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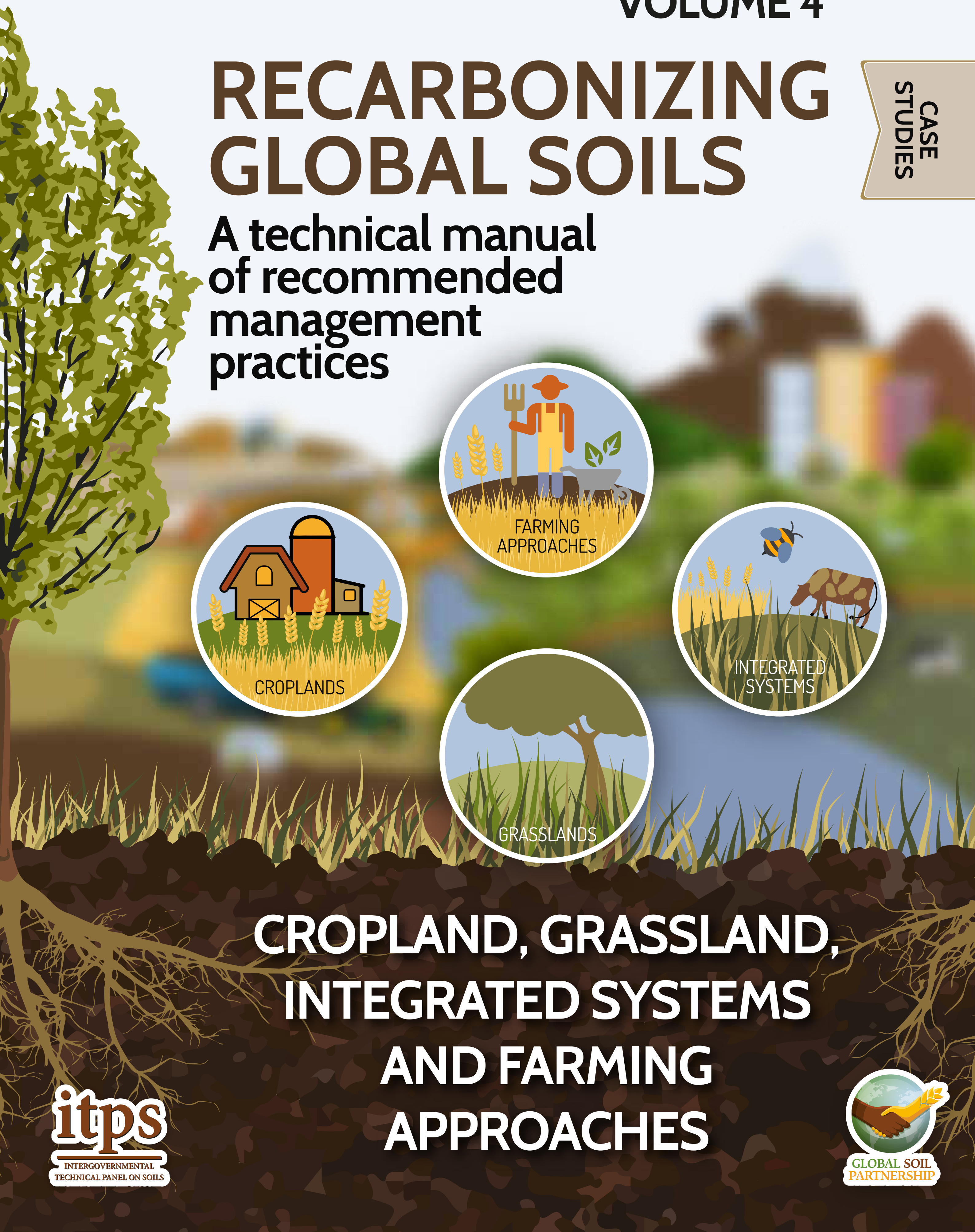
VOLUME 4

CASE STUDIES

RECARBONIZING GLOBAL SOILS

A technical manual of recommended management practices



CROPLAND, GRASSLAND, INTEGRATED SYSTEMS AND FARMING APPROACHES

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INTERGOVERNMENTAL
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GLOBAL SOIL
PARTNERSHIP

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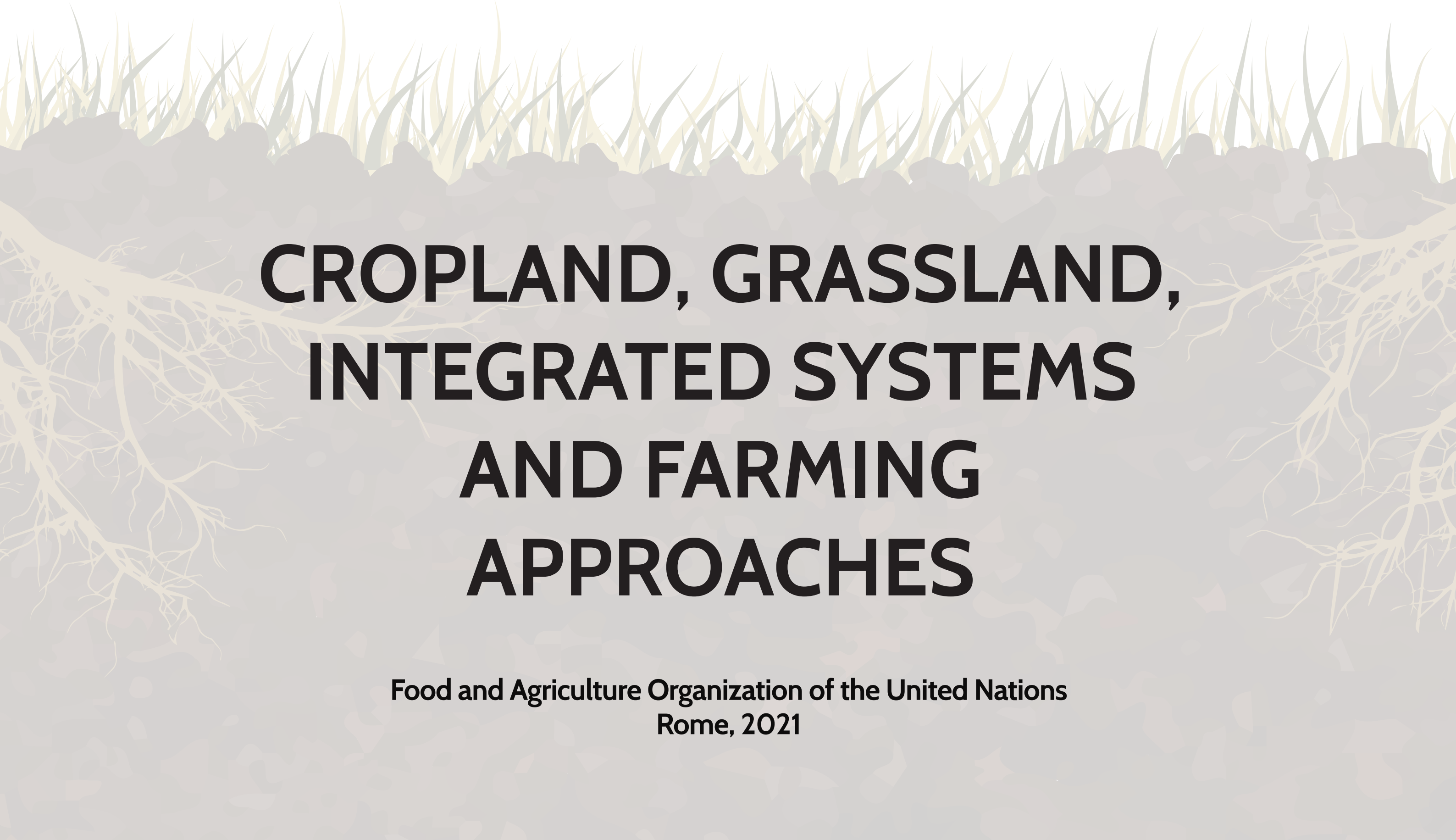

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19. Irrigation and SOC sequestration in the region of Navarre in Spain

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1. Related practices and hot-spot

Adequate irrigation practices, organic agriculture, crop rotations; Drylands

2. Description of the case study

The project REGADIOX, funded by the European Commission LIFE Program was based on the establishment of a regional-scale network of representative agricultural plots in three irrigation districts in Navarre (NE Spain). The project allowed for a rational evaluation of soil organic C (SOC) sequestration and greenhouse gases (GHG) emissions balances by using paired comparisons in terms of soil characteristics in irrigated vs rainfed plots. The results showed a clear influence of irrigation in soil condition, arising from greater SOC storage. The net effect was however modulated by soil characteristics and management practices, in so far as the different agricultural strategies did have different potential to sequester SOC and/or reduce GHG emissions. While permanent crops with green cover (which was possible thanks to irrigation) or semi-permanent crops as alfalfa were win-win strategies with positive C balances, intensive systems with two crops per year, although they also contributed to SOC gains, represented increased GHG emissions.

The observed changes in SOC associated to irrigation with different managements also showed that irrigation adoption can alter the soils' capacity to provide key ecosystem services beyond biomass production, as changes in soils properties related to SOC, such as water-holding capacity or soil erodibility were also observed. These changes were, however, not straightforward and varied depending on soil type, climate and time under irrigation.

3. Context of the case study

The project was led by a farmer's union (UAGN-Fundagro) in the region of Navarre (NE Spain), together with extensionists from the regional Agricultural Extension Institute (INTIA) and researchers from UPNA.

The region has a marked North-South rainfall gradient with average annual rainfall ranging from 380 to 505 mm and reference evapotranspiration (ET_0) of 1 000 to 1 100 mm, which makes agriculture strongly dependent on irrigation in the Southern part of the region.

Soils in the irrigated area are mostly derived from sedimentary rocks and quaternary alluvial deposits and terraces. Most are calcareous (Calcisols, Cambisols) and display high pH and carbonates concentration in the tilled layer. Irrigation is used for producing a variety of crops, from permanent (olive trees, vineyards) to semi-permanent lays (alfalfa (*Medicago sativa*), cereals (wheat (*Triticum aestivum*) and maize (*Zea mays*) and horticultural crops (tomatoes (*Lycopersicon esculentum*) and legumes). The project selected representative irrigation districts and plots in the whole irrigated area of the region and had therefore a regional perspective.

3. Possibility of scaling up

The study could be scaled-up to other irrigated areas in the Mediterranean region.

4. Impact on soil organic carbon stocks

Table 76. Evolution of SOC stocks after different years of irrigation and soil cover in the region of Navarre, Spain

Location	Climate zone	Soil type (Soil Taxonomy, 2014)	Baseline C stock (tC/ha)	Additional C storage (tC/ha/yr)	Duration (Years of irrigation)	Cropping system	Reference
1. Non-permanent crops[1]							
Miranda de Arga	MAP/PET*: 0.59	*Typic Calcixerept*	43.9±4.00	2.08 ± 1.14	6	Irrigated annual cropping	Antón *et al.* (2019)
				3.20 ± 1.82		Irrigated alfalfa	
Funes	MAP/PET: 0.52	*Xeric Haplocalcid*	35.4±0.73	0.84 ± 0.11	13	Irrigated annual cropping	

Location	Climate zone	Soil type (Soil Taxonomy, 2014)	Baseline C stock (tC/ha)	Additional C storage (tC/ha/yr)	Duration (Years of irrigation)	Cropping system	Reference
Valtierra	MAP/PET: 0.51	*Xeric Haplocalcid*	57.3±4.21	0.86 ± 0.68	20	Rainfed organic	
				2.80 ± 0.69		Irrigated annual cropping	
2. Permanent crops^2							
Fontellas	MAP/PET: 0.49	*Typic Calcixerept*	50.2±17.7	2.92 ± 0.86	16	Irrigated grass cover (olives)	Mendioroz *et al.* (2017)
Cascante	MAP/PET: 0.49	*Xeric Calcigypsid*	30.9±2.20	3.23 ± 0.22	9	Irrigated grass cover (grapevines)	

Climate is Warm Temperate Dry according to IPCC (2006)

Measurements were made on 0-30 cm depth

[1] Baseline is rainfed cereal cropping on the same soil unit

[2] Baseline is the same crop (irrigated) with bare soil

*MAP: Mean annual precipitation; PET: Potential Evapotranspiration

5. Other benefits of the practice

5.1. Improvement of soil properties

Positive changes in soil properties were observed in some cases, associated with SOC gains. Significant gains in the water-holding capacity in the upper 30 cm of the soil were for example observed in Miranda de Arga in the irrigated systems (642 L/m^2 on average) compared to dryland cultivation (533 L/m^2). No differences were observed in bulk density, most likely because tillage was conventional in all the studied agrosystems.

5.2 Minimization of threats to soil functions

Table 77. Soil threats

Soil threats	
Soil erosion	Measured erodibility reduced in some cases (Miranda de Arga) with irrigation vs. dryland (Antón *et al.*, 2019).
Soil biodiversity loss	Site-dependent response of soil microbial abundance and diversity (Antón *et al.*, 2019).
Soil water management	Irrigation implied a sufficient supply granting profitable yields. In some cases (Miranda de Arga), irrigation increased the soil water-holding capacity. In others (Valtierra), the opposite was observed (Antón *et al.*, 2019).

5.3 Increases in production (e.g. food/fuel/feed/timber)

Biomass production was between 2.4 and 3.4 times higher in the irrigated systems than in rainfed cereal cropping on the same soil units (Antón *et al.*, 2019).

5.4 Mitigation of and adaptation to climate change

GHG gases emissions were measured and displayed very variable results both when comparing irrigated and non-irrigated systems, and between irrigated systems (Figure 18).

In terms of adaptation, irrigated systems performed better in terms of yield than rainfed crops (less interannual variability and of course higher productivity).

5.5 Socio-economic benefits

The introduction of irrigation implies more stable and profitable yields. Within irrigated systems, horticultural crops, olive trees and grapevines are the most profitable. This means that economic (income) and environmental (SOC gain) drivers did not always match (Antón *et al.*, 2019).

6. Potential drawbacks to the practice

6.1 Tradeoffs with other threats to soil functions

Table 78. Soil threats

Soil threats	
Soil erosion	Sprinkler irrigation can cause erosion depending on crop stage and irrigation intensity.
Nutrient imbalance and cycles	Irrigation implies higher fertilization and increased leaching than rainfed agriculture.
Soil salinization and alkalinization	A risk if drainage is not good.
Soil water management	Efficient water use needed for reducing risks associated with irrigation.

6.2 Increases in greenhouse gas emissions

Information on net balances (emissions vs SOC sequestration) are summarized in Figure 18.

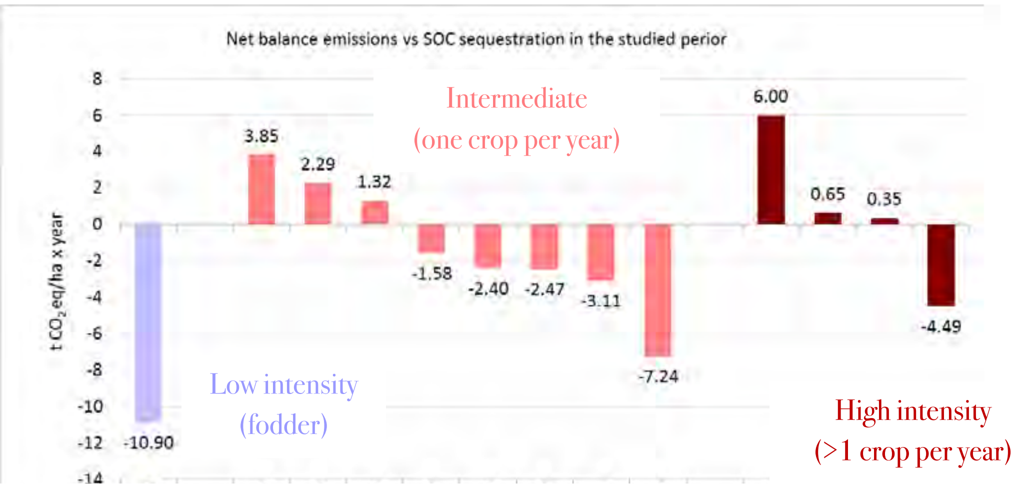

Figure 18. Net balance between GHG emissions and SOC sequestration in the study period in the different irrigated plots studied Positive values indicate net emissions. Negative values indicate mitigation by effective C sequestration

As shown in the figure, low intensity irrigated systems (alfalfa fodder) had the clearest benefit in climate change mitigation, as emissions were low (no N fertilization) and C sequestration high. Very intense systems, with more than one crop per year, although very effective in increasing SOC stocks compared to non-irrigated soil, also had high emissions, mostly associated to N fertilization, with a positive net balance.

Intermediate irrigated agro-systems (one crop per year) displayed the highest variability depending on soil, climate conditions and time since the adoption of irrigation.

7. Potential barriers for adoption

Table 79. Potential barriers to adoption

Barrier	YES/NO	
Biophysical	Yes	All soils cannot be irrigated.
Cultural	Yes	Changing from rainfed to irrigated agriculture is not easy.
Social	Yes	
Economic	Yes	Irrigation can be costly.
Institutional	Yes	Irrigation needs public investment.
Knowledge	Yes	Training needed for farmers adopting irrigation.
Natural resource	Yes	Water is limited.

Reference and more information (In Spanish):

https://life-regadiox.es/wp-content/uploads/2016/12/EvaluacionSocioeconomicaRegadiox_fin.pdf

Photo

Photo 35. Picture of a "boundary" area between newly irrigated land (right of the sprinkler) and the rainfed area on the same soil unit (left of the sprinkler), in winter

Winter wheat grows in the non-irrigated area on the left. Maize is grown in the irrigated area on the right (see maize stover still not incorporated into the soil at the front and deep inversion tillage to incorporate crop residues at the back). Growing maize in the area would be impossible without irrigation. Miranda de Arga, Navarre, Spain. January, 2014.

References

Antón, R., Virto, I., Gonzalez, J., Hernandez, I., Enrique, A., Bescansa, P., Arias, N., Orcaray, L. & Campillo, R. 2019. Extension of irrigation in semi-arid regions: What challenges for soil security? Perspectives from a regional-scale project in Navarre (Spain). *In* D.A. Anne Richer de Forges, Florence Carré, Alex B. McBratney, Johan Bouma, ed. *Global Soil Security. Towards more science-society interfaces*, pp. 79–87

Mendioroz, I., de Echanove, C., Lafarga, A., Maeztu, F., Orcaray, L., Virto, I., Bescansa, P., Enrique, A., Antón, R. & González, J. 2017. *Guía Metodológica. Buenas prácticas agrarias para la mitigación del cambio climático.* Fundación FUNDAGRO. Pamplona, Spain. 36 pp.