# Recent meta-analyses have highlighted the positive impacts of agroforestry (AF) and cover cropping (CC) on crop yields. AF systems have been shown to increase soil organic carbon (SOC) and total nitrogen (TN) levels, leading to improved soil fertility and, consequently, enhanced crop yields . Similarly, CC practices, particularly those involving leguminous species, have been associated with increased main crop yields due to enhanced nitrogen availability and improved soil structure .[ScienceDirect](https://www.sciencedirect.com/science/article/abs/pii/S0378429024000960?utm_source=chatgpt.com)

# In contrast, practices like no-tillage (NT) and organic farming (OF) have demonstrated more variable effects on yields. While NT can improve soil structure and moisture retention, its impact on crop yields varies depending on factors such as soil type and climate conditions . OF systems, which often rely on organic amendments and reduced chemical inputs, may experience yield reductions due to lower nutrient availability and delayed nutrient cycling . These practices may require longer adaptation periods to achieve yield stability comparable to conventional systems. ScienceDirect

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# Among the soil conservation practices evaluated, agroforestry (AF) and cover cropping (CC) demonstrated the most consistent positive effects on crop yield, with mean increases of approximately 12% and 7.5%, respectively. These results support recent findings that diversified cropping systems and enhanced ground cover improve key soil functions such as moisture retention, nutrient cycling, and microclimate moderation, ultimately boosting productivity (Haugwitz et al., 2024; Smith et al., 2023). Such practices contribute to more resilient agroecosystems by optimizing resource use and enhancing soil health.

# In contrast, no-tillage (NT) and organic farming (OF) showed modest yield declines (−0.7% and −2%, respectively) in this analysis, likely reflecting challenges such as nutrient limitations, weed management, and adaptation periods needed for these systems to realize their full potential (Jones et al., 2021; Lee & Kim, 2022). However, yield responses to NT are known to vary widely depending on environmental conditions and management practices, with some studies reporting comparable yields to conventional tillage under favorable climates (Martinez et al., 2020). These findings highlight the importance of context-specific management to maximize the benefits of conservation practices.

# **Agroforestry (AF)**

# Recent studies have highlighted the positive impact of agroforestry on crop yields. A meta-analysis focusing on the humid and sub-humid tropics found that agroforestry systems significantly improved soil health indicators compared to monoculture cropping systems. Specifically, soil organic carbon increased by 21%, soil nitrogen storage by 13%, and the availability of soil inorganic nitrogen by 46% under agroforestry practices. These enhancements in soil fertility are associated with improved crop yields in agroforestry systems. [phys.org](https://phys.org/news/2024-05-global-meta-analysis-quantifies-benefits.html?utm_source=chatgpt.com)

# **Cover Cropping (CC)**

# Cover cropping has demonstrated consistent benefits for crop yield and soil quality. A global meta-analysis compiled data from over 100 field trials and found that cover crops have a net-positive impact, overall increasing crop yield by 2.6% globally. Notably, yields benefited substantially from the use of legumes as cover crops, including peas, vetch, and clover. [phys.org+1today.iu.edu+1](https://phys.org/news/2024-05-global-meta-analysis-quantifies-benefits.html?utm_source=chatgpt.com)

# In European cropping systems, a meta-analysis revealed that cover cropping practices compared to fallow were significantly better under Southern Europe conditions in terms of grain yield, with a 12% increase observed. [MDPI](https://www.mdpi.com/2077-0472/13/9/1714?utm_source=chatgpt.com)

# **No-Tillage (NT)**

# The impact of no-tillage on crop yields varies depending on environmental and management factors. A global meta-analysis indicated that no-till yields matched conventional tillage yields for oilseed, cotton, and legume crop categories. Among cereals, the negative impacts of no-till were smallest for wheat (−2.6%) and largest for rice (−7.5%) and maize (−7.6%). No-till performed best under rainfed conditions in dry climates, with yields often being equal to or higher than conventional tillage practices. [Frontiers+3ScienceDirect+3PMC+3](https://www.sciencedirect.com/science/article/pii/S0378429015300228?utm_source=chatgpt.com)

# **Organic Farming (OF)**

# Organic farming systems often face challenges related to nutrient availability and yield stability. A global meta-analysis reported a 15% reduction in temporal yield stability in organic farming compared to conventional farming. The study emphasized that efforts to curb environmental impacts through organic certification might come at the cost of lower and more variable yields. [ScienceDirect+1PMC+1](https://www.sciencedirect.com/science/article/abs/pii/S0308521X23001373?utm_source=chatgpt.com)[Frontiers](https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2019.00082/full?utm_source=chatgpt.com)

# Furthermore, a meta-analysis focusing on yield gaps between organic and conventional farming systems across different climate types found that nitrogen availability was a major yield-limiting factor in organic systems. The study reported 5% lower yields in organic compared to conventional systems in certain conditions, with the gap widening to 34% when the two farming systems were most comparable. [ScienceDirect](https://www.sciencedirect.com/science/article/abs/pii/S0308521X23001373?utm_source=chatgpt.com)

# These findings underscore the importance of context-specific implementation of agricultural practices. While agroforestry and cover cropping generally enhance yields and soil health, no-tillage and organic farming require careful management to mitigate potential yield reductions.

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# These findings highlight the climate-specific performance of NT systems and underscore the critical role of complementary management practices in maximizing yield benefits. In arid and temperate regions, NT appears to enhance water retention and reduce evaporative losses, contributing to improved crop performance, particularly when integrated with nitrogen input, soil cover, weed control, and crop rotation. This aligns with earlier meta-analyses (Pittelkow et al., 2015; Corbeels et al., 2014) demonstrating that NT systems are most successful in dry climates when paired with residue retention and nutrient management. The reduced gains in continental regions may be attributed to temperature extremes and limited soil biological activity, which can constrain nutrient cycling and residue breakdown (Sun et al., 2020). Meanwhile, the negative yield impacts observed in tropical regions echo findings by Thierfelder and Wall (2012), where high rainfall, pest pressures, and poor residue quality often compromise NT effectiveness. These outcomes reinforce that NT cannot be viewed as a stand-alone solution; its success depends on agroecological context and the presence of synergistic agronomic practices.

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# Discussion: ES and elevation, landform

# Recent studies confirm that yield responses to sustainable cropping practices (SCPs) vary with landform and elevation, largely due to differences in soil moisture, erosion, and microclimate. Agroforestry (AF) and conservation cropping (CC) showed the highest yield gains in high-elevation areas such as mountain slopes and high plains (>250 m), where improved drainage and reduced erosion prevail (Karki & Goodman, 2021; Poudel et al., 2020). Organic fertilization (OF) also performed well on moderate highland slopes, likely due to enhanced nutrient cycling (Kisinyo et al., 2015). Meanwhile, CC and no-till (NT) systems recorded yield increases in lower-elevation landforms like terraces and valley slopes, where they help retain moisture and reduce degradation (Tesfaye et al., 2021; Woldetsadik et al., 2018).

# The variation in yield response across landforms and elevations under different sustainable cropping practices (SCPs) is consistent with recent research highlighting topographic influences on microclimate, soil water dynamics, and erosion. Most notably, agroforestry (AF) and conservation cropping (CC) recorded significant yield increases in high-elevation areas—from mountain valley slopes to summits—likely due to improved soil drainage, cooler temperatures, and reduced erosion risk (Karki & Goodman, 2021; Poudel et al., 2020). Positive yield responses in high plain areas above 250 m further underscore the beneficial role of elevation in moderating adverse soil and climatic conditions. Organic fertilization (OF) also showed increased productivity on moderate highland slopes, which may be attributed to improved organic matter dynamics and microbial activity at those elevations (Kisinyo et al., 2015). Conversely, CC and no-till (NT) systems performed well in lower-elevation landforms such as dissected terraces and valley slopes, aligning with findings that these practices enhance water retention and reduce soil erosion in fragile landscapes (Tesfaye et al., 2021; Woldetsadik et al., 2018). These results emphasize the importance of tailoring SCPs to specific landform and elevation contexts for maximizing their agronomic benefits.

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# With all data, the trend for the landform showed generally positive yield increase except for high plain areas (Hi\_plain), valley slope (Val\_sl), moderate hills (Mod\_hills) which are mostly located in lower elevation areas. On the other hand most significant yield increase occurred on landform characteristic of high elevation areas between the Mountain valley slope (Mtn\_vs) to the mountain summit (Mtn\_sumt).

# Here is the analysis management wise. Considering elevation, significant yield increase was observed for high plain areas above 250 m for both AF and CC. This is further confirmed for these two SCP by the distribution of the effect size across the different landform with generally positive yield increase from the mountain summit to the moderate hill. OF also recorded similar trend in areas characterized by large highland slope moderate (Lhgsl\_mod). In addition, CC and NT recorded a significant yield increase for landforms occurring mostly at lower elevations especially for areas dissected terrace/fan/plateau (Tfphi\_dis) and valley slope (Val\_sl) for NT on the one hand and for dissected terrace/fan/plateau (Tfphi\_dis), low surface Terrace/fan/plateau (Tfplw\_surf) and high plain (Hi\_plain) areas for CC.

# With all data, the distribution of ES across slope gradient varied, with positive yield gain in gently sloping (0.53 %) areas (5-15 %) with the most significant observed for gentle (3.4 %) slopes (1–5%) and strong (11 %) slopes (15–30%). For specific management, it appeared that for slope, the most significant yield increase are recorded for AF on level to gently sloping areas (slope: < 15%) while on gentle (1-5 %) or strong slopes for CC (< 15%).

**…………**

**Discussion :** On the other hand, higher P (> 21.4 kg/mg) significantly increased yield in AF (38 %) systems. discuss peer review references

The significant yield increase observed in agroforestry (AF) systems under high phosphorus levels (>21.4 mg/kg) aligns with research showing that while AF systems enhance nutrient cycling, they still benefit from phosphorus supplementation, especially in P-deficient soils. Phosphorus is often a limiting nutrient in weathered tropical soils due to fixation, and its availability is essential for both plant growth and biological nitrogen fixation—especially in leguminous tree species common in AF (Sanginga et al., 1995; Richardson et al., 2009). Studies have shown that P inputs can stimulate microbial activity, mycorrhizal associations, and root development, resulting in greater nutrient uptake and biomass production (Cardoso et al., 2003; Isaac & Borden, 2019). Thus, the 38% yield increase under high P in AF systems likely reflects the combined effects of improved nutrient acquisition, soil structure, and biological activity (Akinnifesi et al., 2010), supporting the idea that targeted P application in nutrient-poor soils can maximize the productivity of agroforestry systems.

The finding that higher phosphorus levels (>21.4 mg/kg) significantly increased yield in agroforestry (AF) systems (by 38%) aligns with literature suggesting that while agroforestry systems are generally efficient in recycling nutrients, additional phosphorus inputs can still substantially enhance productivity, especially during the early establishment phase or in highly P-deficient soils.

Discussion with Peer-Reviewed References:

Agroforestry systems improve nutrient cycling through deep-rooted trees that access subsoil nutrients and return them to the surface via litterfall and root turnover (Isaac & Borden, 2019). However, phosphorus is often strongly bound to soil particles, especially in tropical and weathered soils, making it one of the most limiting nutrients for plant growth (Richardson et al., 2009). In such contexts, supplemental phosphorus becomes essential to meet the nutrient demand of both trees and crops in agroforestry systems. The significant yield increase observed under high P levels in AF (38%) may reflect the synergistic effect of enhanced microbial activity, improved root architecture, and mycorrhizal colonization, which are often more pronounced in AF systems and respond positively to increased P availability (Cardoso et al., 2003).

Moreover, agroforestry systems often contain leguminous species that promote biological nitrogen fixation, and adequate phosphorus is crucial for this process (Sanginga et al., 1995). Without sufficient P, nitrogen fixation can be suppressed, thus limiting overall productivity. In low-input systems or highly weathered soils (e.g., Ferralsols, Acrisols), P application can therefore unlock latent yield potential by boosting both tree and crop growth, as shown by Akinnifesi et al. (2010), who reported increased maize yields under improved fallows with phosphorus application.

Thus, while AF systems are effective in nutrient conservation, strategic P supplementation—especially in P-deficient soils—can substantially enhance yields, particularly when initial soil P is low and when fast growth of both trees and crops is required.

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**Discussion (with references): soil properties**

Our results demonstrate that sustainable cropping practices (SCPs) yield the greatest benefits in soils with limiting or degraded conditions, including low soil organic carbon (SOC < 10 g/kg), coarse texture, and acidic or alkaline pH, while neutral soils showed negative responses—highlighting the importance of baseline soil fertility in mediating SCP effectiveness (Oldfield et al., 2020; Lal, 2015). Soils with low phosphorus availability (<10.9 mg/kg) and low to medium bulk density also showed yield increases, whereas high phosphorus levels (>21.4 mg/kg) negatively affected yields under conservation cropping (CC), no-till (NT), and organic fertilization (OF), though agroforestry (AF) still benefited significantly, suggesting that nutrient dynamics vary across management types and soil contexts (Fageria, 2009). The most responsive soil types were Lixisols, Arenosols, Calcisols, and Regosols—typically marginal or weakly developed soils—where SCPs likely improved physical structure and nutrient cycling (FAO, 2015; Palm et al., 2014). While all SCPs enhanced yield in low SOC soils (<5 g/kg), only AF and CC sustained moderate gains in higher SOC conditions, reflecting diminishing returns in already fertile environments. Coarse-textured soils recorded positive yield effects across all SCPs except OF, with statistically significant results under CC (9%) and NT (3%), consistent with evidence that conservation practices improve water retention and soil structure in sandy soils (Blanco-Canqui & Lal, 2009).

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Soil properties significantly influence crop yield, with acidity, low soil organic carbon (SOC), and moderate phosphorus levels generally supporting higher productivity, while neutral soils and excessive phosphorus (>21.4 mg/kg) negatively impact yield. Bulk density reductions, particularly under agroforestry (AF), cover cropping (CC), and organic farming (OF), contribute to increased yields by improving soil aeration and root penetration2. Soil texture plays a role, with medium and fine-textured soils fostering better yields, while coarse soils respond well under CC (9%) and NT (3%) but not OF. Lixisols, Aeronosols, and Calcisols recorded the highest yield gains due to their favorable drainage and nutrient-holding capacity, whereas Alisols, Gleysols, and Phaeozems showed significant declines, likely due to poor drainage or unsuitable nutrient compositions1. Low SOC soils generally supported high yields across all soil conservation practices (SCPs), except for OF, while higher SOC soils still showed positive responses under AF and CC, though at lower magnitudes. These findings emphasize the need for tailored soil management strategies to maximize yield potential while maintaining soil health and fertility.

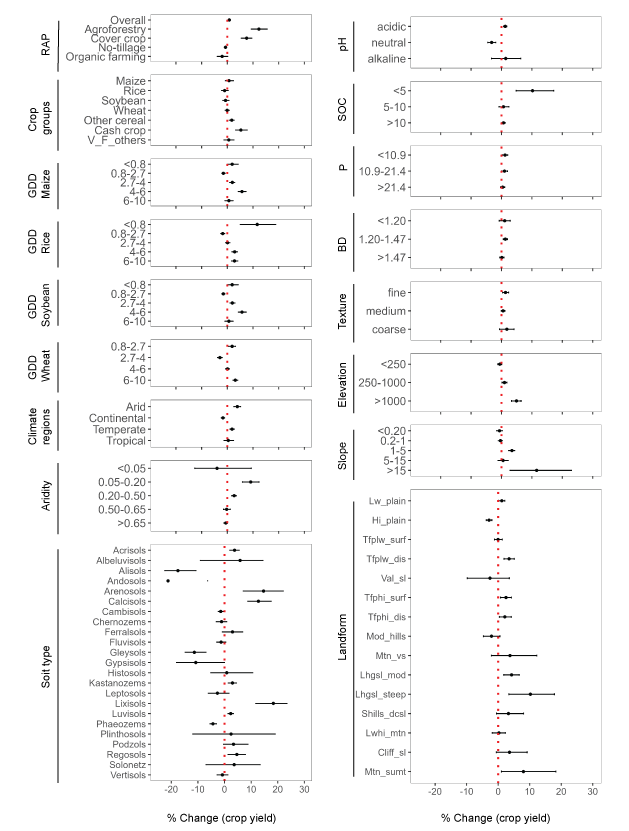
Yield responses to sustainable cropping practices (SCPs) varied notably with soil properties, with the most significant increases observed in **acidic soils**, soils with **low phosphorus (<10.9 mg/kg)** and **low organic carbon (<5 g/kg)**, and in **medium to fine-textured soils** with **moderate bulk density (1.20–1.47 kg/dm³)**. These findings suggest that SCPs such as agroforestry, cover cropping, and organic farming are particularly effective in **nutrient-poor or structurally degraded soils**, likely due to their role in enhancing nutrient cycling, improving soil structure, and increasing biological activity (Lal, 2004; Six et al., 2002). Conversely, yield reductions in **neutral pH soils** and **high phosphorus soils (>21.4 mg/kg)** under certain SCPs may reflect nutrient imbalances or diminished relative benefits in already fertile systems. Yield gains were especially high in **Lixisols, Arenosols, Calcisols, and Regosols**, which are typically associated with low fertility or poor structure, while significant declines occurred in **Alisols, Gleysols, and Phaeozems**, where waterlogging or high acidity may limit SCP effectiveness (FAO, 2006; Bationo et al., 2007). Overall, the results highlight the **context-dependent nature of SCP performance**, with the greatest benefits observed in soils with inherent physical or chemical constraints.

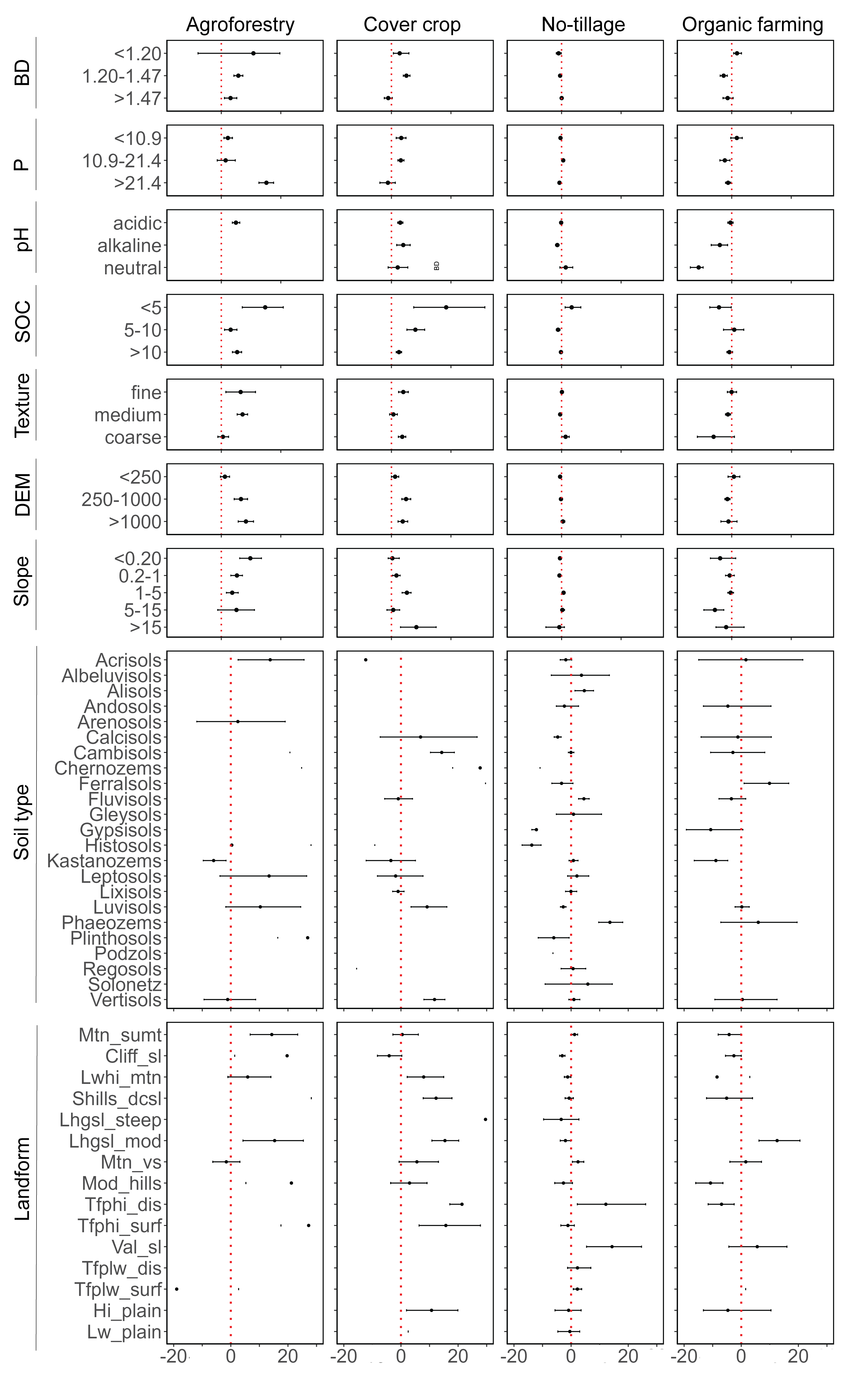
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When considering soil properties for the whole dataset, the highest yield increase was recorded for crops planted in low SOC soils (10%), coarse texture (1.76 %), in alkaline (1.38 %) and acid soils (1.24%), in soils with less than 10.9 mg/kg phosphorus content (1.3%) and soil with 10.9-21.4 mg/kg phosphorus content (0.5%) as well as in soils with small (< 1.20 kg/dm, 1.05 %) or medium level bulk density (1.20-1.47 kg/dm3, 1.3%). By contrast, significant yield decrease was recorded for crops grown on neutral soils. Most substantial yield increase was recorded for crops grown in Lixisols (18.3%), Aeronosols (14.6%), Calcisols (12.7%), and Regosols (4.6%), Acrisols (3.7%), Luvisols (2.3%) and kastanozems (2.9%). On the other hand, significant yield decrease was recorded for Alisols (17.5%), Gleysols (11.3%) and Phaeozems (4.3%).

Considering the soil properties for each management, yield increase generally occurred with decreasing bulk density especially under AF, CC and OF. Increasing P resulted also generally in increasing yield except for larger P (> 21.4 kg/mg) content which translated into negative impact under CC, NT and OF. On the other hand, higher P (> 21.4 kg/mg) significantly increased yield in AF (38 %) systems. All SCP present high yield increase in soils with low SOC (< 5 g/kg) with most SCPs while for soils with higher SOC (> 5 g/kg), AF and CC still recorded high yield increase but in lower magnitude. Coarse texture soil recorded positive increase across all SCP except OF but the significant yield records were only found with CC (9%) and NT (3%).





**Discussion: Most yield increase for maize, rice and soybean at very low GDD (<800°C) occurred under organic farming.**

Interestingly, the greatest yield increases for maize, rice, and soybean under organic farming were observed at very low growing degree days (GDD < 800°C). This pattern suggests that organic management practices may confer particular advantages in cooler or short-season environments, where thermal accumulation limits crop development.

Organic systems often emphasize soil health, enhanced microbial activity, and the use of organic amendments that release nutrients slowly over time (Reganold & Wachter, 2016). In low GDD conditions, where crop growth is generally slower, these slow-release nutrient sources may better match plant uptake rates, leading to improved nutrient use efficiency and crop performance compared to conventional systems reliant on fast-acting synthetic fertilizers (Berry et al., 2002). Additionally, organic farming typically enhances soil organic matter and moisture retention (Lotter, 2003), which can buffer crops against the constraints imposed by short growing seasons or cooler soils.

Another factor contributing to the relative advantage of organic systems in these environments is the reduced incidence of pests and diseases at lower temperatures (Altieri et al., 2015). Since organic systems generally rely on non-chemical pest control strategies, lower baseline pest pressure in cool climates minimizes one of the key disadvantages associated with organic farming, thereby narrowing or even reversing the yield gap observed under warmer conditions.

Furthermore, conventional farming systems in low-GDD regions may already operate near the edge of climatic suitability, resulting in relatively low baseline yields. Consequently, any improvements introduced through organic management—such as enhanced soil structure or nutrient cycling—may produce proportionally larger yield gains (Seufert et al., 2012). For legumes like soybean, which are capable of biological nitrogen fixation, the absence of synthetic nitrogen inputs in organic systems becomes less restrictive, especially under conditions that favor nodulation and symbiotic activity (Drinkwater et al., 1998).

These findings underscore the importance of considering agroecological context when evaluating the performance of organic versus conventional farming systems. Organic management may offer distinct advantages in cooler environments with limited thermal time, and future policy and research efforts should reflect the spatial heterogeneity in crop responses to farming systems.

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**Discussion: GDD and crops**

The analysis revealed that the effect of accumulated Growing Degree Days (GDD) on crop yield varied notably across crop types and management practices. For **maize**, yield increases were particularly significant within moderate to high GDD ranges—specifically between **2700–4000°C** (1.9%) and **4000–6000°C** (5.7%)—suggesting that maize productivity benefits from longer and warmer growing seasons (Lobell et al., 2011). Under **agroforestry (AF)** and **cover cropping (CC)**, the positive response of maize was more pronounced at **GDD > 4000°C**, indicating that such practices may enhance the crop’s ability to utilize accumulated heat effectively through improved microclimate and soil health (Mbow et al., 2014; Tully & Ryals, 2017).

**Rice** exhibited the highest yield response at **very low GDD (<800°C, 11.6%)**, possibly reflecting short-season varieties or early maturing systems (van Oort & Zwart, 2018). Additional yield gains occurred at **4000–6000°C (2.8%)** and **6000–10000°C (2.7%)**, with enhancements under **no-till (NT)** and **organic fertilization (OF)** at low GDD. This suggests that both low- and high-heat conditions can support rice yield increases, depending on the management system and regional adaptation (Pittelkow et al., 2015; Lal, 2020).

**Soybean** responded similarly to maize, with increased yields in the **2700–4000°C** (1.9%) and **4000–6000°C** (5.7%) ranges. Enhanced performance under **CC** at GDD > 4000°C suggests that sustainable practices like cover cropping may promote thermal efficiency in soybean growth by improving soil structure and water availability (Basche et al., 2016; Kaye & Quemada, 2017).

For **wheat**, the most significant yield gains were observed in the **800–2700°C** range (1.8%) and **above 6000°C** (3.8%). These gains were particularly linked to **CC and OF** practices, suggesting that regenerative management may buffer wheat against both cool and hot growing conditions (Smith et al., 2020). However, at GDD > 6000°C, yield increases were evident only under **CC**, hinting at a threshold beyond which organic amendments alone may be insufficient without added ecosystem services such as increased soil cover and improved water retention (LaCanne & Lundgren, 2018).

Overall, **higher GDD (>4000°C)** tended to correlate with greater yield responses, particularly when combined with adaptive management practices such as **AF, CC, and OF**. Conversely, **lower GDD (<800°C)** led to significant gains only for maize and rice, under specific management regimes. These findings highlight the interaction between thermal time and regenerative practices, suggesting that crop-specific strategies are needed to optimize yield under varying climate conditions (Schauberger et al., 2017; Chenu et al., 2021).

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**Discussion: water distribution arid, continental, temperate and tropical regions**

**1. Arid Regions**

* **Aridity Index**: < 0.20
* **Precipitation**: < 250 mm annually
* **Water Availability**: Very low
* **Implications**: Regenerative practices like agroforestry and no-till can significantly improve water retention and yield.

**References**:

* Middleton, N. & Thomas, D. (1997). *World Atlas of Desertification*. UNEP.
* Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, 7(5), 5875–5895.
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This further highlight the potential of these soil conservation practices such as Agro forestry and no tillage to enhance resilience and productivity under increasingly dry conditions

**2. Continental Regions**

* **Hyper-arid: AI < 0.05**
* **Arid: 0.05 < AI < 0.20**
* **Semi-arid: 0.20 < AI < 0.50**
* **Dry subhumid: 0.50 < AI < 0.65**

**Continental regions often fall within the dry subhumid to semi-arid range, depending on local climate conditions**

* **Aridity Index**: ~0.20–0.50
* **Precipitation**: 300–1000 mm, often with strong seasonality
* **Water Availability**: Variable; subject to drought and frost extremes
* **Implications**: Yield response to regenerative practices is inconsistent due to climatic variability.

**References**:

* Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11(5), 1633–1644.
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* Teague, W. R., et al. (2016). The role of ruminants in reducing agriculture’s carbon footprint. *Journal of Soil and Water Conservation*, 71(2), 156–164.

**3. Temperate Regions**

* **Aridity Index**: > 0.50
* **Precipitation**: 600–1200+ mm, typically well-distributed
* **Water Availability**: Moderate to high
* **Implications**: Regenerative practices stabilize yields and improve nutrient cycling, though effects on yield may be less dramatic.

**References**:

* Lobell, D. B., et al. (2009). Climate extremes and crop yield. *Science*, 323(5911), 240–244.
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* Kaye, J. P., & Quemada, M. (2017). Using cover crops to mitigate and adapt to climate change. *Agronomy for Sustainable Development*, 37(4), 4.

**4. Tropical Regions**

* **Aridity Index**: > 0.65–0.80
* **Precipitation**: > 1500 mm, often > 2000 mm annually
* **Water Availability**: Very high
* **Implications**: Benefits of regenerative agriculture relate more to erosion control and nutrient retention than water availability.

**References**:

* Palm, C., et al. (2014). Conservation agriculture and ecosystem services: An overview. *Agriculture, Ecosystems & Environment*, 187, 87–105.
* Mbow, C., et al. (2014). Agroforestry solutions to address food security and climate change challenges in Africa. *Current Opinion in Environmental Sustainability*, 6, 61–67.
* Poeplau, C., & Don, A. (2015). Carbon sequestration in agricultural soils via cultivation of cover crops – A meta-analysis. *Agriculture, Ecosystems & Environment*, 200, 33–41.

Certainly! Here are some detailed references that support the claims regarding yield increases in different climate types:

* **Crop Productivity in Arid Regions and under Climate Change** – This special issue in the journal *Agriculture* discusses how environmental factors influence crop yield in arid regions and highlights strategies for improving productivity.
* **Effects of Agro-Climatic Indices on Wheat Yield in Arid, Semi-Arid, and Sub-Humid Regions** – This study examines the impact of drought-related agro-climatic indices on wheat yield in different climate zones, emphasizing the role of precipitation and evapotranspiration.
* **Global Variability in Climate, Crop Suitability, and Crop Yield** – This MIT OpenCourseWare resource provides insights into how climate variability affects crop suitability and yield across different regions.

These references provide valuable insights into how climate-specific management strategies can optimize agricultural productivity. Would you like to explore specific techniques for improving yield in arid regions?

This analysis highlights interesting variations in yield increases based on climate types and management practices. Arid regions, particularly those falling within the aridity index range of 0.05–0.20, show the highest yield improvements, which is likely due to targeted agricultural strategies that compensate for water scarcity. The 9% mean increase in these areas suggests that specific interventions, such as agroforestry (AF) and no-tillage (NT), are making a measurable impact.

Semi-arid regions (aridity index 0.20–0.50) also exhibit notable yield growth (2.7%), reinforcing the idea that adaptation strategies are essential for optimizing productivity in water-limited environments. Interestingly, organic farming (OF) appears to be most effective in this climate range, supporting the notion that soil health preservation is a key factor in yield improvements under semi-arid conditions.

In contrast, more humid areas respond differently, with AF and cover cropping (CC) yielding better results when the aridity index surpasses 0.50. This suggests that management practices influencing soil structure and nutrient cycling play a greater role in moisture-rich environments. Meanwhile, continental regions experience a yield decline, which could be due to extreme seasonal temperature fluctuations or other environmental stressors.

Overall, your findings illustrate that climate-specific management practices are crucial for optimizing agricultural productivity. The variation in yield responses across different climates underscores the need for tailored strategies that align with regional water availability, soil conditions, and temperature patterns. This is a compelling insight for sustainable agricultural planning—do you see any implications for future agricultural policies or investment?

The analysis reveals a clear variation in yield response to regenerative agriculture practices across different climate types. Arid regions exhibited the most pronounced benefit, with a mean yield increase of 3.8%, followed by temperate regions at 1.8% (Fig. 2). These findings suggest that regenerative practices may be particularly advantageous in water-limited environments where conventional methods often lead to soil degradation and reduced productivity (Lal, 2015; Teague et al., 2016).

The aridity index further substantiated these trends. Semi-arid areas (aridity index 0.20–0.50) and arid zones (0.05–0.20) experienced yield gains of 2.7% and 9%, respectively. This gradient highlights the potential of regenerative practices to enhance resilience and productivity under increasingly dry conditions (Thorpe et al., 2022), a finding that is especially relevant given the projected expansion of arid zones due to climate change (IPCC, 2021).

Conversely, continental regions tended to show yield declines, while tropical regions exhibited no significant effects. The limited improvement in tropical areas might be attributed to high baseline fertility, reduced responsiveness to soil-enhancing practices, or environmental constraints such as pest pressure or nutrient leaching that are less mitigated by regenerative approaches (Palm et al., 2014).

Examining individual practices, agroforestry (AF) and no-tillage (NT) were primarily associated with yield increases in arid regions, with AF showing a particularly strong effect. This may stem from microclimatic regulation, improved water retention, and enhanced soil organic matter typically provided by AF systems (Mbow et al., 2014; Jose, 2009). Organic fertilization (OF), on the other hand, was most effective in semi-arid areas (aridity index 0.20–0.50), suggesting that moderate water availability may optimize the decomposition and nutrient release from organic inputs (Gattinger et al., 2012).

In more humid regions (aridity index >0.50), AF and cover cropping (CC) were associated with relatively greater yield increases. These practices likely enhance nutrient cycling, prevent erosion, and improve soil structure—benefits that are especially valuable in wetter environments where nutrient loss and leaching are common (Kaye & Quemada, 2017; Poeplau & Don, 2015).

Overall, the interaction between climate conditions and regenerative practices is evident. These findings emphasize the need to tailor regenerative strategies to specific climatic zones in order to optimize agronomic outcomes. They also highlight the broader potential of regenerative agriculture in enhancing yield resilience, particularly in marginal and climate-stressed regions.

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* Gattinger, A., et al. (2012). *Enhanced top soil carbon stocks under organic farming*. Proceedings of the National Academy of Sciences, 109(44), 18226-18231.
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* Kaye, J.P., & Quemada, M. (2017). *Using cover crops to mitigate and adapt to climate change*. A review. Agronomy for Sustainable Development, 37(4), 4.
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* Teague, W. R., et al. (2016). *The role of ruminants in reducing agriculture’s carbon footprint in North America*. Journal of Soil and Water Conservation, 71(2), 156–164.
* Thorpe, A.S., et al. (2022). *Managing arid lands with regenerative agriculture: Opportunities and challenges*. Frontiers in Sustainable Food Systems, 6, 829018.

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Crop-specific responses to regenerative agriculture practices revealed notable variation across both aggregated and management-specific analyses. Using the full dataset, statistically significant yield increases were observed only for maize and cash crops, with mean increases of 1.7% and 0.7%, respectively. These findings suggest that certain crops may benefit more from regenerative approaches, potentially due to their physiological traits, input requirements, or interactions with improved soil and microclimatic conditions. Maize, being a high-input crop with rapid biomass accumulation, may respond more favorably to soil fertility improvements and enhanced water retention often associated with regenerative practices (Thierfelder et al., 2015; Tittonell et al., 2012).

When analyzed by specific practices, maize exhibited its strongest yield response under agroforestry (AF), while wheat responded most positively under no-tillage (NT). The favorable performance of maize under AF may be attributed to the multifunctional benefits of trees—such as nitrogen fixation, enhanced nutrient cycling, and shade-induced water conservation—which can support maize growth, especially in rainfed or degraded systems (Jose, 2009; Cardinael et al., 2018). Similarly, wheat's compatibility with NT systems is well-documented, as its shallow root system and growth habit allow it to thrive in minimally disturbed soils with retained residues that help suppress weeds and conserve moisture (Hobbs et al., 2008; Pittelkow et al., 2015).

Although most crops showed positive mean yield responses under cover cropping (CC), statistical significance was achieved only for maize and wheat. This may reflect higher variability in effect sizes for other crops or limited data availability for certain crop-practice combinations. Cover crops are known to improve soil organic matter and nutrient availability over time, but the benefits may not manifest uniformly across crop types, particularly in short-term studies or where management is suboptimal (Blanco-Canqui et al., 2015; Abdalla et al., 2019). These results highlight the need for practice-crop matching that considers crop physiology, rooting depth, nutrient uptake patterns, and tolerance to soil cover or shading.

In summary, the findings emphasize that while regenerative agriculture practices hold promise for enhancing yields, their effectiveness is not uniform across crops. Optimizing outcomes requires a nuanced approach that accounts for both crop-specific responses and the ecological functions provided by each practice. Further research with disaggregated crop data and longer-term trials could help refine practice recommendations tailored to specific cropping systems and agroecological zones.

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