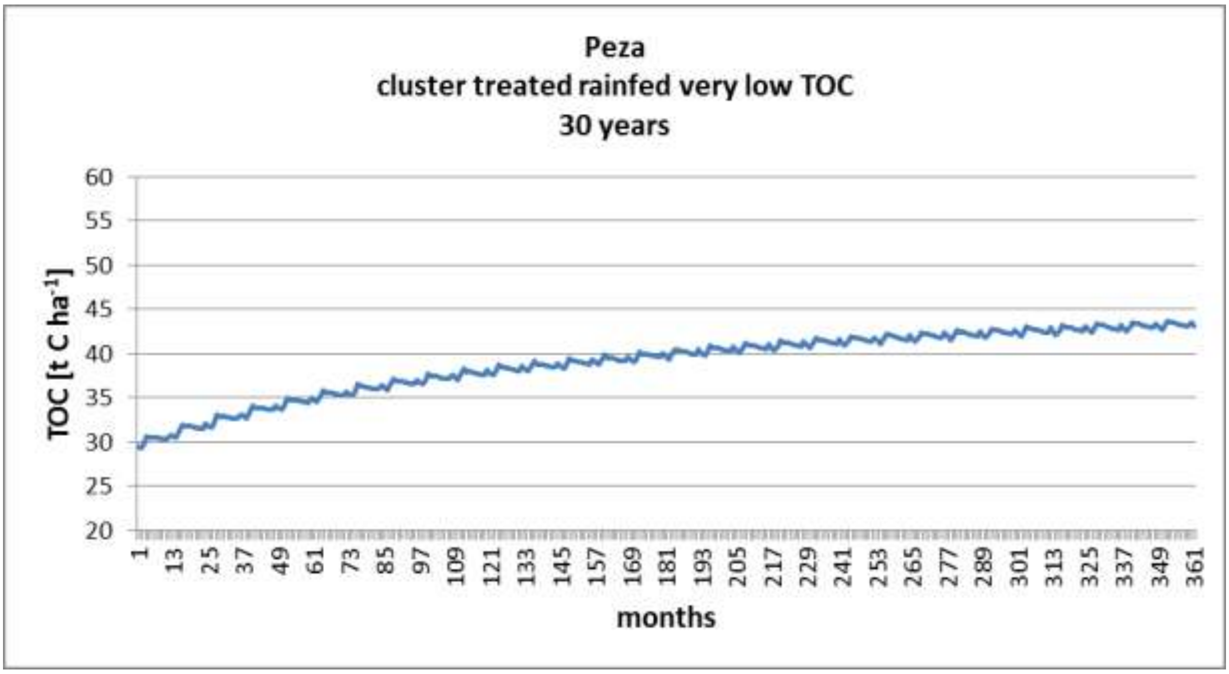


2. Treated rainfed very low TOC

3 plots: 53504 79801 79807 (old code)
Sand= 30,9% Silt= 41,1% Clay= 28%

Avg n. trees ha^{-1}= 167

Soil Organic C from 0,83% to 1,21% in 30 years → storage of 0,45 t C ha^{-1} $year^{-1}$ in soil = 1,65 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere

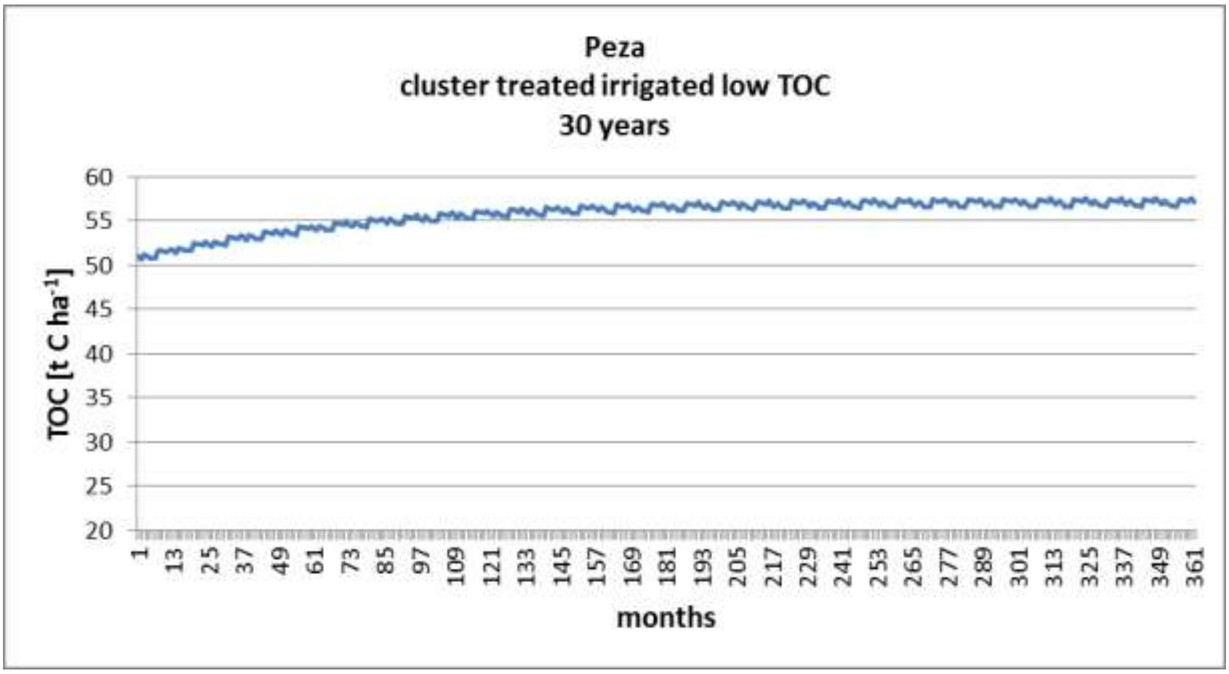


3. Treated irrigated low TOC

1 plot: 1508 (old code)
Sand= 43,2% Silt= 30% Clay= 26,8%

Avg n. trees ha^{-1}= 117

Soil Organic C from 1,4% to 1,56% in 30 years → storage of 0,2 t C ha^{-1} $year^{-1}$ in soil = 0,75 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere

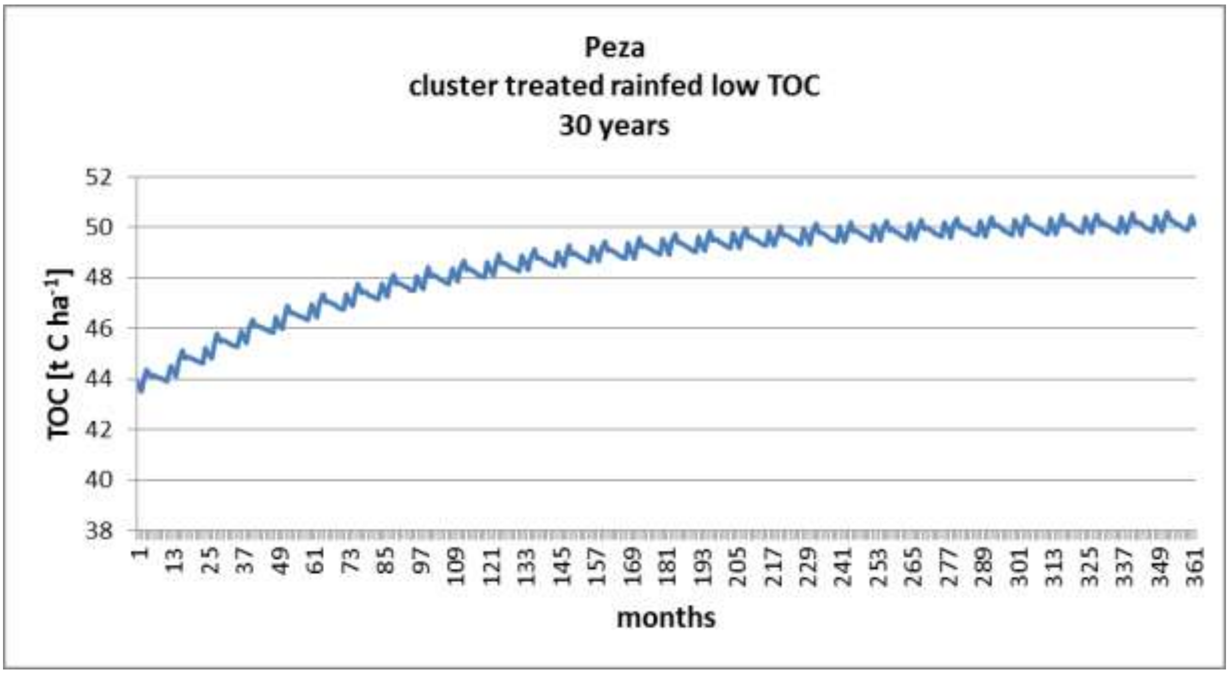


4. Treated rainfed low TOC

Plots: 105106 24101 59001 79803 79804 87204 95203 (old code)
Sand= 28,6% Silt= 37,4% Clay= 34%

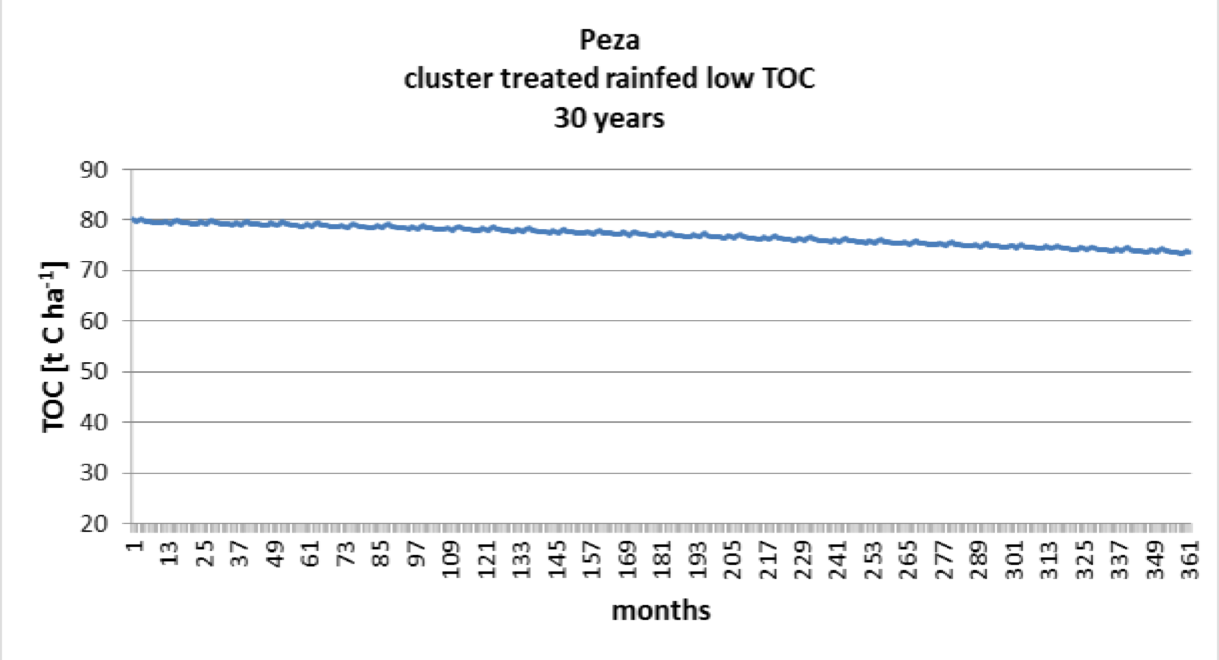
Avg n. trees ha^{-1}= 191

Soil Organic C from 1,26% to 1,44% in 30 years → storage of 0,21 t C ha^{-1} year^{-1} in soil = -0,77 t CO_2 ha^{-1} year^{-1} removed from atmosphere



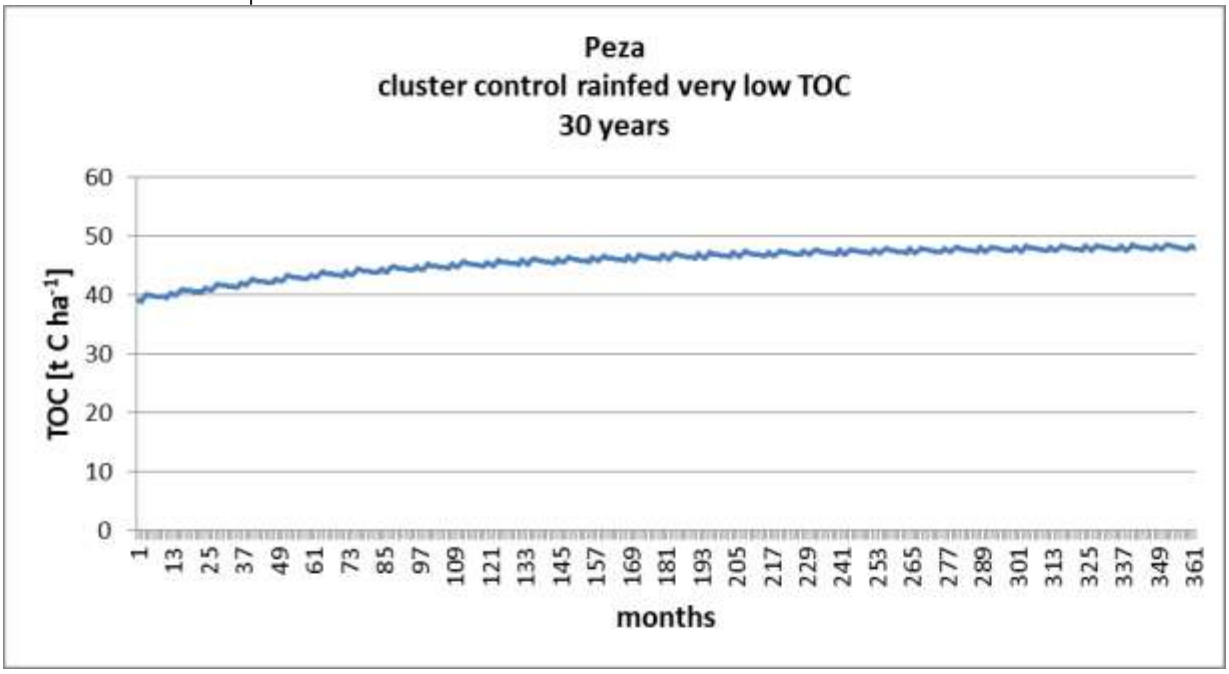
5. Treated rainfed medium TOC

2 plots: 105107 87206 (old code)
Sand= 25,8% Silt= 28,8% Clay= 45,4%
Avg n. trees ha^{-1}= 142
Soil Organic C from 2.38% to 2,18% in 30 years → decrease of 0,22 t C ha^{-1} $year^{-1}$ in soil = 0,81 t CO_2 ha^{-1} $year^{-1}$ emitted to atmosphere



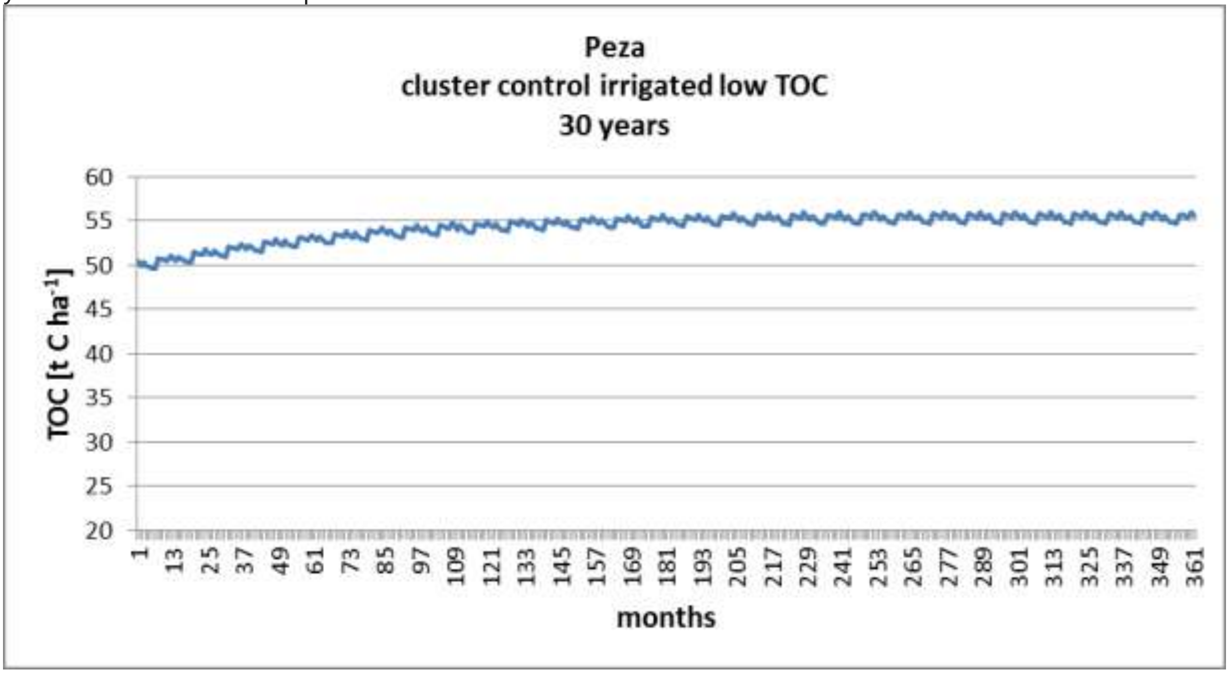
6. Control rainfed very low TOC

1 plot: 103006 (old code)
Sand= 62% Silt= 21,6% Clay= 16,4%
Avg n. trees ha^{-1}= 235
Soil Organic C from 0,99% to 1,21% in 30 years → storage of 0,29 t C ha^{-1} $year^{-1}$ in soil = 1,08 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



7. Control irrigated low TOC

3 plots: 3501 3502 25917 (old code)
Sand= 56,5% Silt= 26,8% Clay= 16,7%
Avg n. trees ha^{-1}= 191
Soil Organic C from 1,29% to 1,41% in 30 years → storage of 0,17 t C ha^{-1} $year^{-1}$ in soil = -0,62 t CO_2 ha^{-1} $year^{-1}$ removed from atmosphere



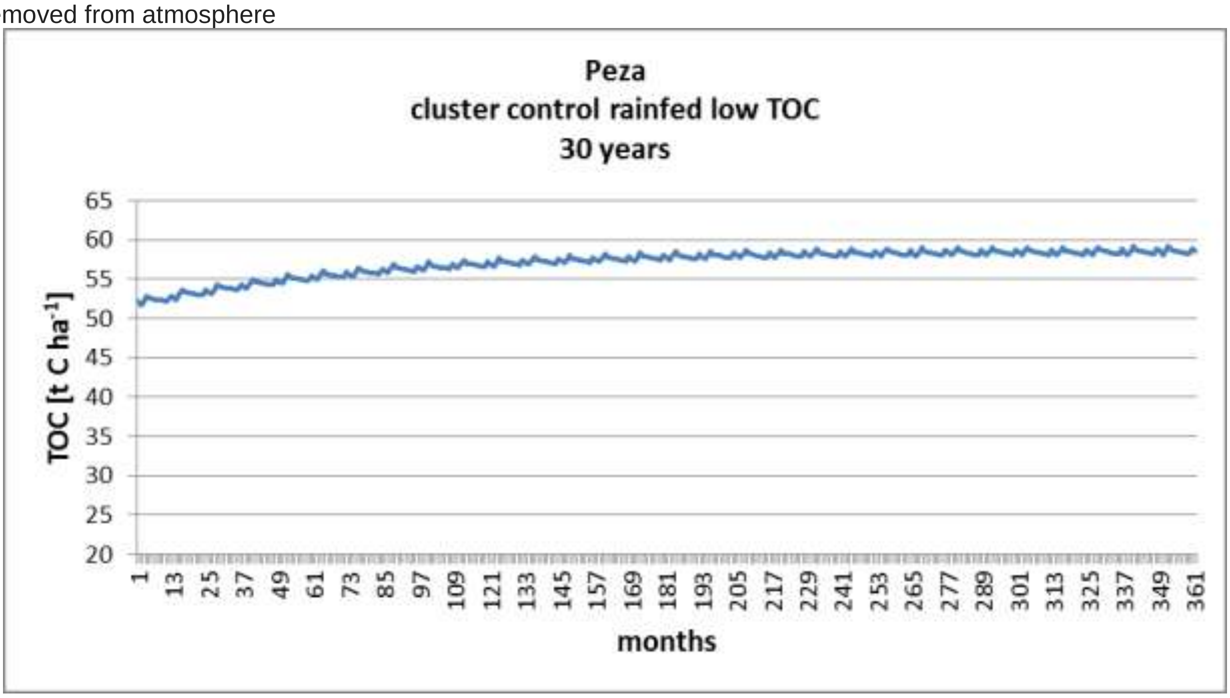
8. Control rainfed low TOC

14 plots: 105102 105104 105105 1501 22917 2407 24109 25910 5105 5201 53501 59005 64006 87207 (old code)

Sand= 28,3% Silt= 38,6% Clay= 33,2%

Avg n. trees ha^{-1}= 207

Soil Organic C from 1,49% to 1,67% in 30 years → storage of 0,21 t C ha^{-1} year^{-1} in soil = 0,78 t CO_2 ha^{-1} year^{-1} removed from atmosphere



5. Conclusions

This report focussed the suitable framework for the determination of the C balance in a olive ecosystem providing, in a preliminary form, the scientific base for the methodology to account the fluxes. Particularly, the NECB method highlights the significant impact of growers' management choices on the overall C budget and in turn on the potential mitigation of the atmospheric CO_2 provided by olive ecosystems.

The simulations for the soil carbon changes as affected by management and water supply highlight the beneficial effect of the introduction of sustainable practices. In addition, simulations show that in some cases despite the adoption of the sustainable practices a decline in SOC is expected (see case 5 at Peza) suggesting that the import of organic raw material should be increased.

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