Technische Universität München

CEBAS
CENTRO DE EDAFOLOGÍA Y BIOLOGÍA APLICADA DEL SEGURA

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

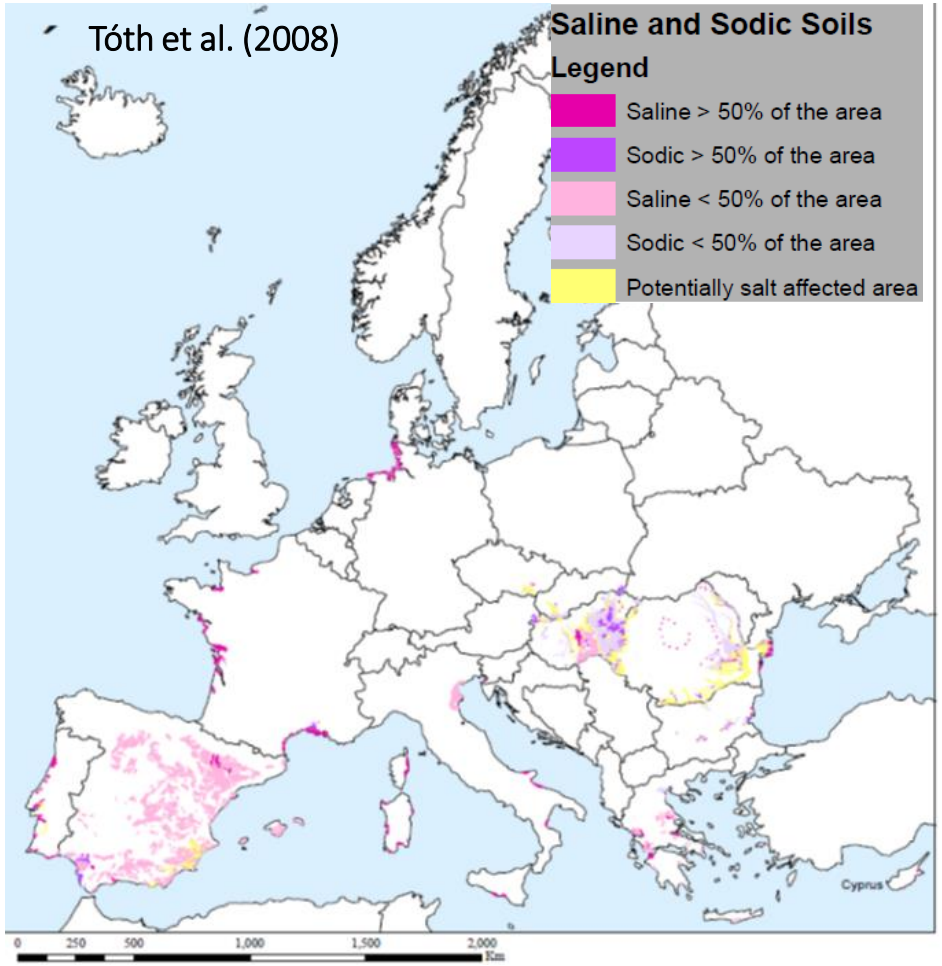
GLOBAL SYMPOSIUM ON SALT-AFFECTED SOILS

20 - 22 October, 2021
Virtual meeting

Long-term combination of **pruning residues** incorporation, **reduced tillage** and **drip irrigation** to improve SOM stabilization and structure of salt-affected soils in a semi-arid Citrus tree orchard

Noelia Garcia-Franco

FAO 2009: Irrigated agriculture in semi-arid areas represents **20%** of the total cultivated land, and contributes **40%** of the total worldwide produced food



Nearly **11% of irrigated semi-arid soils are saturated with salts** (primary and/or secondary formation), which is a widespread problem that threatens food security

Salinity: refers to high loads of water-soluble salts within the soil, which is typical for Solonchaks, while sodicity is understood to mean high levels of Na^+ on the exchange sites **(Bischoff et al., 2018):**

$$SAR = \frac{Na^+}{\left(Ca^{2+} + Mg^{2+}\right)^{0.5}}$$

- **EC**: electric conductivity
- **SAR**: sodium adsorption ratio

EC > 4 dSm^{-1} and SAR < 13 dSm^{-1} → **Salt-affected soil**

FAO 2009; FAO 2001; FAO 2009; Qadir et al. 2001; Wicke et al. 2011, 2013

Garcia-Franco et al., 2021. Soil & Tillage

Poor soil structure **(FAO,2016)**: desertification, erosión, salinity, loss of nutrients…

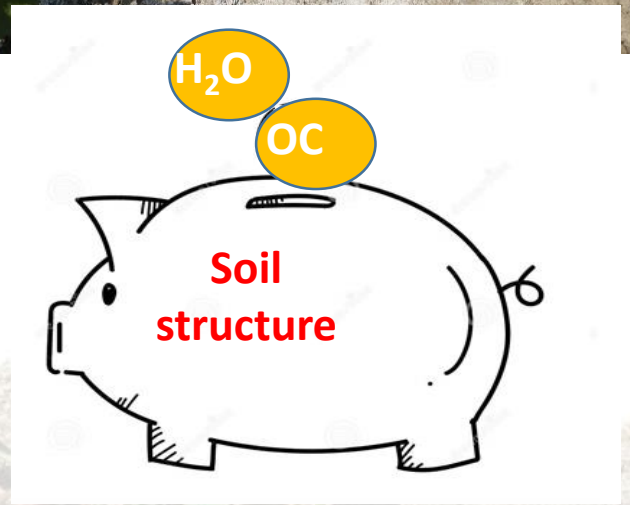
Historical land use: Low SOC saturation, high potential capacity of SOC storage.

Hot spots: importance for crop production and human food security

Restauration of these areas is a major challenge **(Six and Paustian, 2014; Almagro et al., Almagro et al., 2016;Garcia-Franco et al., 2018)**

Salt-affected soils will **become more frequent** as a result of climate change **(Bischoff et al., 2018).**

Nevertheless, **little is known about organic matter (OM) dynamics** in salt-affected soil soils, though OM is crucial for **soil fertility** and represents **an important carbon sink.**



Garcia-Franco et al., 2021. Soil & Tillage

Soil physical properties

Affect the behaviour of soil and functional processes required to meet environmental and socio-economic human needs…

Example: Texture, bulk density, porosity, water content…

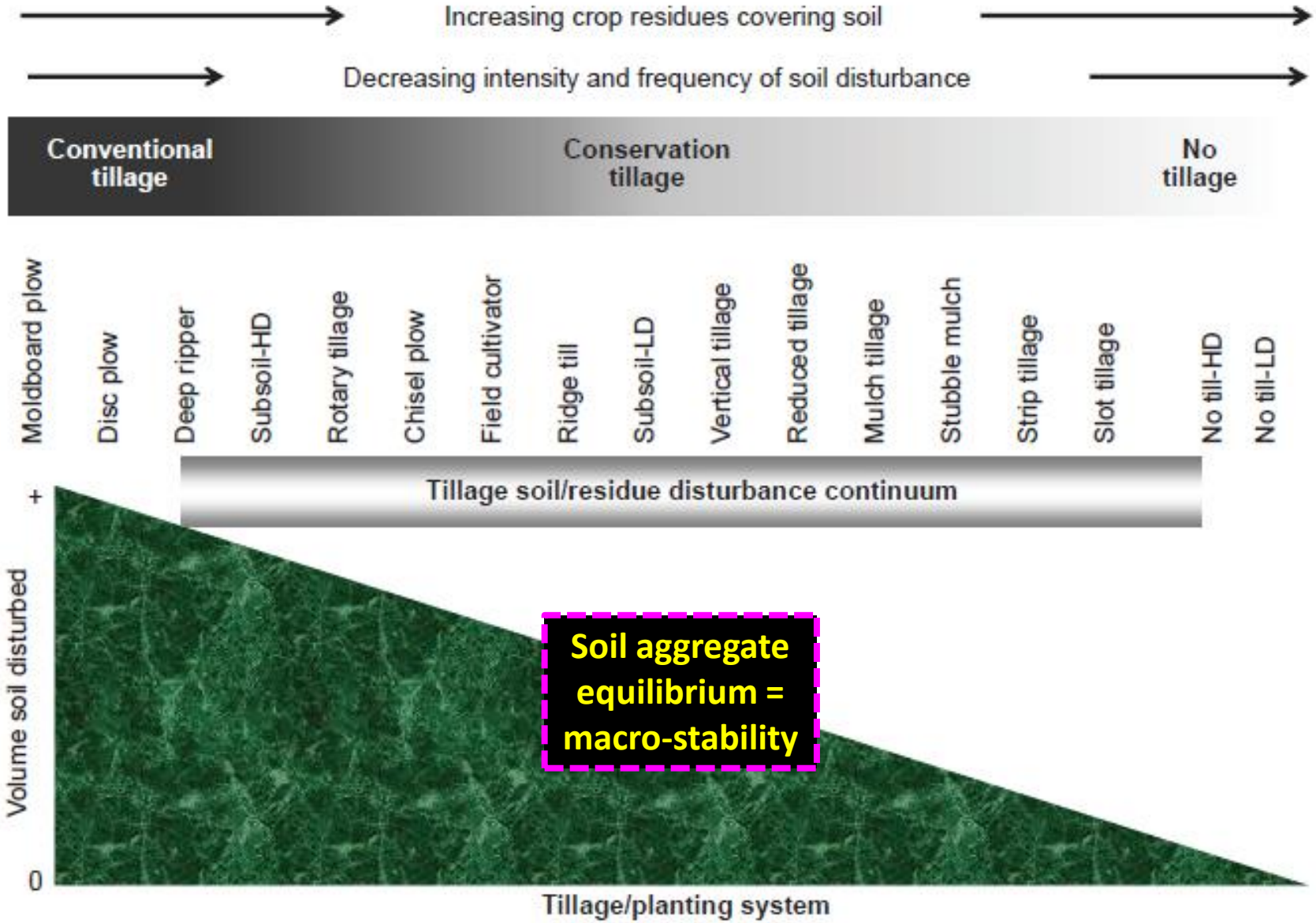
Good indicator of soil health = soil quality

Aggregation/ Aggregate stability (Wiesmeier et al., 2019)

Arrangement of primary soil particles (sand, silt, clay) around SOM, roots, hyphae, microorganisms products, cementing/binding agents…through particle association

Soil aggregate stability is the result of complex interaction among biological, chemical and physical process in the soil (Tisdall and Oades, 1985; Chen et al., 1998; Wiesmeier et al., 2019; Six et al., 2006…)

Reicosky, 2015



Combination of different agricultural management practices in **long-term**

Increase SOC (and N) stock? + **Soil aggregate stability and associated OC (and N) ?** + **Qualitiy and quantity of different OM pools?**

Hero = Sink of OC?

Villain = Source of OC?

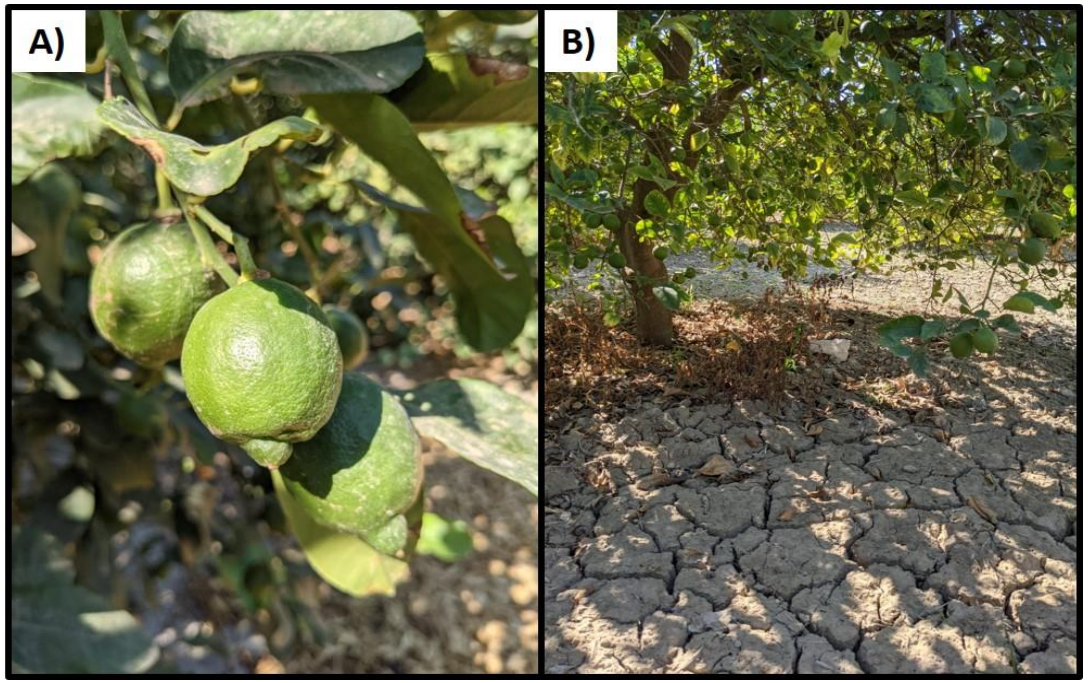
Garcia-Franco et al., 2021. Soil & Tillage

Semiarid Mediterranean ecosystems

MAP = 300-370 mm yr^{-1}
MAT = 18-16°C
EVAP = 800-1000 mm yr^{-1}

50 % of total lemon production in Spain is from Murcia

Calcaric Solonchak (WRB, 2015)



A) *Citrus lemon* tree and B) salt-affected soil in the studied semi-arid area (Librilla, Spain)

Canal of Taibilla
(Source: https://www.mct.es/web/mct)

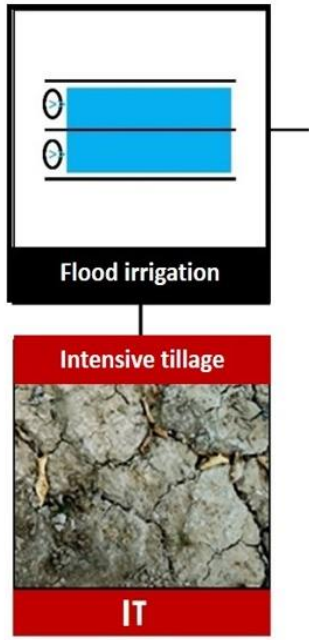
Garcia-Franco et al., 2021. Soil & Tillage

In 2017: Composited samples 0-5 and 5-15 cm (3 samples x 3 blocks x 2 depths)→ In total 18 samples

Description of different management practices in the management systems**: i) intensive tillage with flood irrigation (IT); ii) no-tillage plus lemon pruning residues on the topsoil as mulch (NT+PM); and iii) reduced tillage plus incorporation of lemon pruning residues (RT + PI).**

Management practices	IT
Tillage	until 40 cm soil depth, 3 times per year
Addition of pruning	-
Addition of Ca^{2+} and Mg^{2+}	-
Irrigation	Flood (since 1987)
Fertilization	-
Pesticides	+

Garcia-Franco et al., 2021. Soil & Tillage

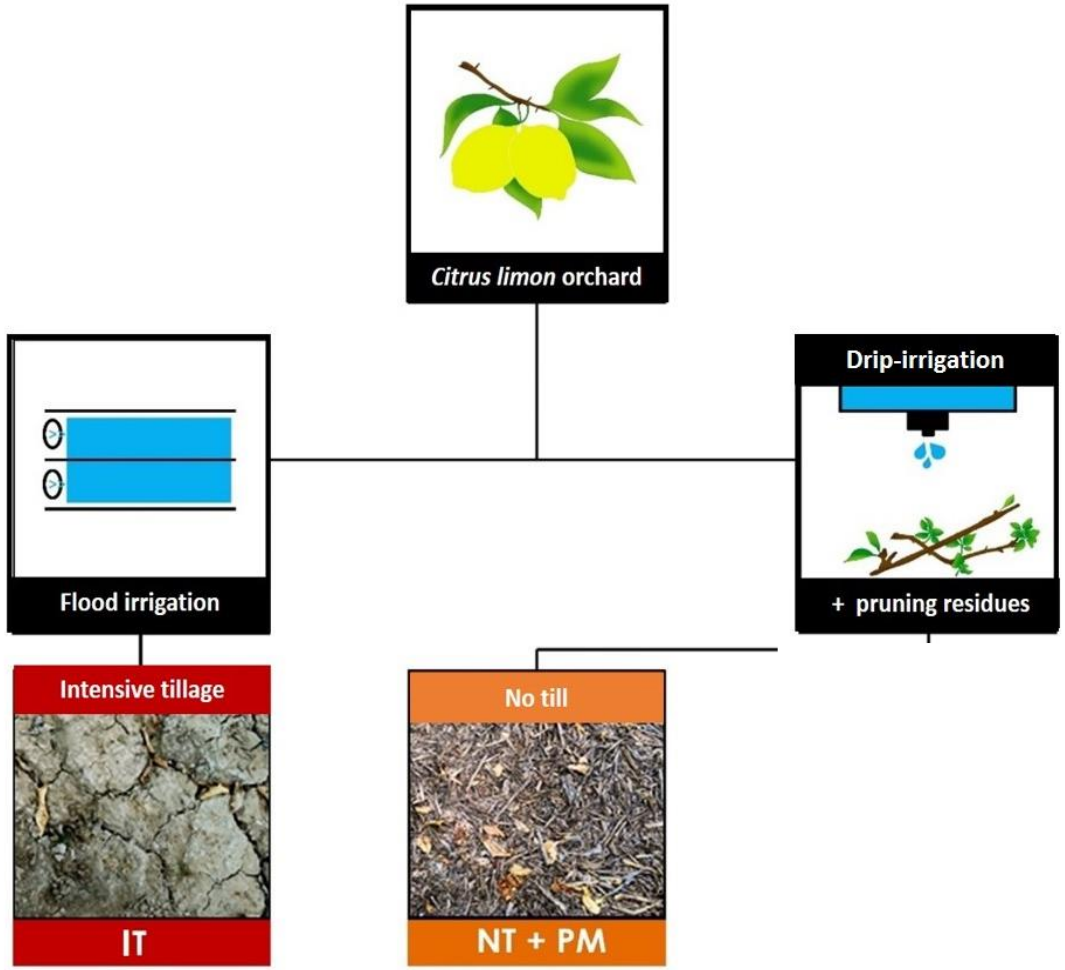


Garcia-Franco et al., 2021. Soil & Tillage

In 2017: Composited samples 0-5 and 5-15 cm (3 samples x 3 blocks x 2 depths)→ In total 18 samples

Description of different management practices in the management systems**: i) intensive tillage with flood irrigation (IT); ii) no-tillage plus lemon pruning residues on the topsoil as mulch (NT+PM); and iii) reduced tillage plus incorporation of lemon pruning residues (RT + PI).**

Management practices	IT	NT+PM
Tillage	until 40 cm soil depth, 3 times per year	-
Addition of pruning	-	Mulching
Addition of Ca^{2+} and Mg^{2+}	-	+
Irrigation	Flood (since 1987)	Drip-irrigation (since 2000)
Fertilization	-	+
Pesticides	+	+



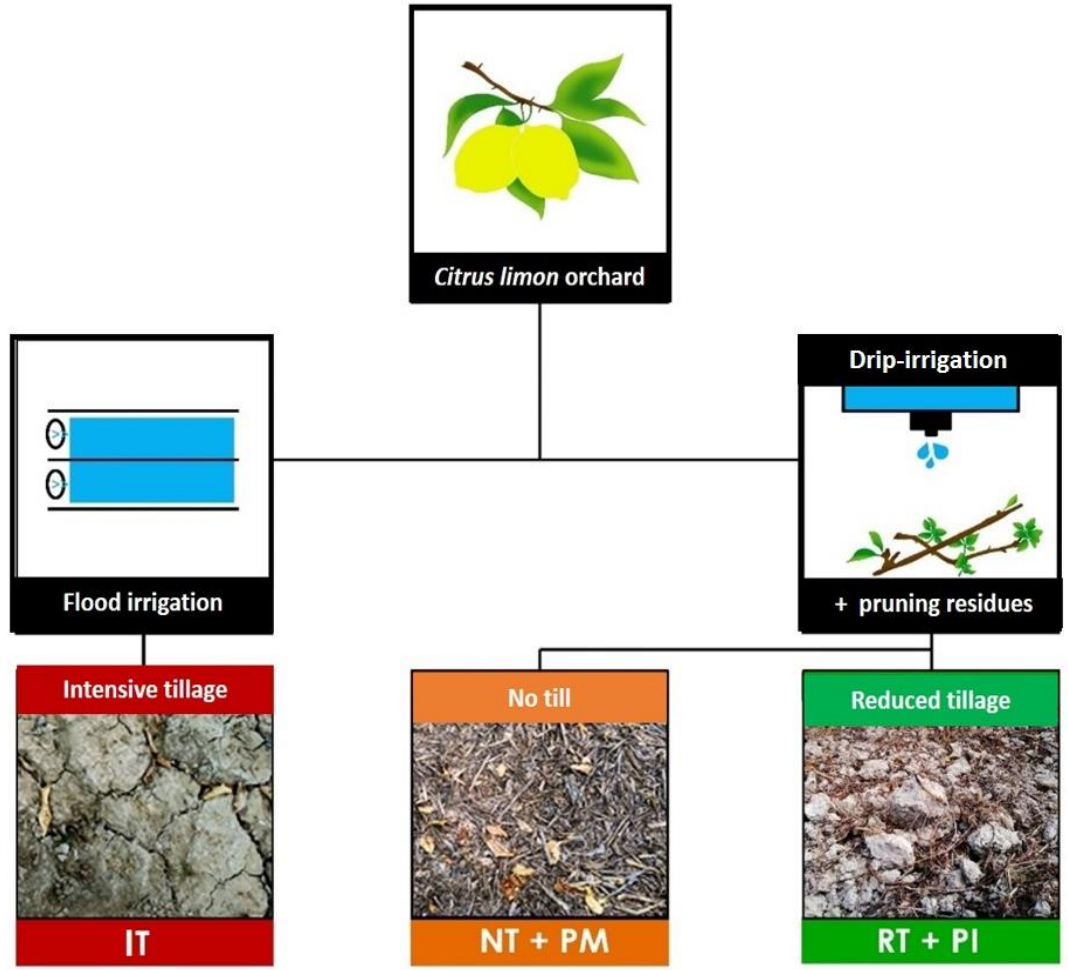
Garcia-Franco et al., 2021. Soil & Tillage

Garcia-Franco et al., 2021. Soil & Tillage

In 2017: Composited samples 0-5 and 5-15 cm (3 samples x 3 blocks x 2 depths)→ In total 18 samples

Description of different management practices in the management systems**: i) intensive tillage with flood irrigation (IT); ii) no-tillage plus lemon pruning residues on the topsoil as mulch (NT+PM); and iii) reduced tillage plus incorporation of lemon pruning residues (RT + PI).**

Management practices	IT	NT+PM	RT+PI
Tillage	until 40 cm soil depth, 3 times per year	-	until 15 cm soil depth, 1 time per year
Addition of pruning	-	Mulching	Incorporation into the soil
Addition of Ca^{2+} and Mg^{2+}	-	+	+
Irrigation	Flood (since 1987)	Drip-irrigation (since 2000)	Drip-irrigation (since 2000)
Fertilization	-	+	+
Pesticides	+	+	+



Garcia-Franco et al., 2021. Soil & Tillage

Drip ferti-irrigation system (Copyright: Simeón Ruíz Cayuela)

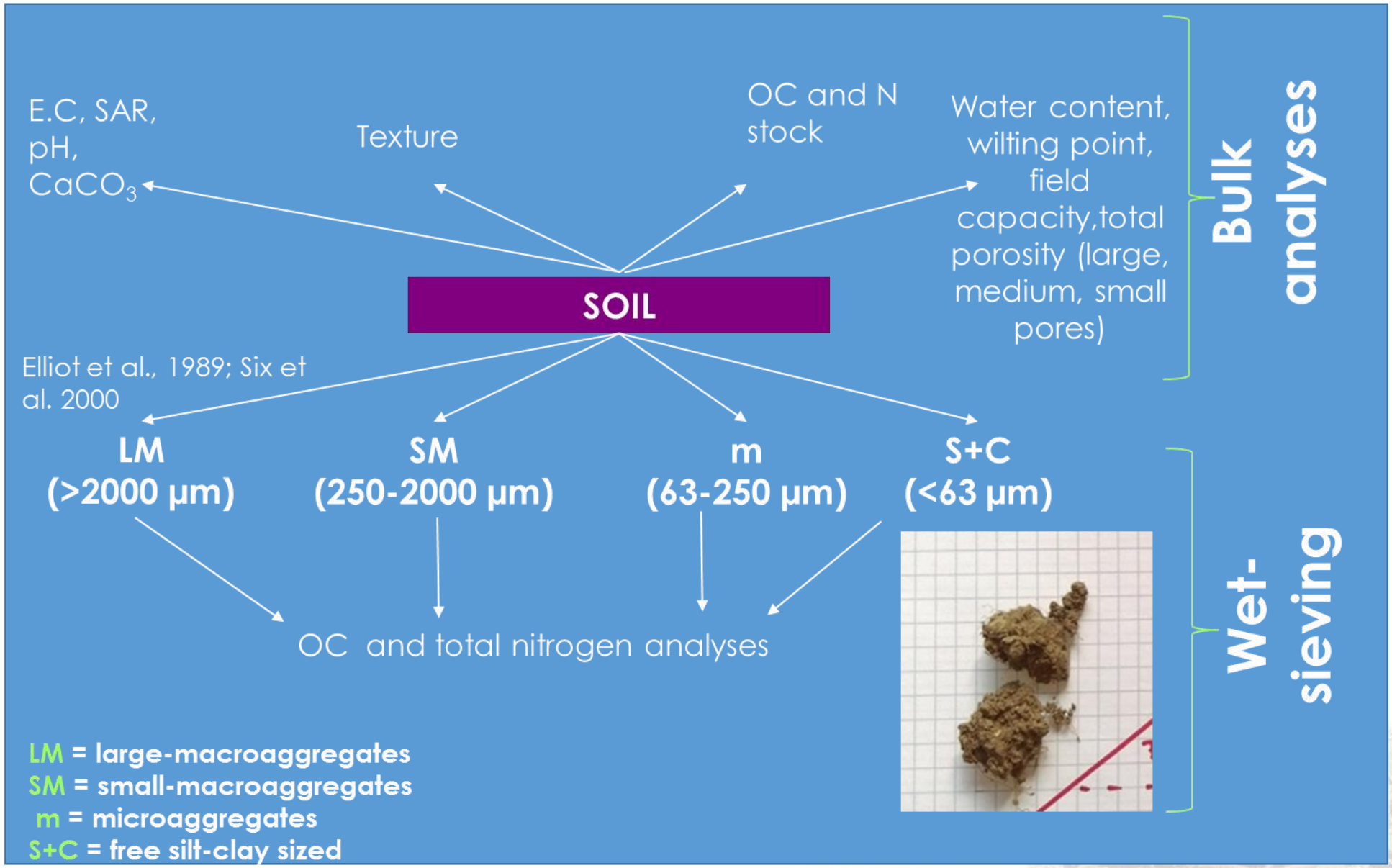
Garcia-Franco et al., 2021. Soil & Tillage

Soil profile (Copyright: Simeón Ruíz Cayuela)

NT + PM system (Copyright: Simeón Ruíz Cayuela)

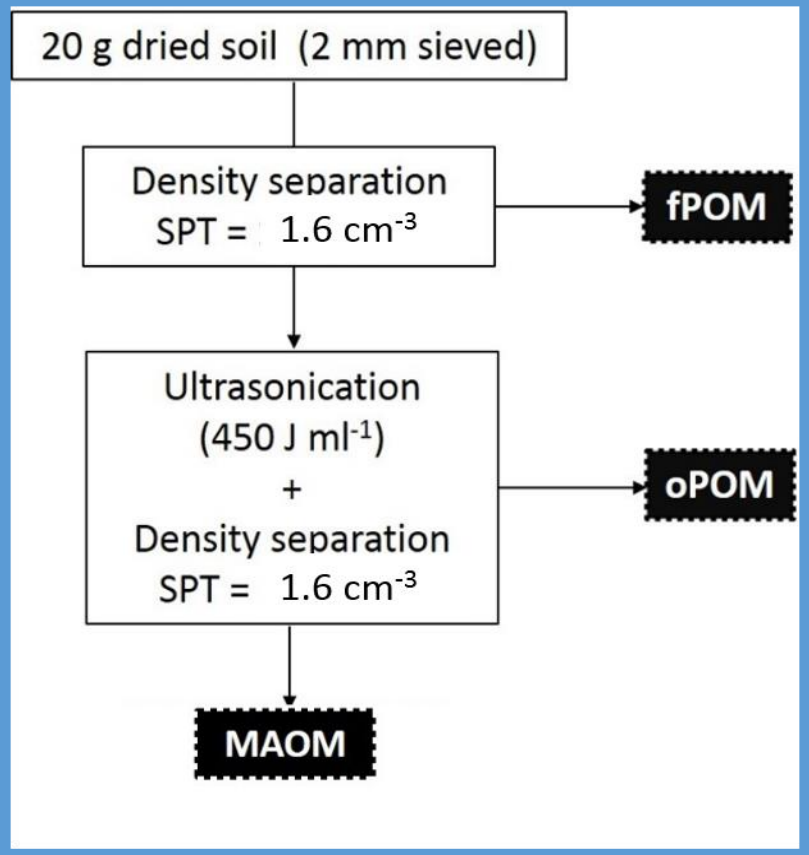
IT system (Copyright: Simeón Ruíz Cayuela)

RT+PI system (Copyright: Simeón Ruíz Cayuela)



Garcia-Franco et al., 2021. Soil & Tillage

Density fractionation



Analyses
- OC, total N
- ^{13}C NMR

fPOM = free particulate orgaic matter
oPOM = occluded particulate organic matter
MAOM = mineral associated organic matter

Garcia-Franco et al., 2021. Soil & Tillage

Soil properties	Soil depth (cm)	IT	NT+PM	RT + PI
pH	0- 5	8.5a	8.4a	8.5a
	5-15	8.6a	8.5a	8.5a
EC (µS cm^{-1})	0- 5	**694.3a**	**356.6b**	**459.6b**
	5-15	**391.7a**	317.5a	356.1a
BS (%)	0- 5	99.8a	100.0a	99.9a
	5-15	99.8a	99.8a	99.9a
SAR	0- 5	**1.1a**	0.3b	0.1b
	5-15	**1.1a**	0.3b	0.1b
$CaCO_3$	0- 5	51.8a	49.7a	48.6a
	5-15	53.4a	49.3a	48.3a

Garcia-Franco et al., 2021. Soil & Tillage

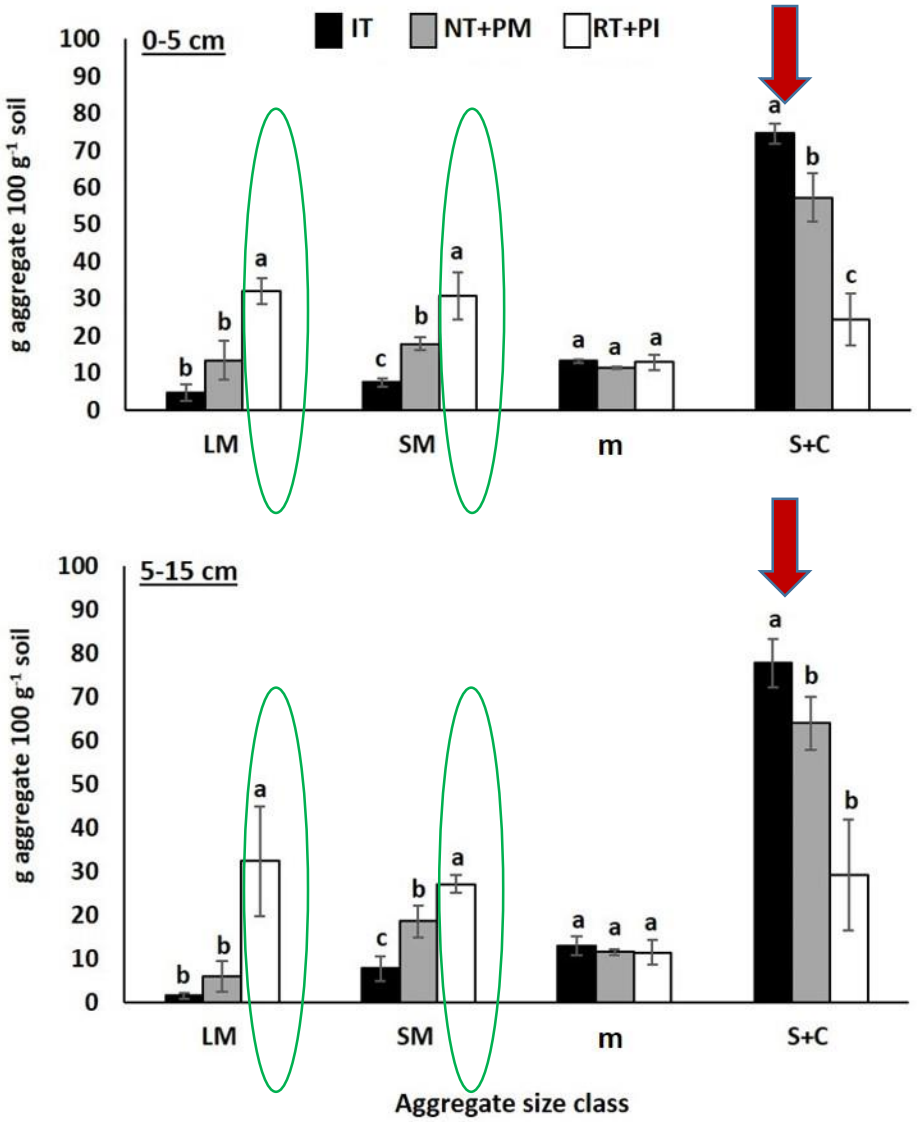
Texture (%)	Soil depth (cm)	IT	NT+PM	RT + PI
Clay	0- 5	24.0a	22.6a	22.5a
	5-15	25.1b	28.2a	26.5a
Silt	0- 5	70.4a	64.4a	70.9a
	5-15	69.8a	69.3a	67.8a
Sand	0- 5	5.6b	13.0a	6.6b
	5-15	5.2a	2.5b	5.7a
BD (g cm^{-3})	0- 5	**1.6a**	1.3b	1.1b
	5-15	**1.6a**	1.3b	1.2b
MWD (mm)	0- 5	0.3c	0.7b	**1.5a**
	5-15	0.2c	0.5b	**1.5a**

Garcia-Franco et al., 2021. Soil & Tillage

Pore size distribution (%):	Soil depth (cm)	IT	NT+PM	RT + PI
Fine pores	0- 5	16.4 a	18.7a	**16.6a**
	5-15	15.1c	**18.2a**	**16.9b**
Medium pores	0- 5	9.9b	11.2b	**15.2a**
	5-15	10.1b	10.4b	**15.5a**
Large pores	0- 5	15.0b	22.0ab	**27.2a**
	5-15	12.6b	21.1a	**20.1a**
WHC (%)	0- 5	26.2c	29.9b	**31.8a**
	5-15	25.2c	28.6b	**32.4a**
Total porosity(%)	0- 5	41.2b	51.9ab	**59.0a**
	5-15	37.8b	49.7a	**50.5a**

Garcia-Franco et al., 2021. Soil & Tillage

Aggregate size class distribution (g aggregate 100 g^{-1} soil):



IT

The accumulation of Na^+ and the dispersion of clay particles, with a subsequent breakdown of soil aggregates

RT + PI

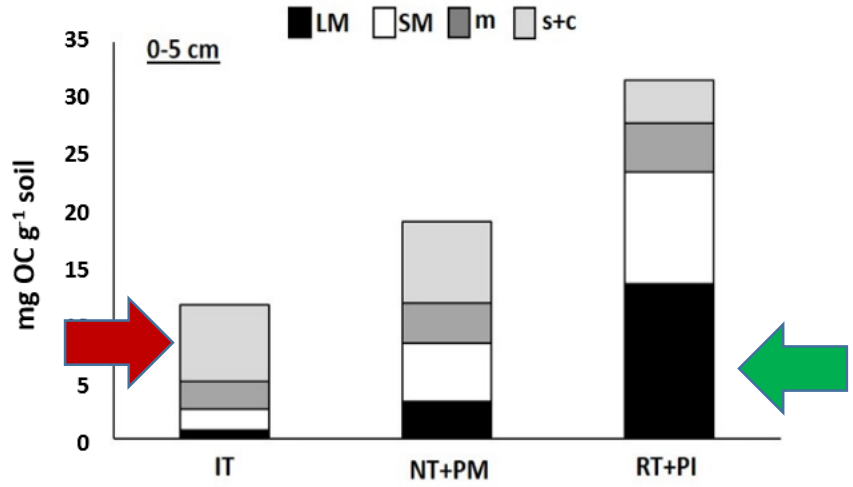
Higher macroaggregate distribution (LM and SM) in both soil depths

Garcia-Franco et al., 2021. Soil & Tillage

Contribution of OC contents (mg g^{-1} soil) of aggregate size classes to total SOC of bulk soils

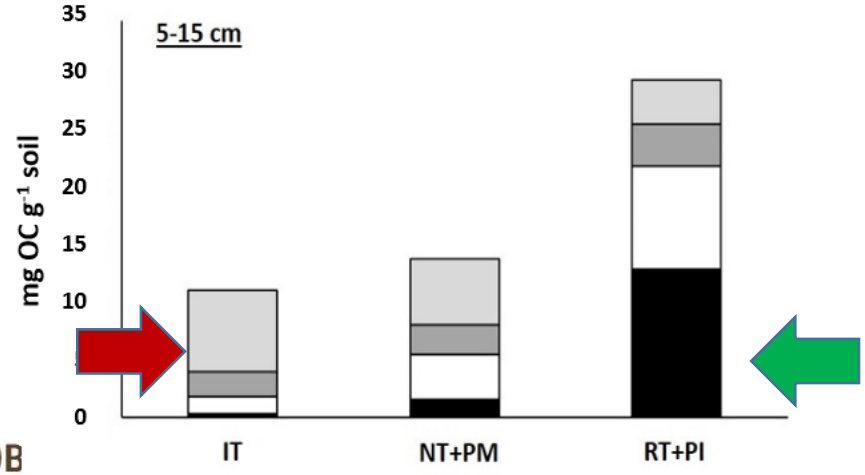
RT + PI

Higher contribution of OC in macroaggregates to the total OC of the bulk soil in both depth



IT

Opposite trend respect to RT+PI: High contribution of the OC of s+c to the total OC of the bulk soil



GLOB ber, 2021

Garcia-Franco et al., 2021. Soil & Tillage

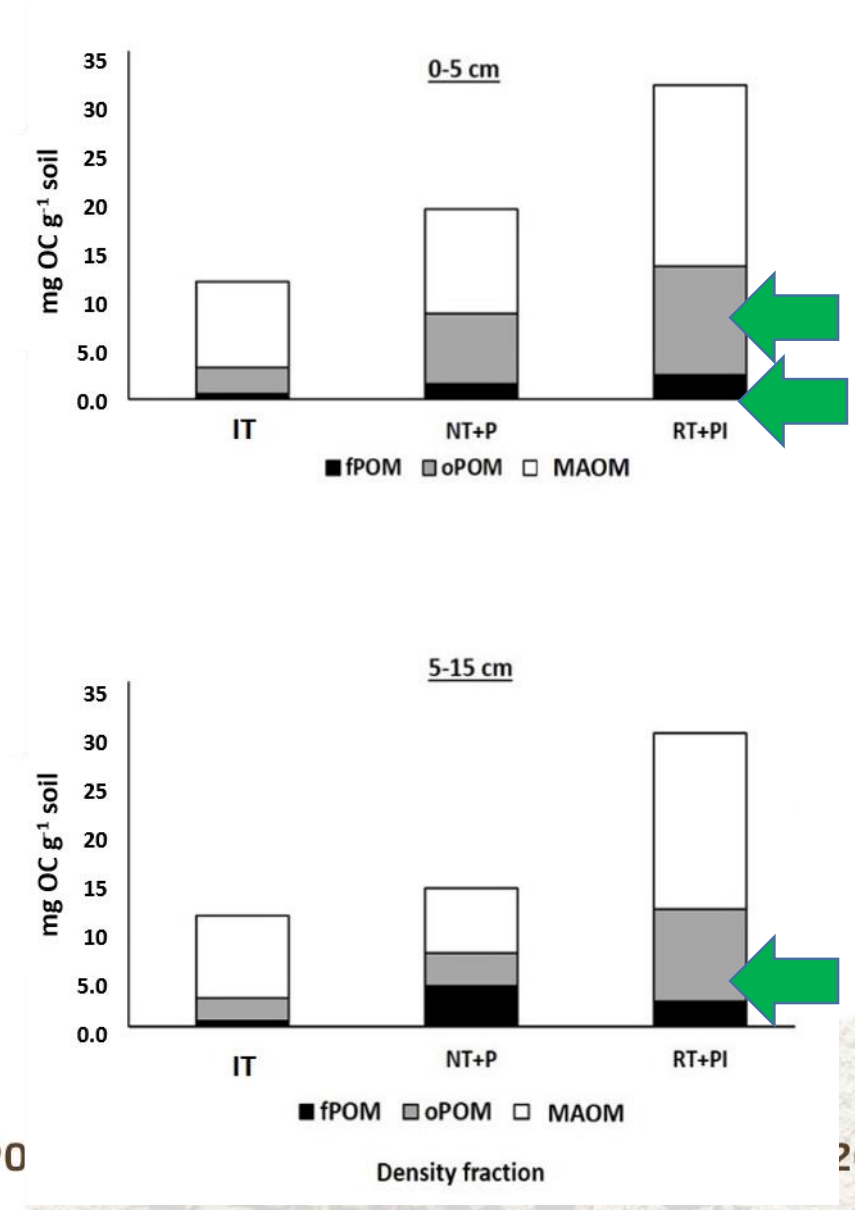
Weight distribution of SOM fractions (g fraction 100 g^{-1} soil):

(g fraction 100 g^{-1} soil)

0-5 cm	fPOM	oPOM	MAOM
IT	0.2c	0.7c	**99.2a**
NT+PM	0.4b	**4.2a**	95.4c
RT+PI	**0.7a**	3.0b	96.4b
5-15 cm			
IT	0.2c	0.8c	96.1a
NT+PM	1.2b	1.4b	97.5a
RT+PI	**0.8a**	**2.6a**	96.6a

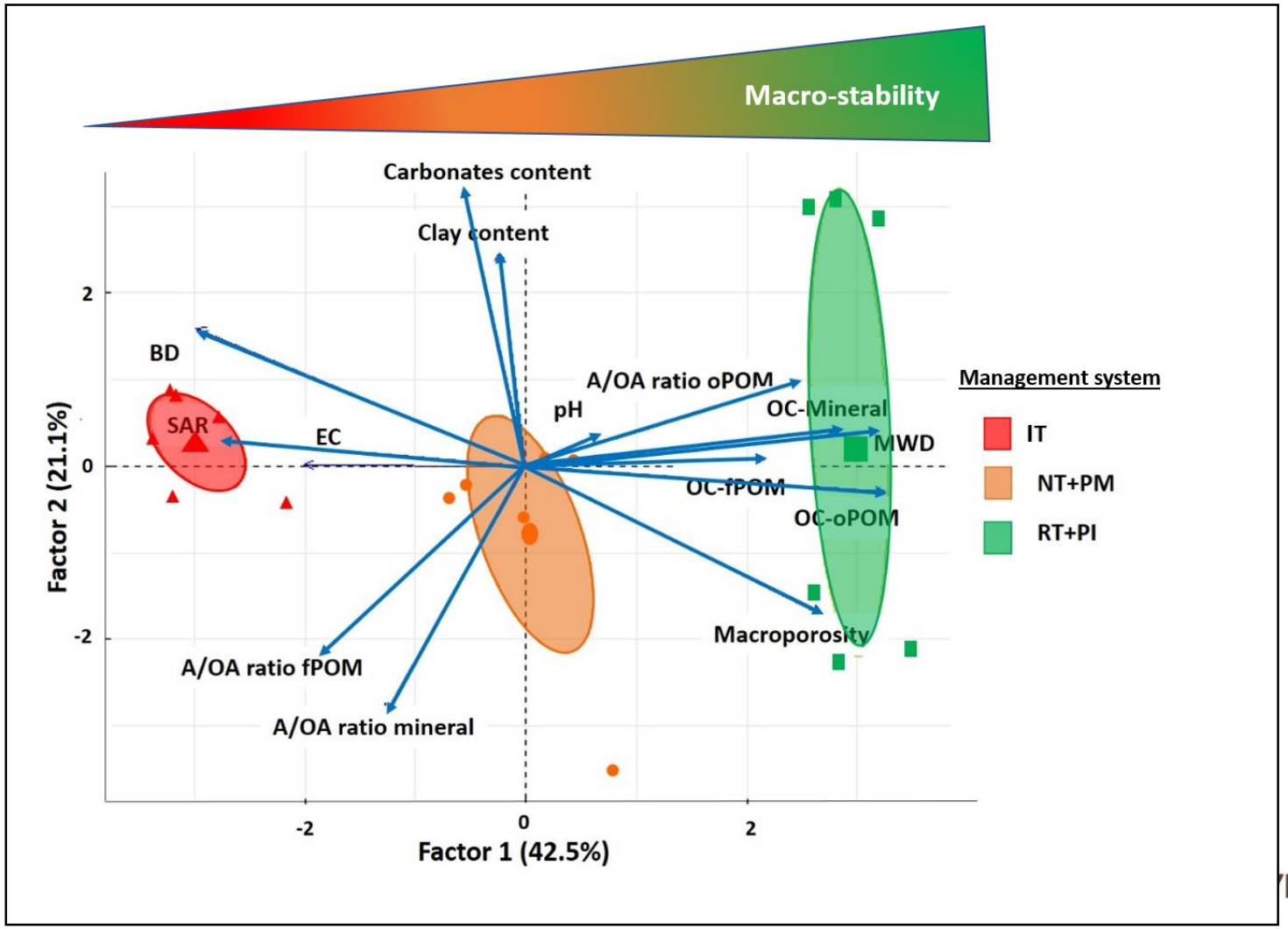
fPOM (particulate organic matter), oPOM (occluded particulate organic matter)
MAOM (mineral-associated organic matter)

OC (mg g^{-1} soil) in SOM fractions:

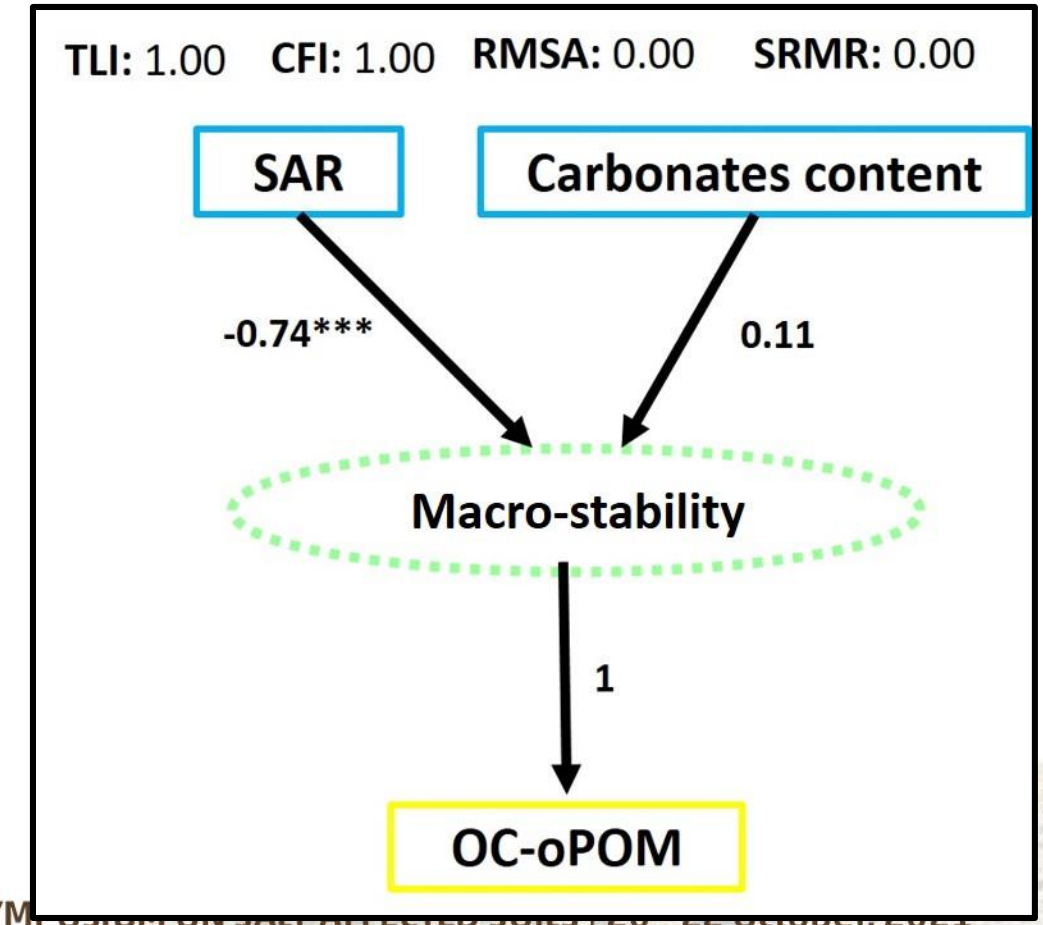


Garcia-Franco et al., 2021. Soil & Tillage

PCA (Principal Component Analysis) results of the factors facilitating macro-aggregation and SOC stabilization

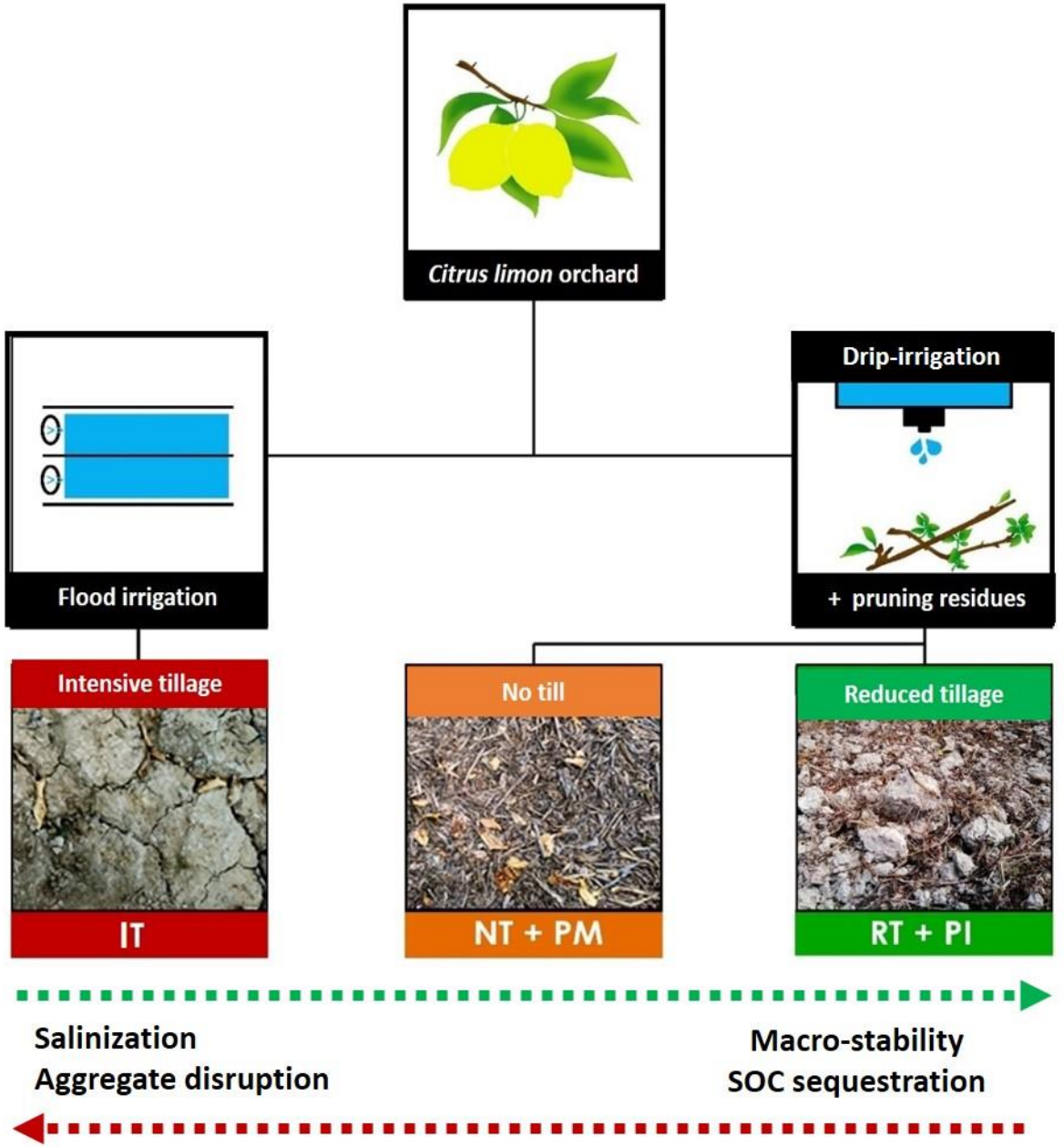


SEM
(structural equation model)

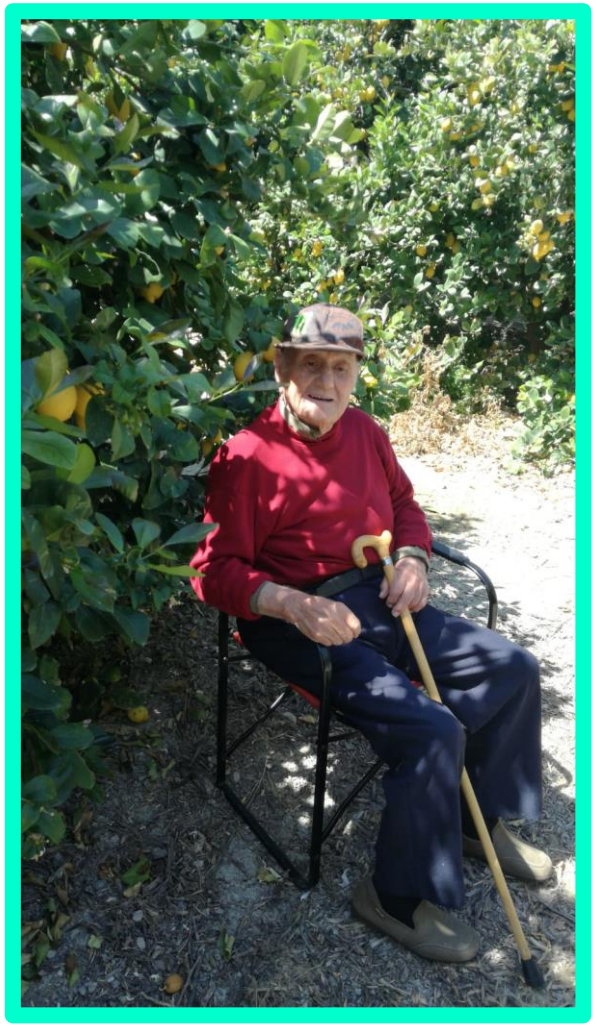


Garcia-Franco et al., 2021. Soil & Tillage

- Soil structural degradation in *Citrus* orchards after 17 years of intensive tillage and flood irrigation
- Pruning incorporation with reduced tillage and drip-irrigation improve soil structure and OC sequestration
- Application of pruning residues as mulch was less effective
- SOM pools were a good indicator of soil macro-stability and soil OC sequestration
- 40% more Citrus production in RT+PI and NT+PM in last 8 years compared with IT. (An socio-economic study about it is course)



Aknowledgement to the farmers



- Family Ruíz-Cayuela

Technische Universität München

- Prof. Dr. Ingrid Kögel-Knabner
- Dr. Martin Wiesmeier
- Franzisca Fella
- Dr. Luis Carlos Colocho Hurtarte

CEBAS CENTRO DE EDAFOLOGÍA Y BIOLOGÍA APLICADA DEL SEGURA

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

- Dr. María Martínez-Mena
- Dr. María Almagro
- Eloisa Garcia Martínez

Intelligence is the ability to adapt to change. —*Stephen Hawking*

GLOBAL SYMPOSIUM ON SALT-AFFECTED SOILS

20 - 22
October, 2021
Virtual meeting