Mitigazione del Cambiamento Climatico:
il Contributo di Agricoltura e Foreste

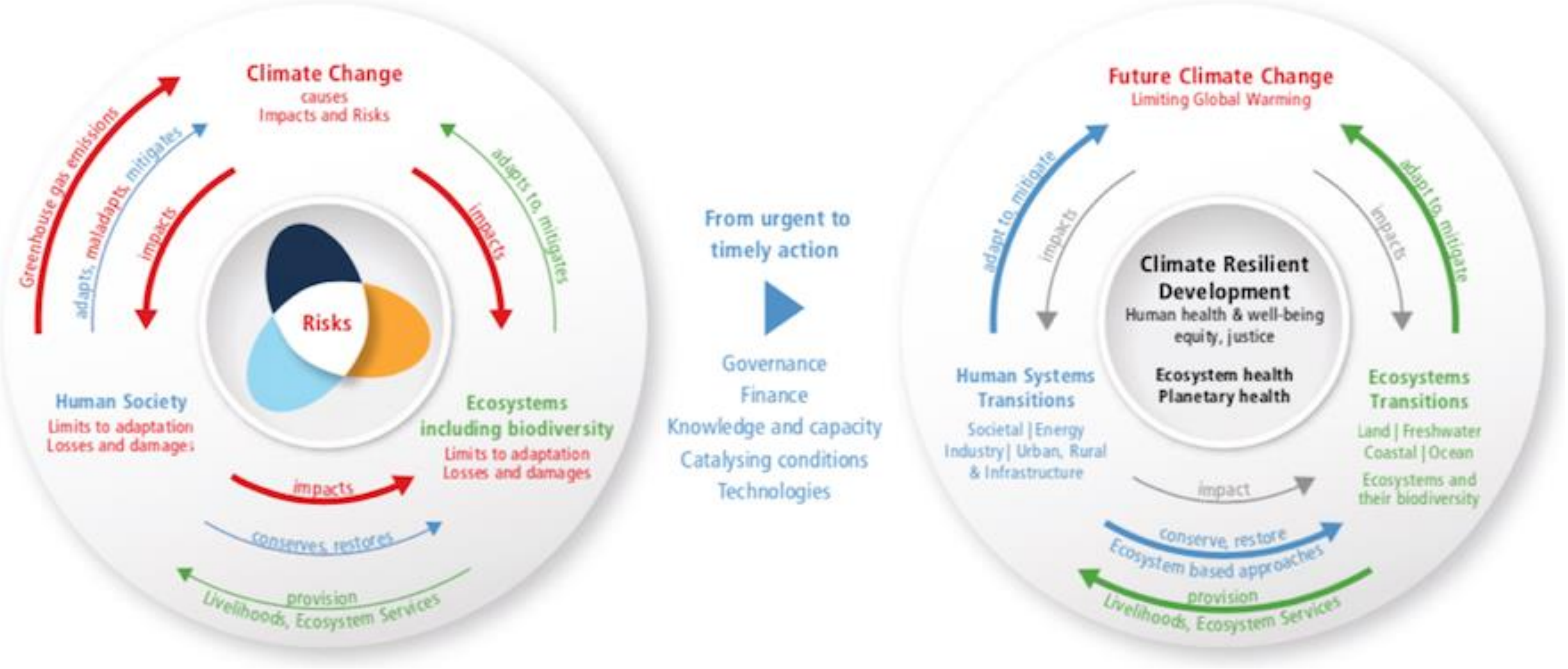
CONVEGNO | 6 – 7 OTTOBRE 2022

Aranciera dell'Orto Botanico, Largo Cristina di Svezia 24 , Roma e piattaforma **GoToWebinar**

La mitigazione dei cambiamenti climatici attraverso la decarbonizzazione dei sistemi agricoli e forestali

Domenico Ventrella, Roberta Farina

Consiglio per la ricerca in Agricoltura e l'Analisi dell'Economia Agraria – Centro di Ricerca Agricoltura e Ambiente



IPCC, 2022: Summary for Policymakers [H.-O.Pörtner et al. (eds.)]. In: **Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change** [H.-O.Pörtner, et al. (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–33, doi:10.1017/9781009325844.001.

Agriculture, Ecosystems and Environment 319 (2021) 107551

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Review

Impacts of agronomic measures on crop, soil, and environmental indicators: A review and synthesis of meta-analysis

Madaline D. Young*, Gerard H. Ros, Wim de Vries

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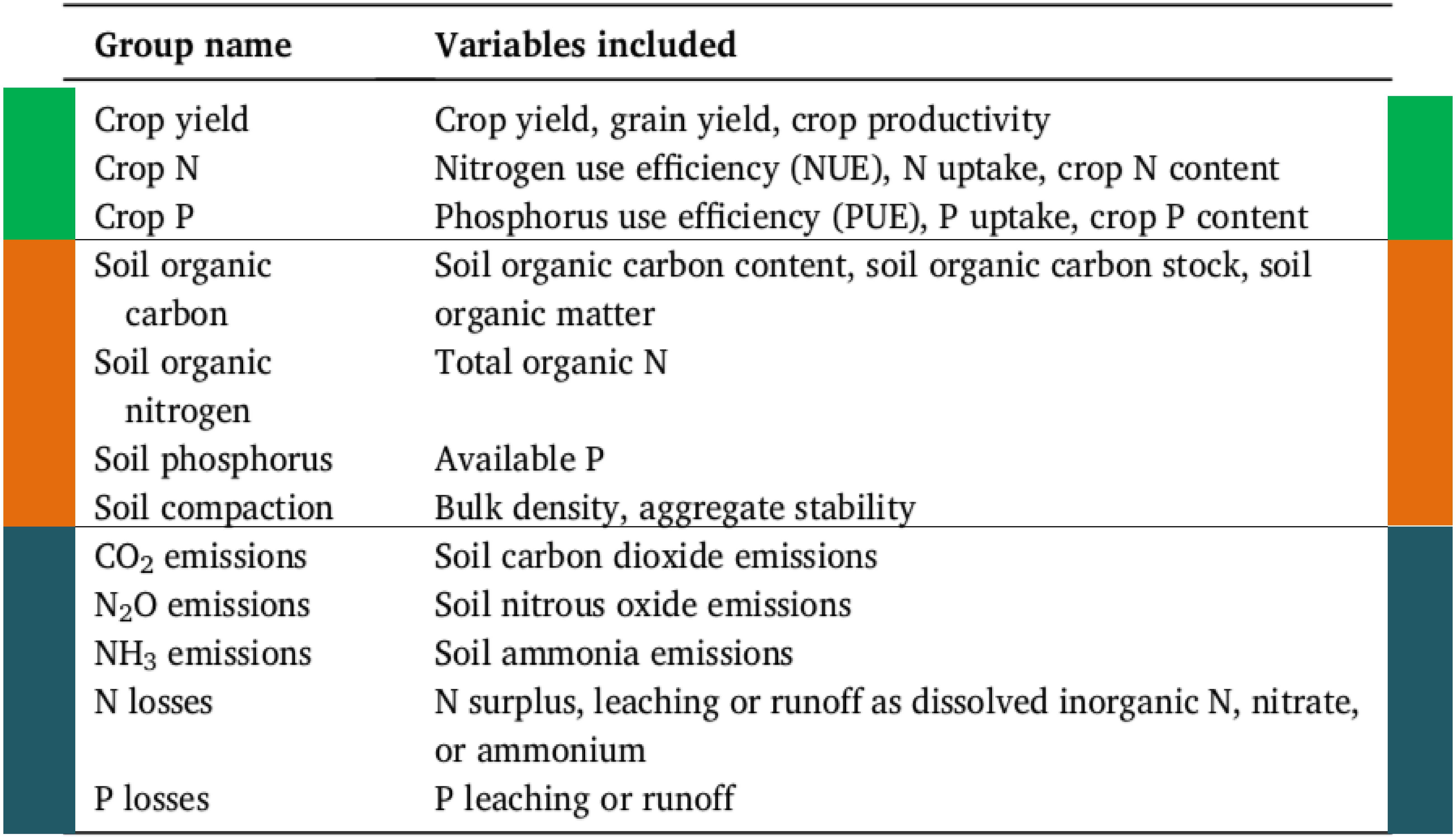
Goal: to review studies assessing impacts of crop management measures (**rotation**, **cover cropping**, **residue retention**), soil and water measures (**irrigation**, **tillage**), soil **amendments** (enhanced efficiency products, biochar), **fertilizer** (organic, mineral, combined effects) and the **4R fertilizer strategies** (right source, rate, timing, placement)

ON

production, **soil quality** and **environment**. Focus was on improved management of arable farming systems including grains, maize and root crops.

Indicators and variables included in each group



Group name	Variables included
Crop yield	Crop yield, grain yield, crop productivity
Crop N	Nitrogen use efficiency (NUE), N uptake, crop N content
Crop P	Phosphorus use efficiency (PUE), P uptake, crop P content
Soil organic carbon	Soil organic carbon content, soil organic carbon stock, soil organic matter
Soil organic nitrogen	Total organic N
Soil phosphorus	Available P
Soil compaction	Bulk density, aggregate stability
CO_2 emissions	Soil carbon dioxide emissions
N_2O emissions	Soil nitrous oxide emissions
NH_3 emissions	Soil ammonia emissions
N losses	N surplus, leaching or runoff as dissolved inorganic N, nitrate, or ammonium
P losses	P leaching or runoff

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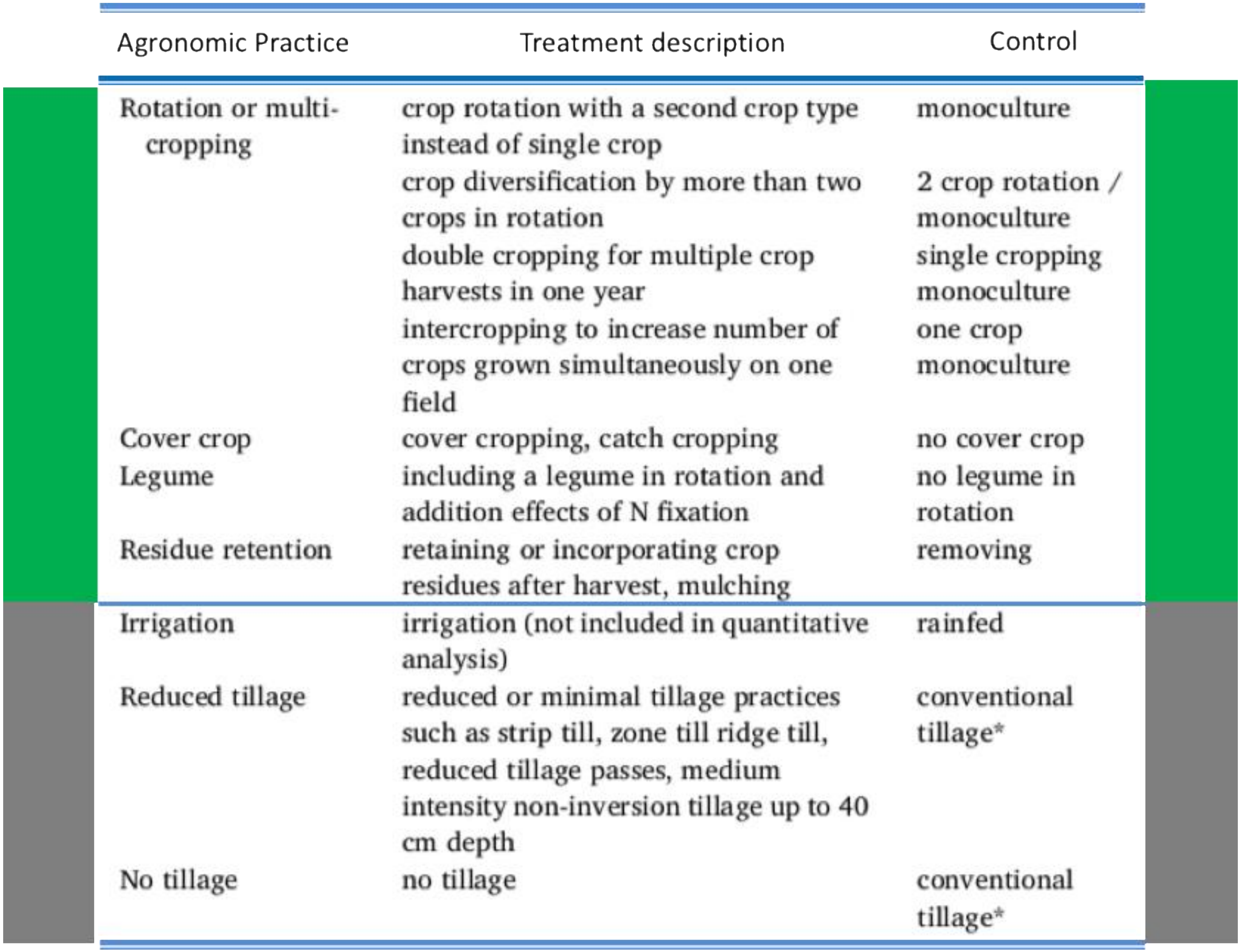
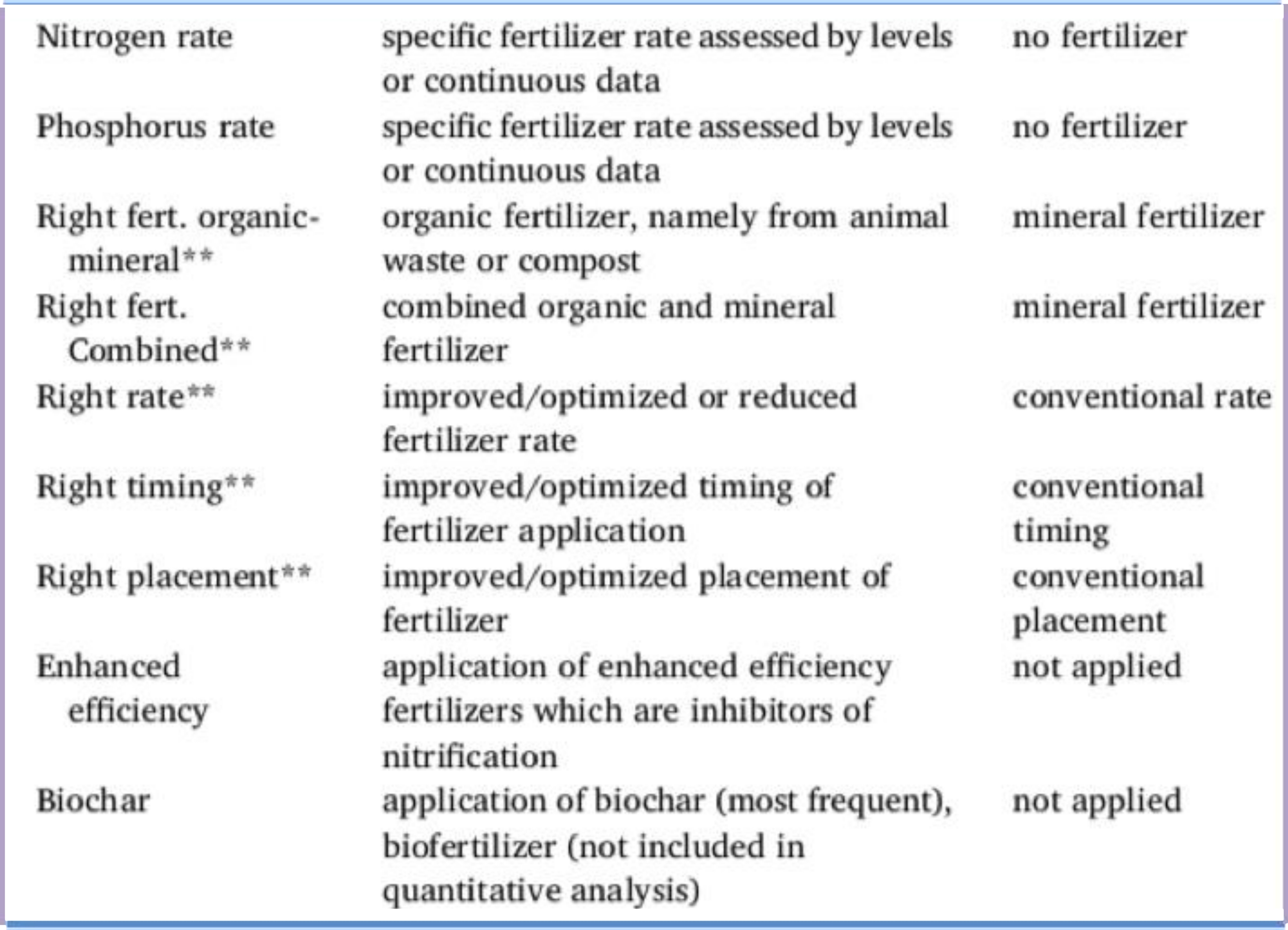


Agronomic Practice	Treatment description	Control
Rotation or multi-cropping	crop rotation with a second crop type instead of single crop	monoculture
	crop diversification by more than two crops in rotation	2 crop rotation / monoculture
	double cropping for multiple crop harvests in one year	single cropping monoculture
	intercropping to increase number of crops grown simultaneously on one field	one crop monoculture
Cover crop	cover cropping, catch cropping	no cover crop
Legume	including a legume in rotation and addition effects of N fixation	no legume in rotation
Residue retention	retaining or incorporating crop residues after harvest, mulching	removing
Irrigation	irrigation (not included in quantitative analysis)	rainfed
Reduced tillage	reduced or minimal tillage practices such as strip till, zone till ridge till, reduced tillage passes, medium intensity non-inversion tillage up to 40 cm depth	conventional tillage*
No tillage	no tillage	conventional tillage*

Young et al. 2021, Agriculture, Ecosystems and Environment 319: 107551



Agronomic Practice	Treatment description	Control
Nitrogen rate	specific fertilizer rate assessed by levels or continuous data	no fertilizer
Phosphorus rate	specific fertilizer rate assessed by levels or continuous data	no fertilizer
Right fert. organic-mineral**	organic fertilizer, namely from animal waste or compost	mineral fertilizer
Right fert. Combined**	combined organic and mineral fertilizer	mineral fertilizer
Right rate**	improved/optimized or reduced fertilizer rate	conventional rate
Right timing**	improved/optimized timing of fertilizer application	conventional timing
Right placement**	improved/optimized placement of fertilizer	conventional placement
Enhanced efficiency	application of enhanced efficiency fertilizers which are inhibitors of nitrification	not applied
Biochar	application of biochar (most frequent), biofertilizer (not included in quantitative analysis)	not applied

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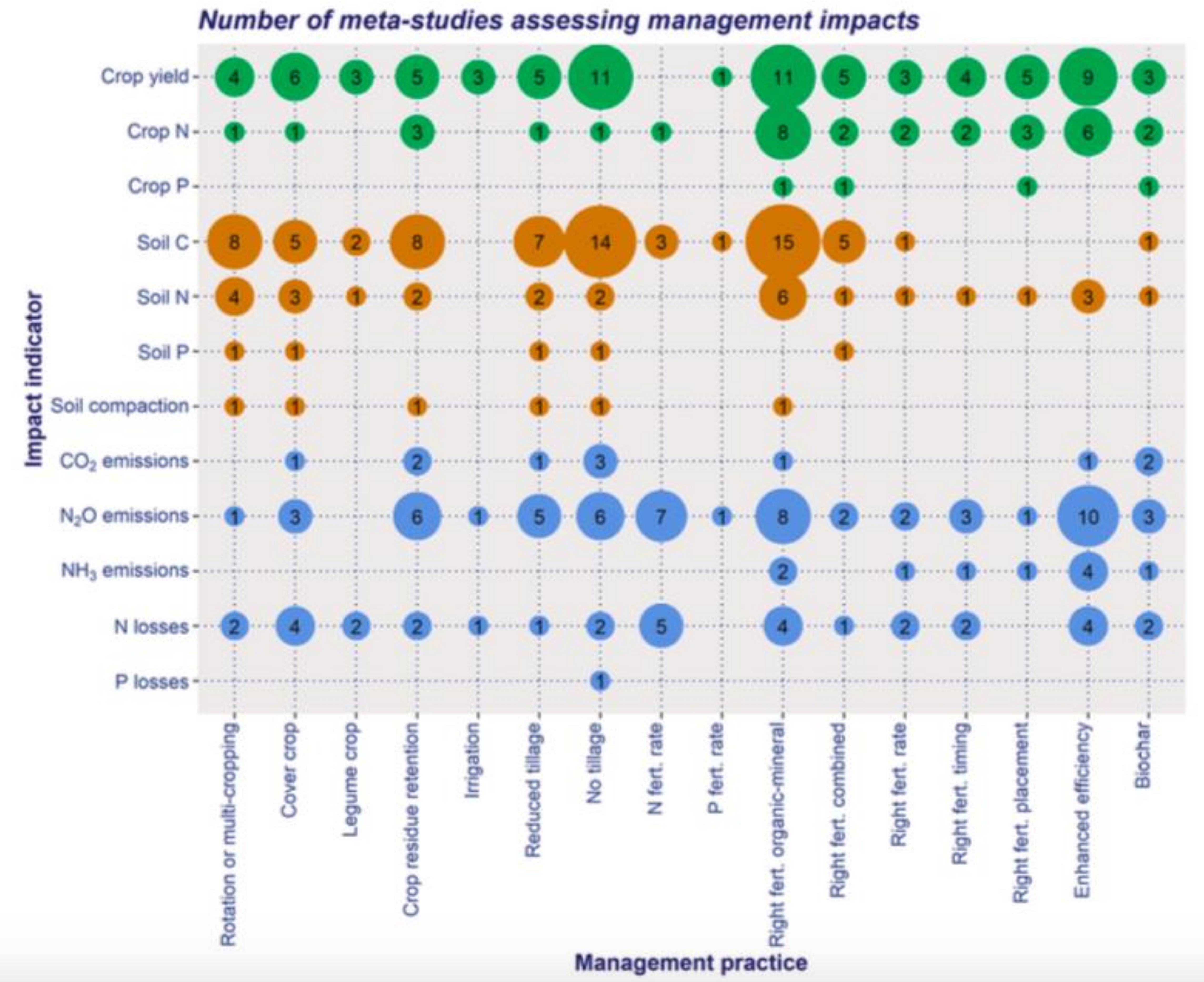
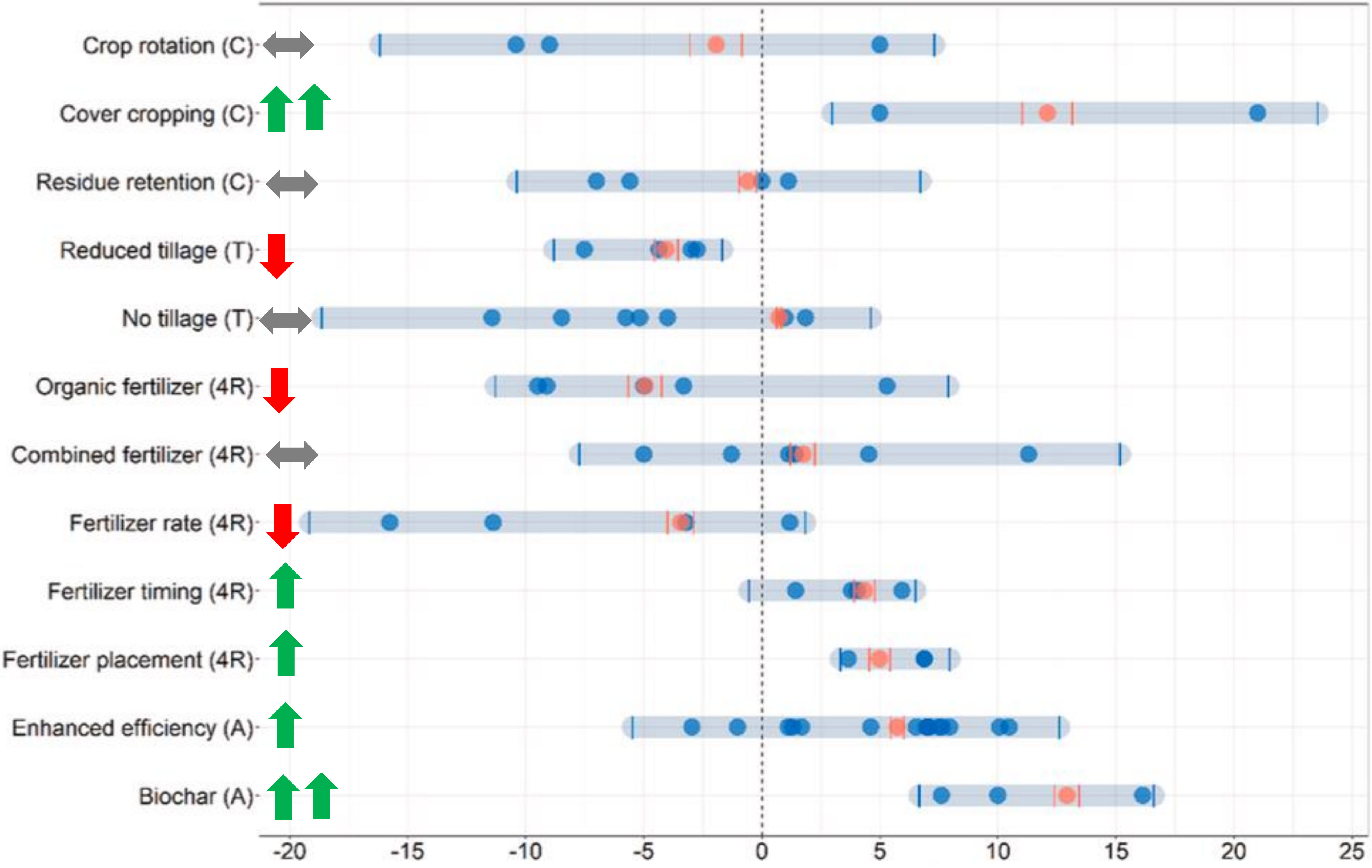


113 studies

Young et al. 2021, Agriculture, Ecosystems and Environment 319: 107551

Change in **Yield** (% $year^{-1}$)



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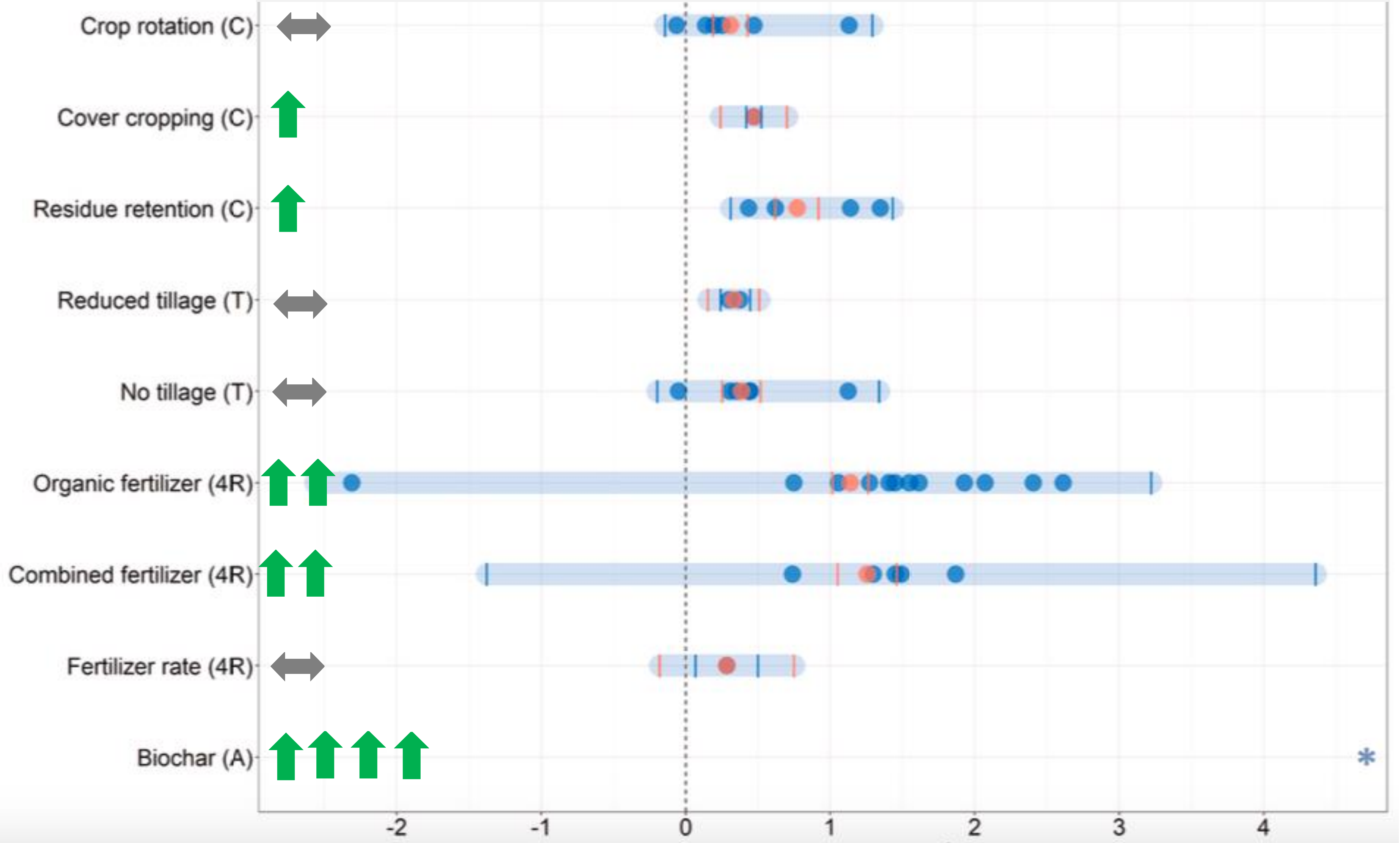
Change in **Soil Organic Carbon** (% year^{-1})

Δ weighted means = +0.28 ÷ +1.3 % y^{-1}



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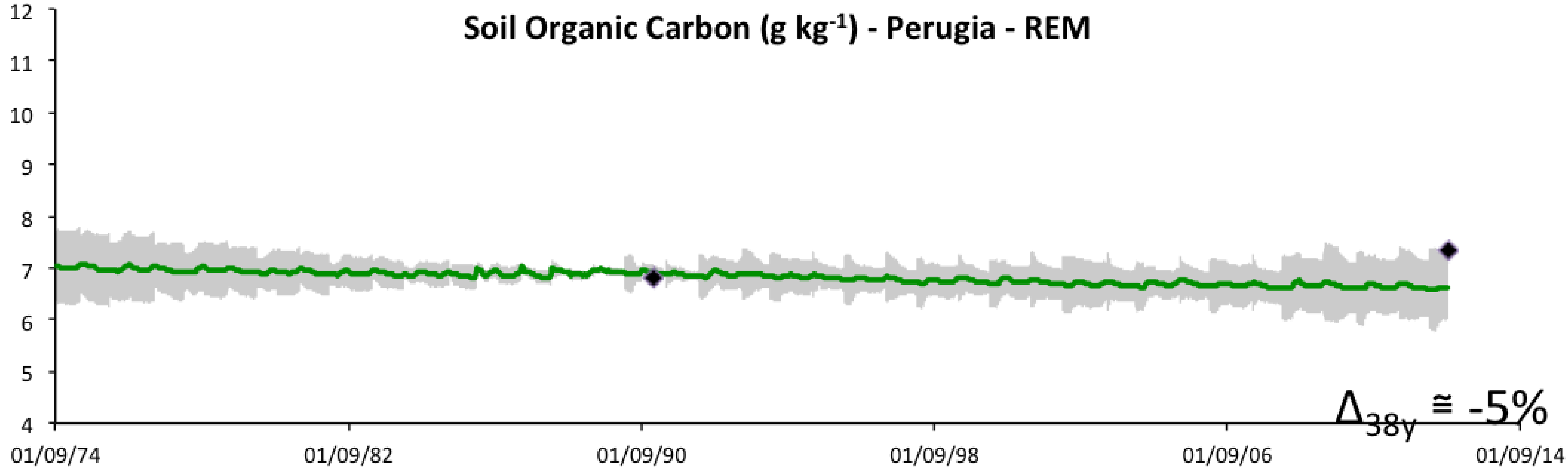
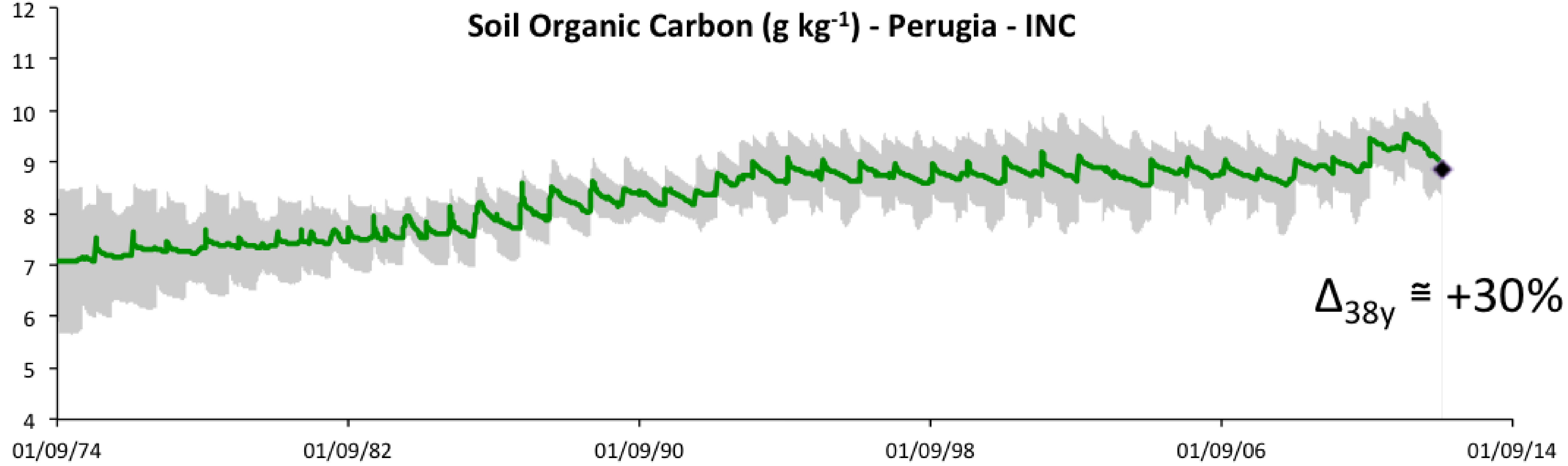
Soil Organic Carbon in Long Term Experiment: mais monocolture



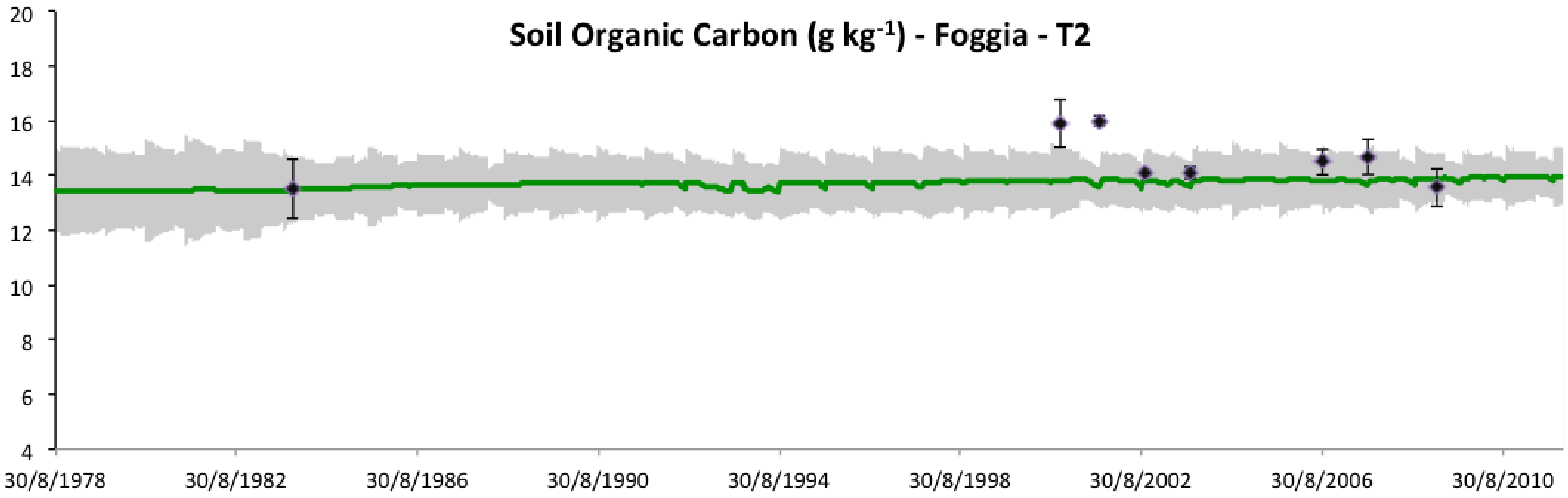


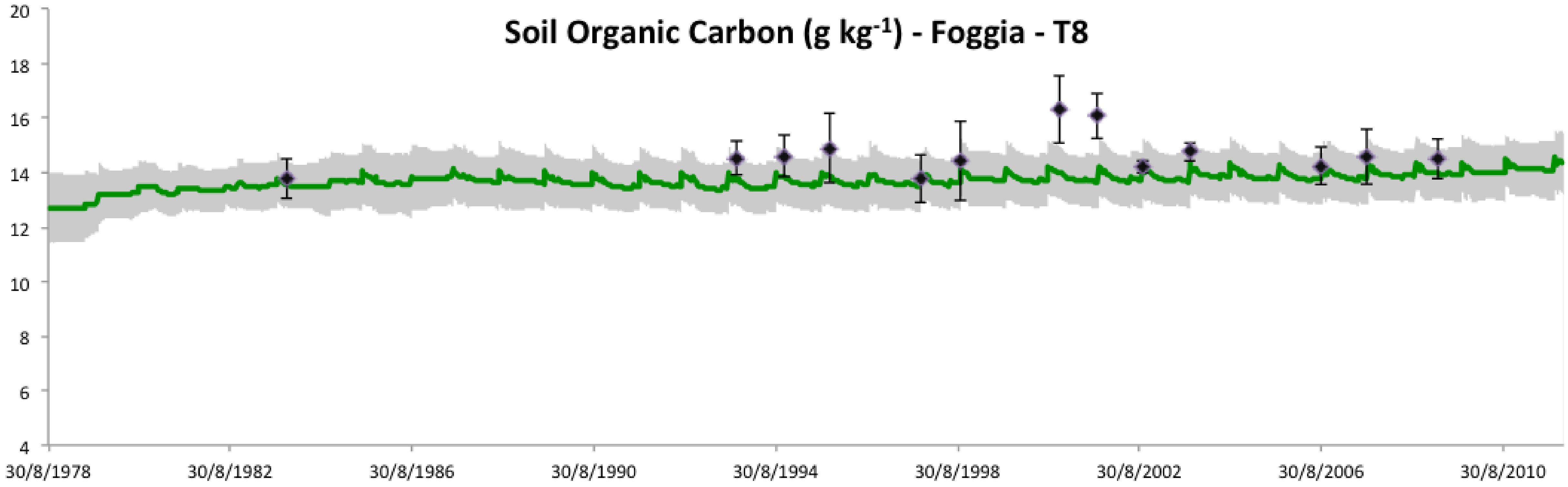
Garofalo et al. 2022. Crop residue management as a strategy for adaptation and mitigation of climate change: analysis of two Italian long-term experiments on the effects on soil organic carbon and crop yield with a multi-model ensemble approach (submitting to European Journal of Agronomy)

LInking Long Term Observatories with Crop Systems Modeling For a better understanding of Climate Change Impact and Adaptation StRategies for Italian Cropping Systems

PRIN 2010-2011

Soil Organic Carbon in Long Term Experiment: wheat monocolture





Garofalo et al. 2022. Crop residue management as a strategy for adaptation and mitigation of climate change: analysis of two Italian long-term experiments on the effects on soil organic carbon and crop yield with a multi-model ensemble approach (submitting to European Journal of Agronomy)

LInking Long Term Observatories with Crop Systems Modeling For a better understanding of Climate Change Impact and Adaptation StRategies for Italian Cropping Systems

PRIN 2010-2011

Modelling of Soil Organic Carbon as affected by Climate Change

RE: asportazione dei residui colturali (RC) e aratura

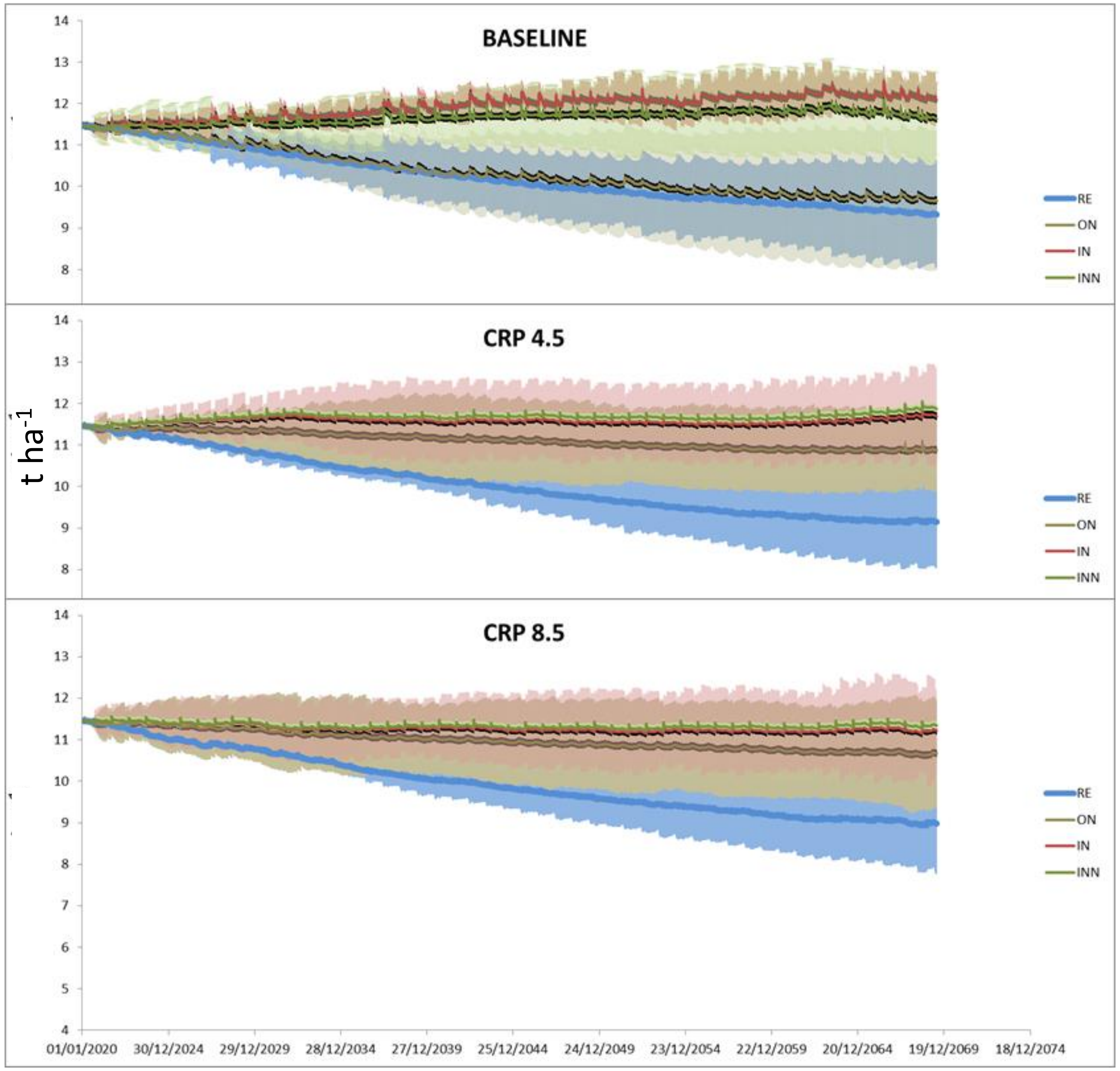
ON: mulch di RC (agric. Conservativa: no-tillage)

IN: interramento di RC con aratura

INN: aggiunta di N-urea (50 kg N ha^{-1}) pre-interramento

Garofalo et al. 2022. Crop residue management as a strategy for adaptation and mitigation of climate change: analysis of two Italian long-term experiments on the effects on soil organic carbon and crop yield with a multi-model ensemble approach (submitting to European Journal of Agronomy)

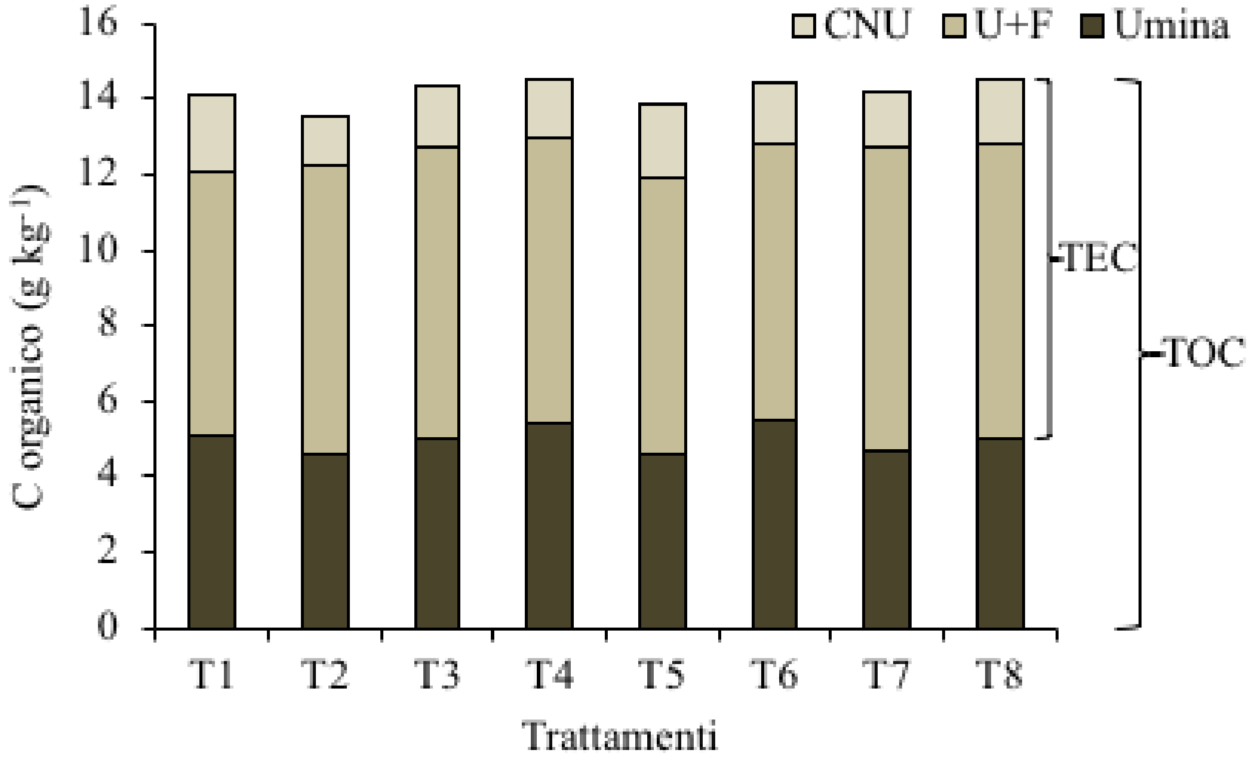
Foggia - Soil organic carbon (median ± s.d.) - 0 – 40 cm



Change in Soil Organic Carbon (% year^{-1})

Azienda Sperimentale “Podere 124” in Foggia (CREA-AA). Dal 1977, Long Term Experiment di grano duro in monosuccessione sottoposto a 8 trattamenti di gestione dei residui colturali. Analisi della fertilità del suolo effettuata dopo 32 anni di trattamento (Marzo 2009)

T1	**Bruciatura dei residui del frumento**
T2	Interramento dei residui del frumento
T3	Interramento + 50 kg ha^{-1} N (urea) sui residui prima dell’interramento
T4	Interramento + 100 kg ha^{-1} N sui residui prima dell’interramento
T5	Interramento + 150 kg ha^{-1} N sui residui prima dell’interramento
T6	Come T4 + 50 mm di acqua sui residui prima dell’interramento
T7	Come T5 + 50 mm di acqua sui residui prima dell’interramento
T8	Come T6 + 50 mm di acqua sui residui prima dell’interramento
100 kg P_2O_5 (perfosfato min) e 100 kg ha N (nitrato ammonico) tranne la T9	
Blocco randomizzato con 5 ripetizioni	



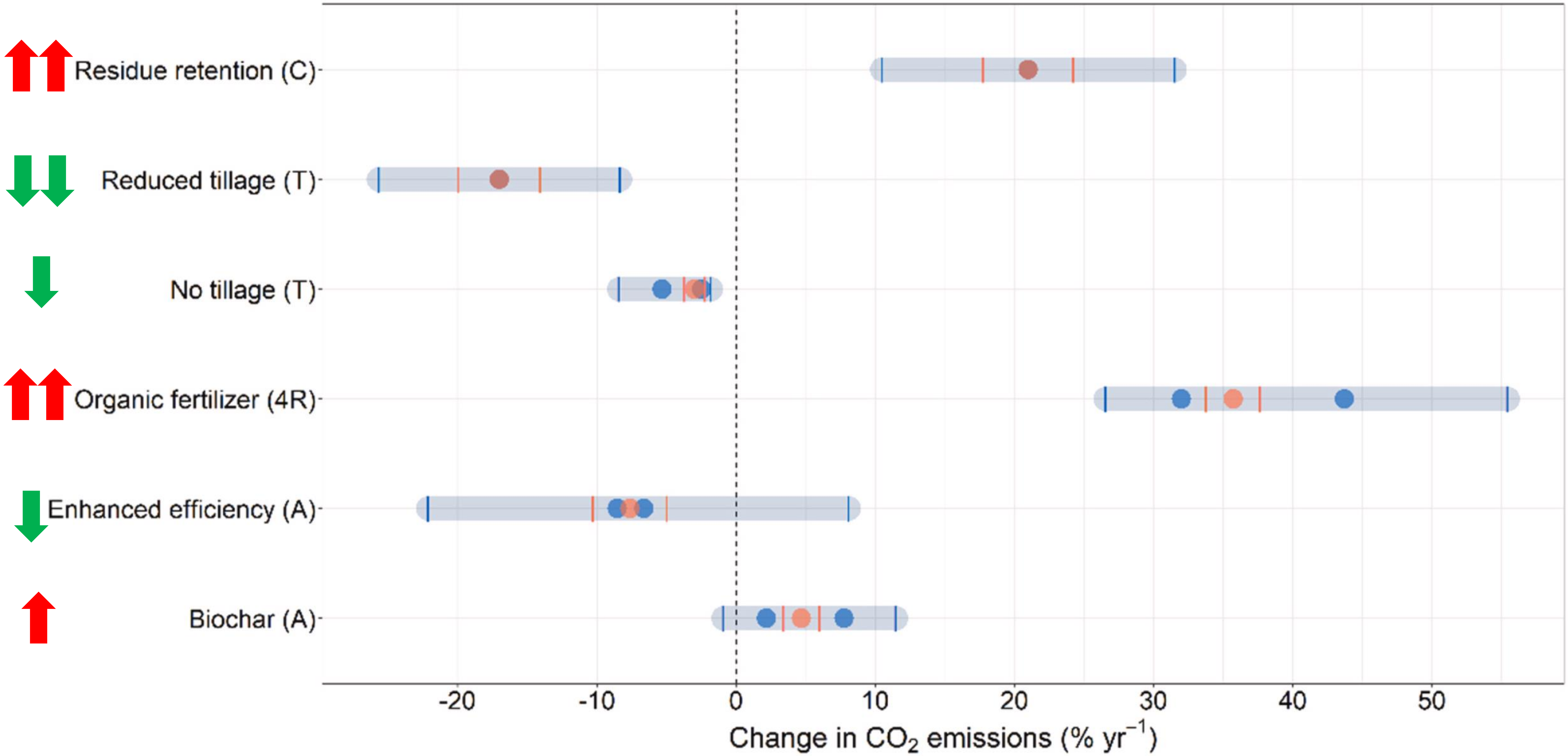
TEC=Total Extracted Carbon; **CNU**=Not Humified Carbon

Contrasti Significativi	TOC			U+F		
	C1	C2	D(%)	C1	C2	D(%)
Bruc *(T1)* vs. All *(T2_T8)*				7.0	7.6	**-7.7**
Nres *(T3_T8)* vs. **No_N** *(T2)*	14.3	13.6	**+5.7**			

Change in **CO_2** emission (% year^{-1}): few studies

Pratiche che apportano C stimolano l’attività dei micorganismi del suolo aumentando il tasso di decomposizione

Il minor disturbo del suolo del minimum- no-tillage tende a ridurre le emissioni di CO_2, insieme all’applicazione di inibitori della nitirificazione (enanched efficiency)



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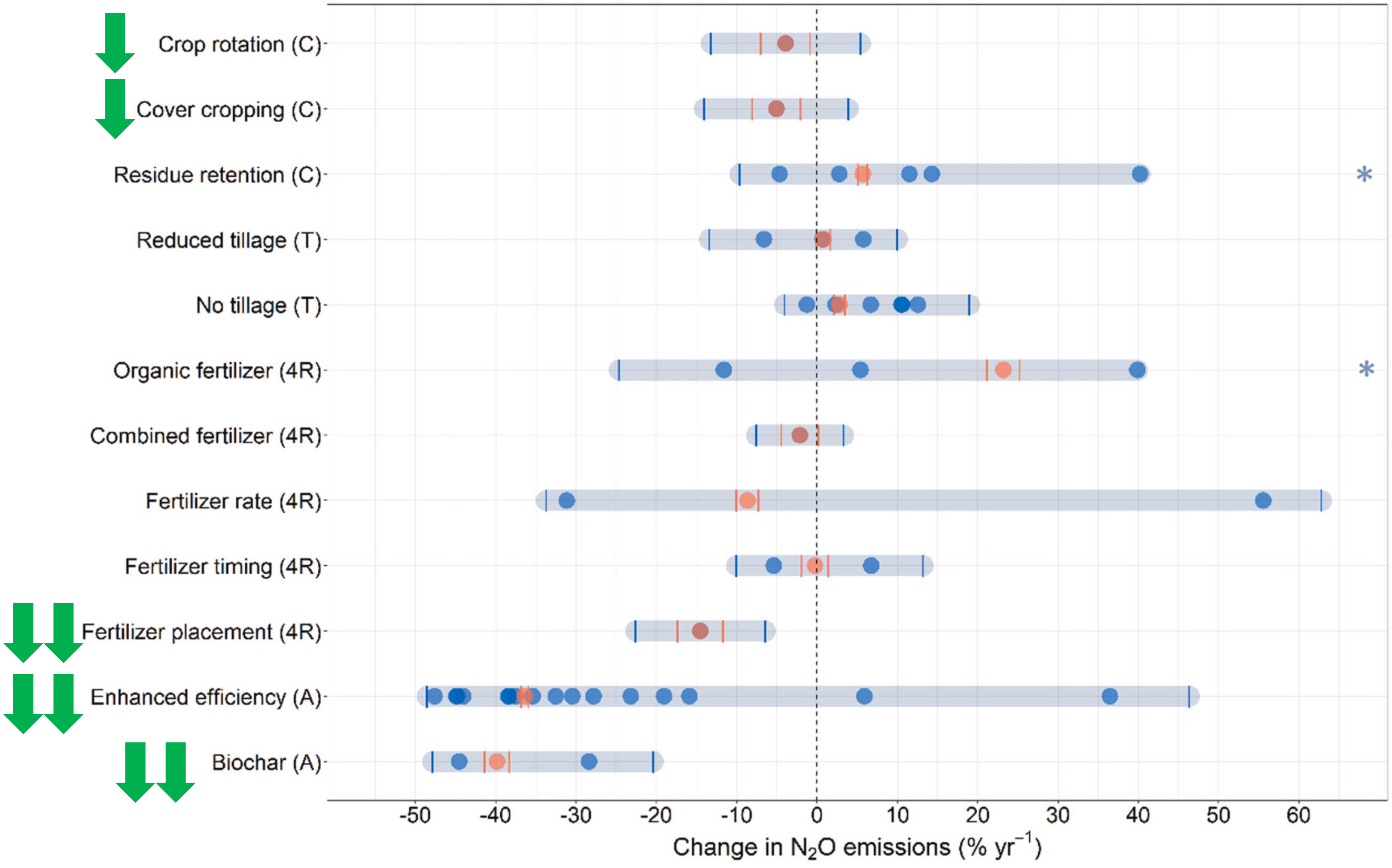
Change in **N_2O** emission (% year^{-1})



I risultati in generale non mostrano chiari impatti.

Quasi tutti i range di medie individuali comprendono lo zero

Biochar: effetto su potenziale redox o per durata breve degli studi?

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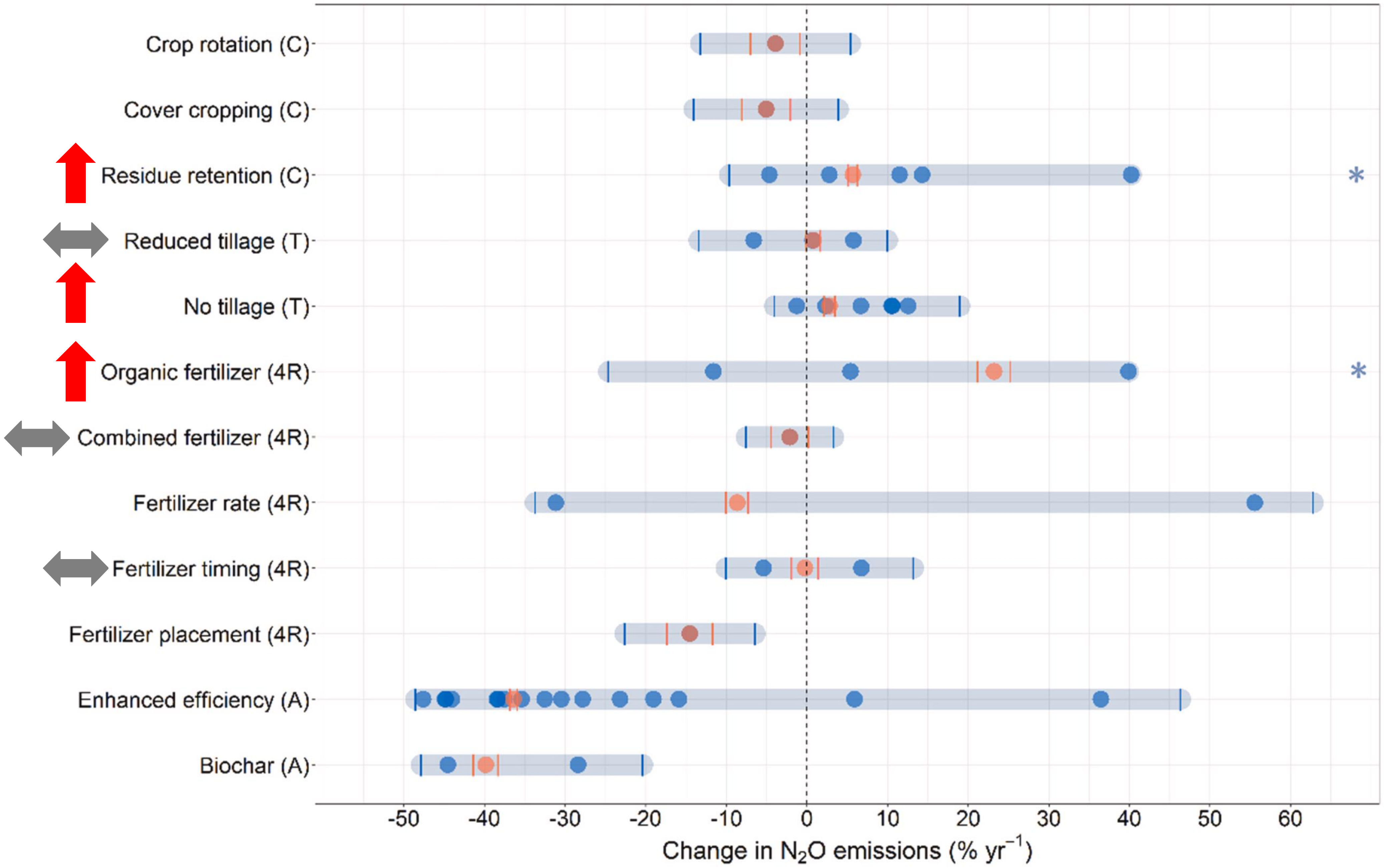
Change in **N_2O** emission (% year^{-1})



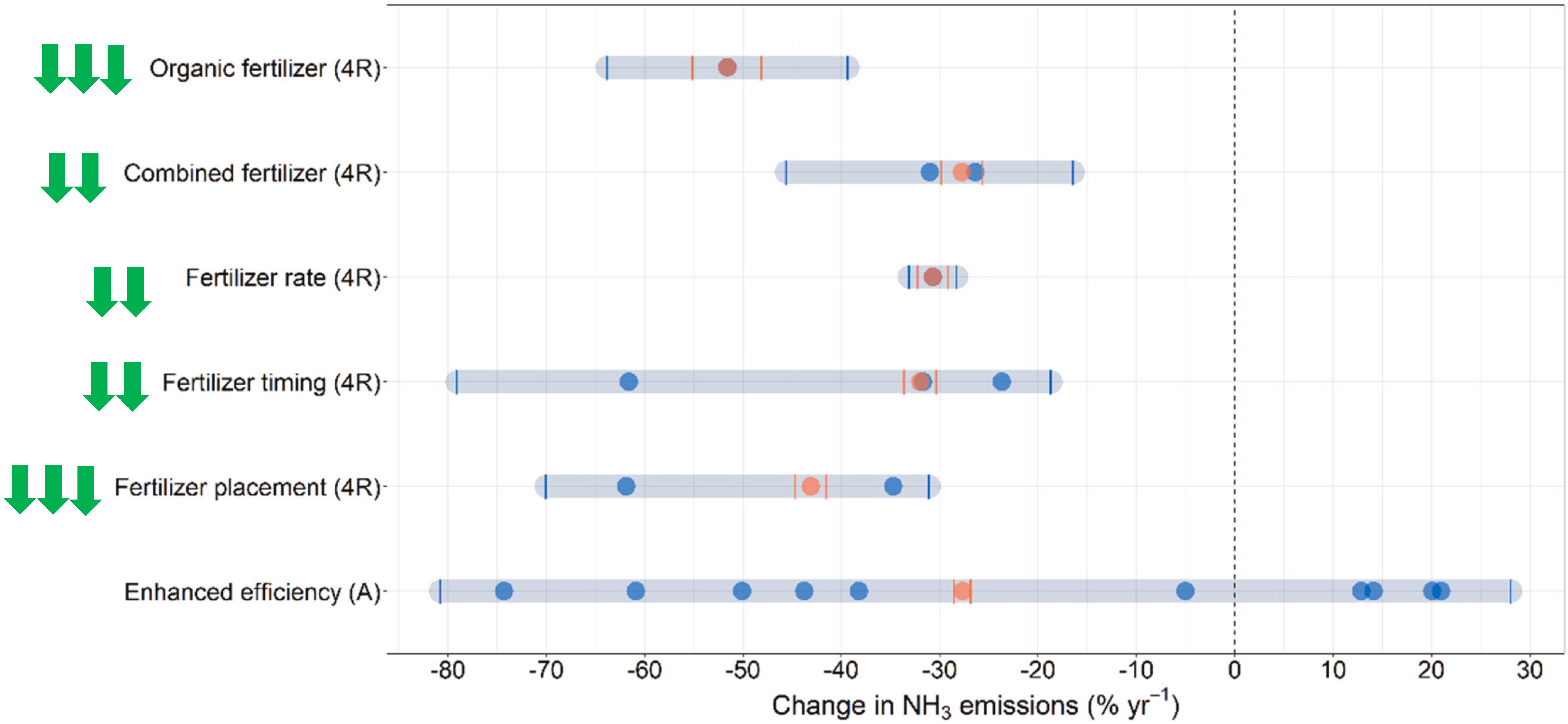
Residue Retention: N_2O soprattutto in condizioni aerobiche e con residui con C:N alti, interazioni con mineralizzazione e SWC

Organic fertilizer: Elevata incertezza per la varietà di matrici considerate (liquami, letame, ecc.), quantità apportate, ecc.

Young et al. 2021, Agriculture, Ecosystems and Environment 319: 107551

Change in $\mathbf{NH_3}$ emission (% year^{-1})

Le emissioni di ammoniaca possono essere contenute agendo sul tipo di fertilizzante, ottimizzazione della dose e modalità di spandimento. Valide le raccomandazioni di interramento subito dopo l'applicazione di letami/liquami e fertilizzanti ammoniacali.



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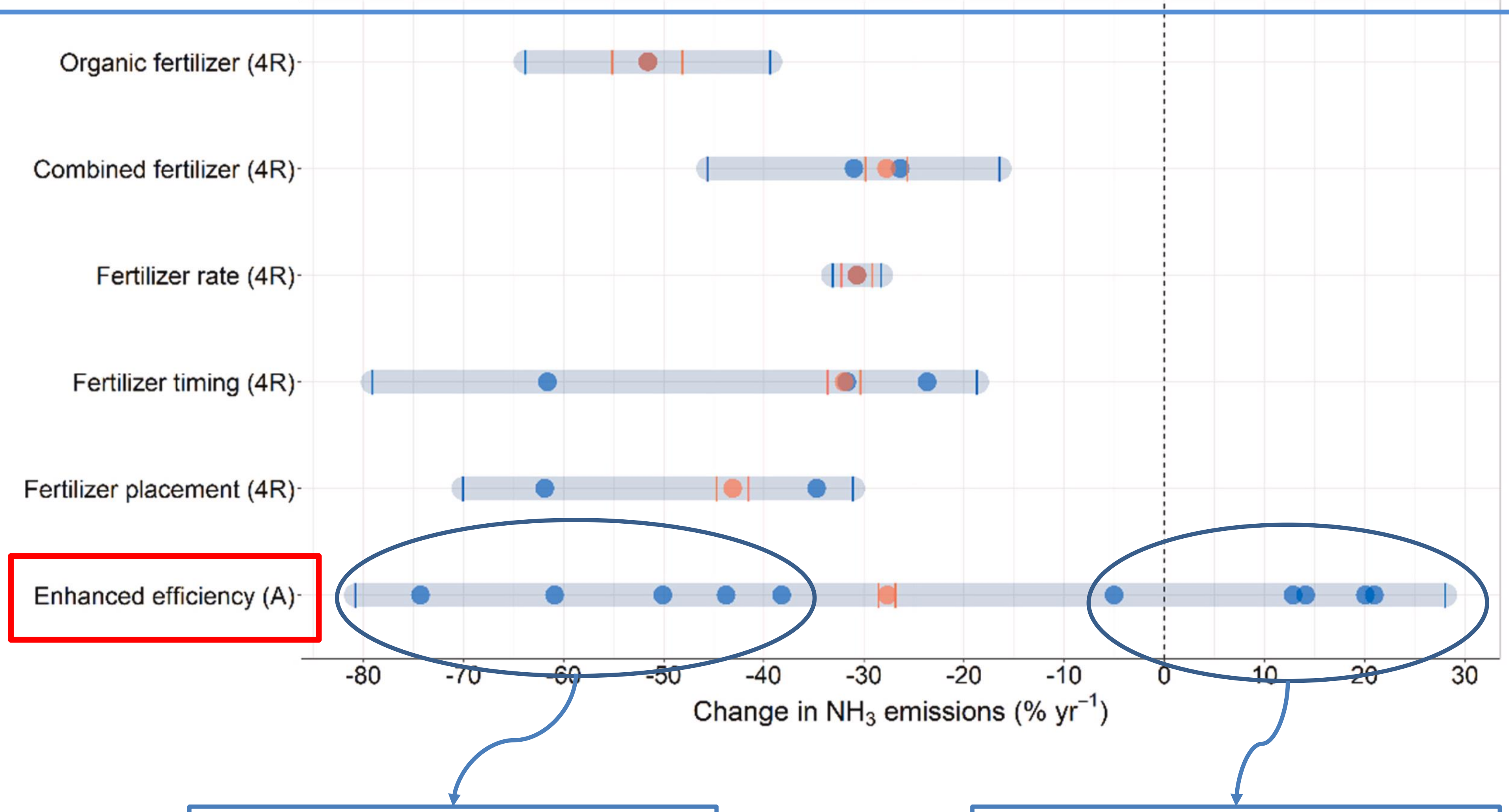
Change in **NH_3** emission (% year^{-1})

«**Enhanced efficiency**» mostra un forte decremento (-28%), ma con grande incertezza.

Variabilità dovuta ai diversi ammendanti utilizzati.

Inibitori dell’ureasi sono efficaci nel ridurre le emissioni di NH_3 (da -74% -44%)

Gli inibitori della nitrificazione sono efficaci nel ridurre le emissioni di N_2O, mentre gli studi riportano incrementi di emissioni di NH_3 (dal 5 al 21%)



- Urease in-hibitors
- Controlled-release fertilizers

- Nitrification inhibitors

Young et al. 2021, Agriculture, Ecosystems and Environment 319: 107551

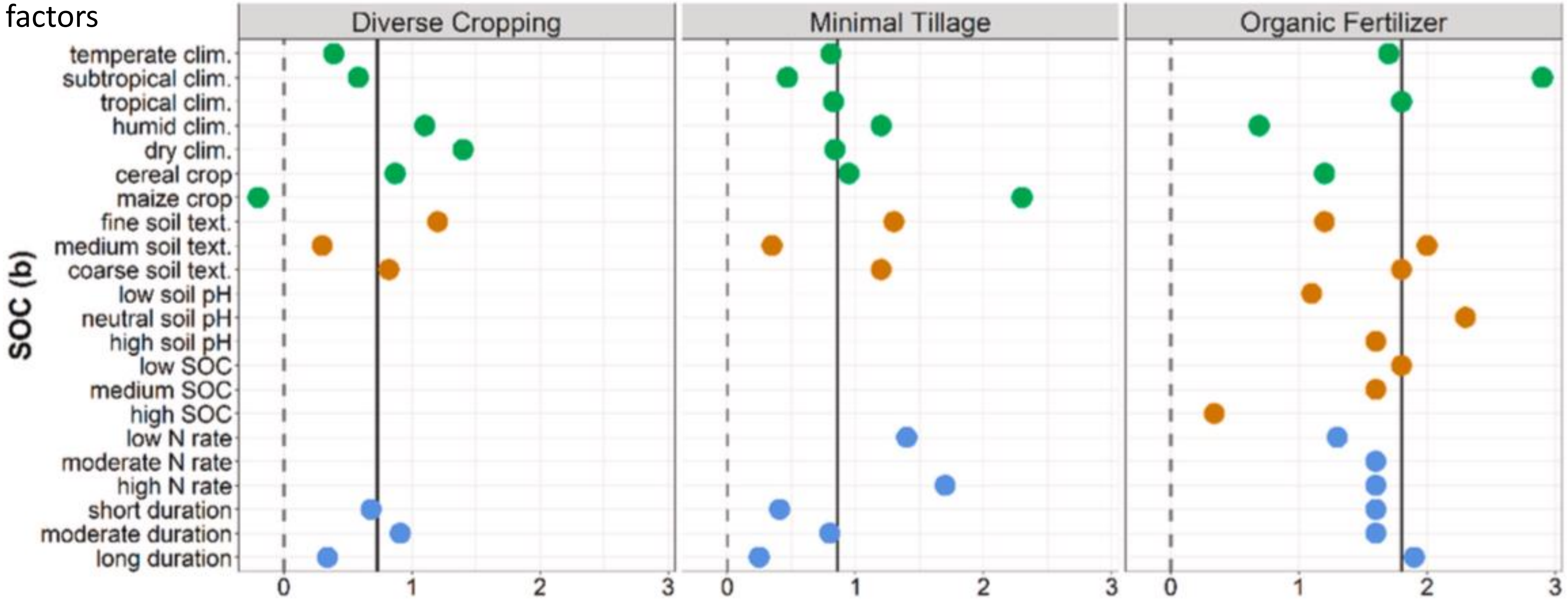
Covariate analysis for **SOC** and **N_2O** emission (% year^{-1})

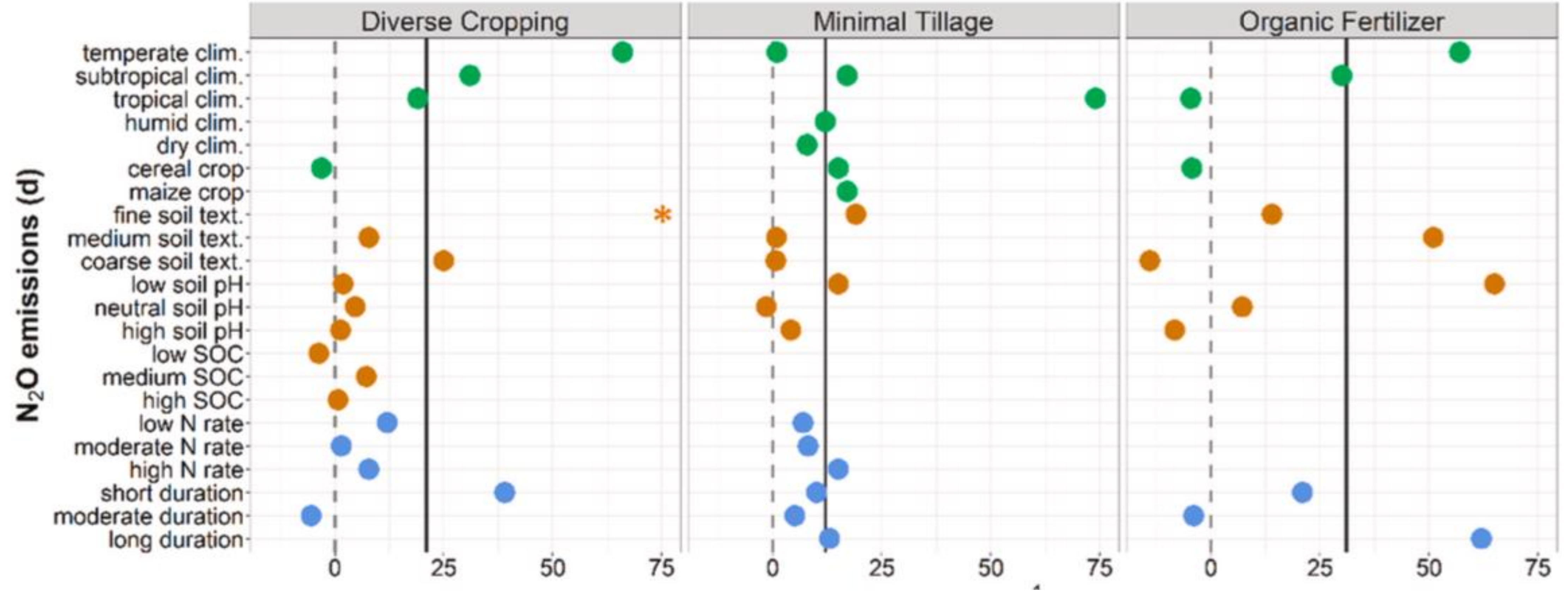
Site-specific factors

Crop rotation, Cover, Residue

Reduced- and no-tillage

Organic and combined fertilizer





- ✓ **Diverse Cropping**: basso impatto, meglio in climi aridi e suoli argillosi.
- ✓ **Minimum tillage**: basso impatto, meglio in suoli argillosi e per il mais
- ✓ **Organic fertilizer**: alto impatto, meglio con applicazioni di lunga durata

	Yield	SOC sequestration	Soil Emissions		
			N_2O	NH_3	CO_2
Crop rotation		+	-		
Residue retention		+	+		
Cover cropping	+	+	-		
Nitrif. inibitors	+		--		-
Ureasi inibitors	+			--	
Biochar	+	++	--		
4R strategies	+	+	--	--	
Minimum tillage	-	+	+/-		-

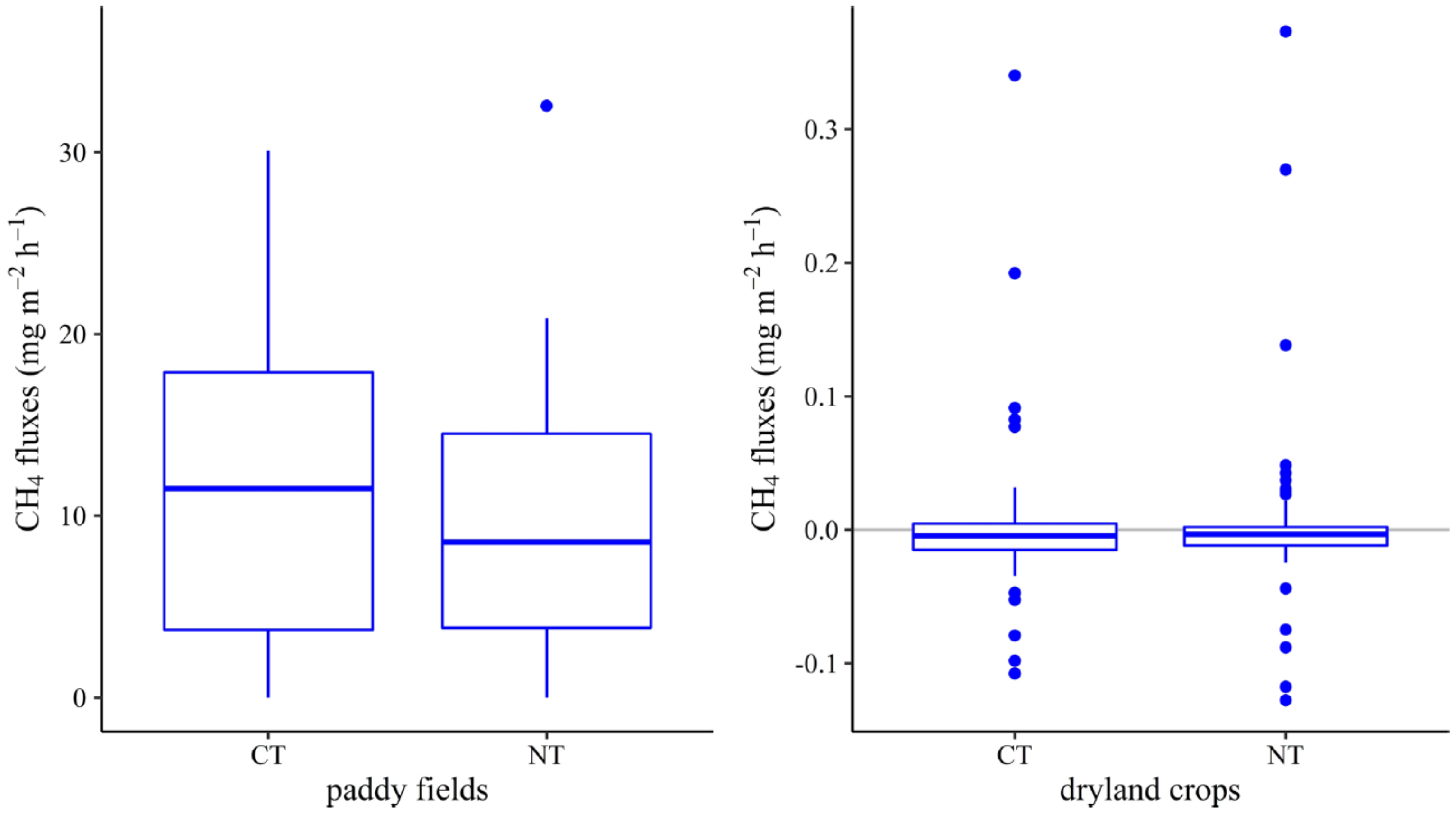
Effetto del no-tillage su emissioni di CH_4

In una recente review, Maucieri et al. hanno valutato la gestione del suolo come potenziale strumento la mitigazione delle emissioni di CH_4 di origine antropica.

NT ha ridotto significativamente le emissioni di CH_4 dalle risaie (o suoli in sommersione con altre colture) e una non significativa tendenza ad aumentare le emissioni di CH_4 in campi coltivati a mais.

I risultati indicano che il NT sulle emissioni di CH4 è nullo per colture non-sommerse.

E’ possibile una notevole riduzione delle emissioni di CH_4 in sistemi risicoli o altri sistemi di produzione che utilizzano suoli in sommersione.



Maucieri et al. (2021: No-tillage effects on soil CH4 fluxes: A meta-analysis. Soil & Tillage Research: 212, 105042

Capacità di mitigazione della gestione dei residui colturali

Per ridurre emissioni di N_2O:

- Rimozione dei residui colturali
- Interramento superficiale
- Interramento di residui con rapporto C:N > 30
- Interramento di residui colturali maturi

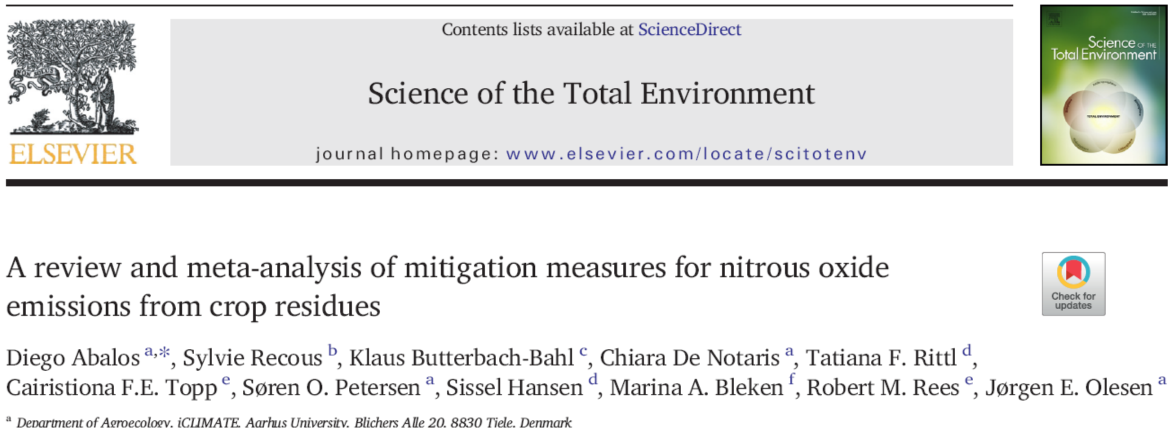
Minore efficacia di mitigazione:

- Epoca di interramento
- Impiego di fertilizzanti

Necessità di valutare effetti collaterali negativi su resa, sequestro di Carbonio, lisciviazione dei nitrati e/o volatilizzazione dell'ammoniaca.

Strategie Win-Win:

- Trattamento dei residui colturali prima dell'applicazione in campo, ad es. conversione dei residui in biochar o digestato anaerobico,
- Co-applicazione con inibitori della nitrificazione o materiali N-immobilizzanti come il compost con un elevato rapporto C:N, scarti di carta o segatura
- Utilizzo di residui ottenuti da miscele colturali



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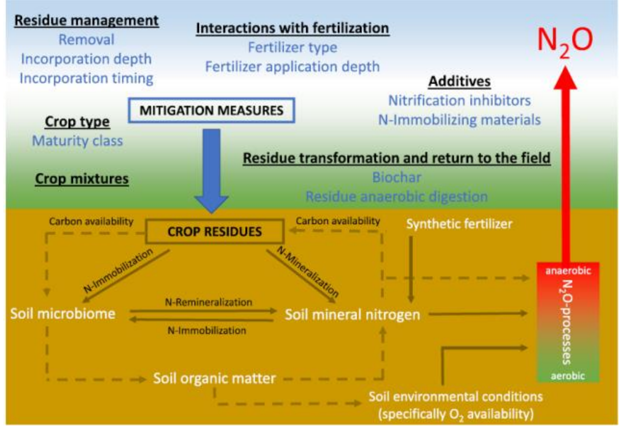
A review and meta-analysis of mitigation measures for nitrous oxide emissions from crop residues

Diego Abalos [a,*], Sylvie Recous [b], Klaus Butterbach-Bahl [c], Chiara De Notaris [a], Tatiana F. Rittl [d], Cairistiona F.E. Topp [e], Søren O. Petersen [a], Sissel Hansen [d], Marina A. Bleken [f], Robert M. Rees [e], Jørgen E. Olesen [a]

[a] Department of Agroecology, iCLIMATE, Aarhus University, Blichers Alle 20, 8830 Tiele, Denmark



Global Warming Potential

Wang et al. 2019 (Soil & Tillage Research)

$$SOC\ sequestration\ rate = \frac{SOC\ stock_{2016} - SOC\ stock_{2007}}{T}$$

$$NGWP = CH_4 \times 28 + N_2O \times 265 - SOC\ sequestration\ rate \times 44/12$$

$$NGWP = \left[kg\ CO_2eq\ ha^{-1}y^{-1}\right]$$

$$GHGI = \frac{NGWP}{yield}$$

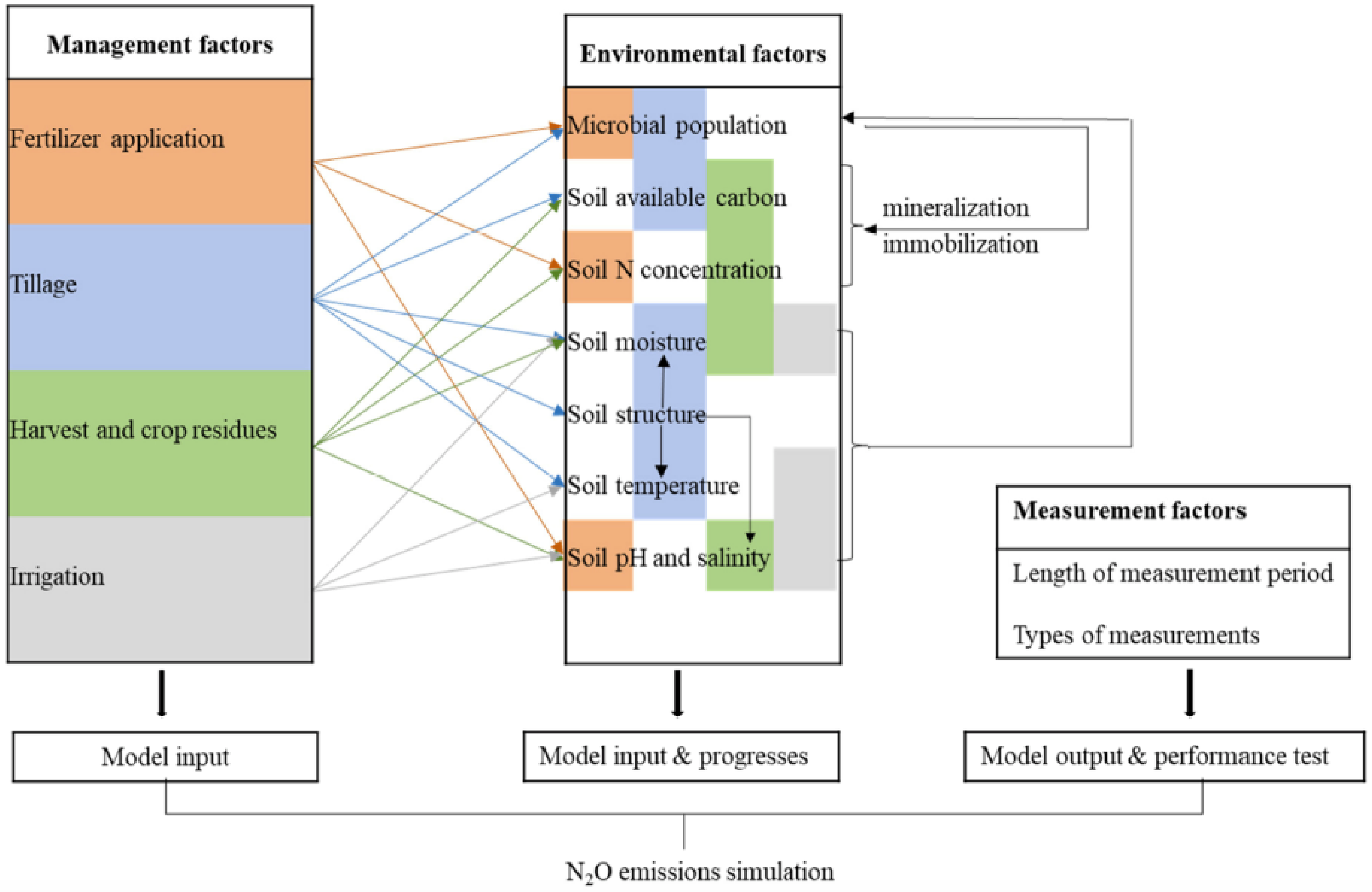
$$GHGI = \left[kg\ CO_2eq\ t_{cropyield}{}^{-1}y^{-1}\right]$$

Ghimire et al. 2017, Nutr Cycl Agroecosyst

$$\text{Net GWP} = \left(\text{GWP}_{\text{inputs.}} + \text{GWP}_{\text{CH}_4} + \text{GWP}_{\text{N}_2\text{O}} + \text{GWP}_{\text{SOC}}\right)$$

CO2 eq. For irrigation, tillage, fertilations, etc.: West and Marland 2002, Agr. Ecosyst Environ

Global Warming Potential del sistema colturale



Wang C., Amon B., Schulz K., Mehdi B. 2021. Factors That Influence Nitrous Oxide Emissions from Agricultural Soils as well as Their Representation in Simulation Models: A Review. Agronomy 2021, 11, 770.

Numerosità dei fattori coinvolti (Clima, Suolo, Pianta, Microrganismi, Falda, Agronomia), la complessità delle relazioni e delle interazioni, anche di tipo nonlineare, richiedono strumenti di analisi potenti, affidabili e scientificamente basati.

- Necessario determinare il GWP dei Sistemi Colturali e non delle singole pratiche agronomiche
- Riprogettare i Sistemi Colturali, ottimizzandoli per ridurre il loro GWP per aumentare la loro sostenibilità in termini di Mitigazione e Adattamento

Modellizzazione del Global Warming Potential del sistema colturale per aumentarne la resilienza

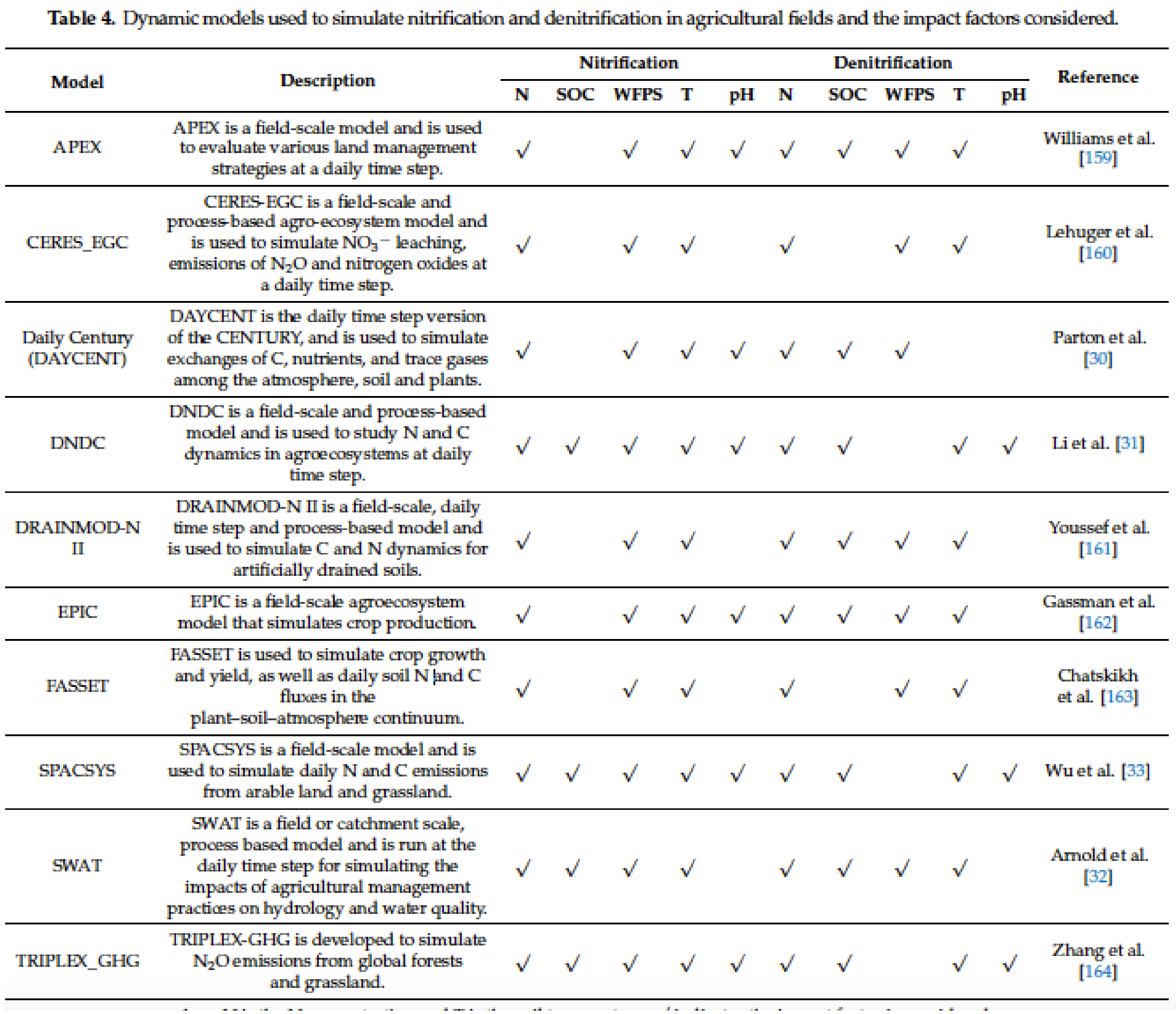


Table 4. Dynamic models used to simulate nitrification and denitrification in agricultural fields and the impact factors considered.

Model	Description	Nitrification					Denitrification					Reference
		N	SOC	WFPS	T	pH	N	SOC	WFPS	T	pH	
APEX	APEX is a field-scale model and is used to evaluate various land management strategies at a daily time step.	√		√	√	√	√	√	√	√		Williams et al. [159]
CERES_EGC	CERES-EGC is a field-scale and process-based agro-ecosystem model and is used to simulate NO_3^- leaching, emissions of N_2O and nitrogen oxides at a daily time step.	√		√	√		√		√	√		Lehuger et al. [160]
Daily Century (DAYCENT)	DAYCENT is the daily time step version of the CENTURY, and is used to simulate exchanges of C, nutrients, and trace gases among the atmosphere, soil and plants.	√		√	√	√	√	√	√			Parton et al. [30]
DNDC	DNDC is a field-scale and process-based model and is used to study N and C dynamics in agroecosystems at daily time step.	√	√	√	√	√	√	√		√	√	Li et al. [31]
DRAINMOD-N II	DRAINMOD-N II is a field-scale, daily time step and process-based model and is used to simulate C and N dynamics for artificially drained soils.	√		√	√		√	√	√	√		Youssef et al. [161]
EPIC	EPIC is a field-scale agroecosystem model that simulates crop production.	√		√	√	√	√	√	√	√		Gassman et al. [162]
FASSET	FASSET is used to simulate crop growth and yield, as well as daily soil N and C fluxes in the plant–soil–atmosphere continuum.	√		√	√		√		√	√		Chatskikh et al. [163]
SPACSYS	SPACSYS is a field-scale model and is used to simulate daily N and C emissions from arable land and grassland.	√	√	√	√	√	√	√		√	√	Wu et al. [33]
SWAT	SWAT is a field or catchment scale, process based model and is run at the daily time step for simulating the impacts of agricultural management practices on hydrology and water quality.	√	√	√	√		√	√	√	√		Arnold et al. [32]
TRIPLEX_GHG	TRIPLEX-GHG is developed to simulate N_2O emissions from global forests and grassland.	√	√	√	√	√	√	√		√	√	Zhang et al. [164]

Wang C., Amon B., Schulz K., Mehdi B. 2021. Factors That Influence Nitrous Oxide Emissions from Agricultural Soils as well as Their Representation in Simulation Models: A Review. Agronomy 2021, 11, 770.

- Ottimizzazione dei Sistemi Colturali a scala territoriale, in determinati contesti pedoclimatici, agronomici e sociali
- Modelli di simulazione sempre più numerosi, potenti ed affidabili (accoppiati a remote sensing, intelligenza artificiale, LCA, ecc.)
- Modello ARMOSA (Disaa, Università degli studi di Milano)
- BioMA – CRONO (CREA-AA)