Impacts of Agroforestry and Cover Cropping on Crop Yield

**Mechanisms of Yield Enhancement in Agroforestry and Cover Cropping**

Agroforestry (AF) – the integration of trees/shrubs with crops – and cover cropping (CC) both show consistent yield benefits. Studies report average crop yield increases of roughly **~12%** under agroforestry and **~7–9%** under cover cropping across diverse conditions[vtechworks.lib.vt.edu](https://vtechworks.lib.vt.edu/items/84405546-bbe8-4de0-9691-244a167a7378#:~:text=that%20CA%20practices%20were%20associated,However%2C%20other%20agricultural%20systems)[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). These benefits arise from multiple ecosystem-service mechanisms. For AF, trees improve soil fertility and microclimate; for CC, groundcover plants boost soil health and nutrient supply. Below we summarize key mechanisms for each practice.

**Agroforestry (AF) – Key Mechanisms**

* **Soil health and fertility:** Tree roots and litter inputs build soil organic matter and nutrients. Meta-analyses in sub-Saharan Africa found AF significantly increased **soil organic carbon, total N and available P** (all ~20% higher than monocultures) and improved soil structure[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were)[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=available%20P%2C%20and%2073%20reported,P%2C%20and%20SOC%20for%20all). Deep roots and nitrogen-fixing trees recycle nutrients from subsoil into the crop root zone[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). Over time this enhanced fertility supports higher crop yields (e.g. one review reports mean yield gains in AF systems)[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were)[vtechworks.lib.vt.edu](https://vtechworks.lib.vt.edu/items/84405546-bbe8-4de0-9691-244a167a7378#:~:text=crop%20to%20absorb%20nutrient%20elements,However%2C%20other%20agricultural%20systems).
* **Water retention and microclimate:** Trees modulate the crop microclimate. Their canopy shading lowers daytime soil and air temperatures, reducing heat stress on crops[frontiersin.org](https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2021.606631/full#:~:text=Trees%20mitigate%20microclimatic%20extremes%2C%20creating,ecosystem%20services%20from%20agricultural%20land)[llnl.gov](https://www.llnl.gov/article/49856/cover-cropping-can-increase-farming-yields#:~:text=The%20analysis%20unveiled%20that%20increases,inputs%20increased%20or%20when%20legume). Roots and mulch from trees increase infiltration and soil moisture: AF systems show **higher infiltration rates and soil moisture content** than treeless controls[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). By acting as windbreaks, trees also slow evaporation. Together these effects buffer crops against drought. (However, note that in very dry regions tree–crop competition can still reduce water for the understory crop unless managed carefully.)
* **Biodiversity and pest control:** Trees increase habitat complexity. Mixed plantings boost beneficial insect and microbial diversity. For example, higher plant diversity in AF is linked to **reduced crop disease incidence**[frontiersin.org](https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2021.606631/full#:~:text=Trees%20mitigate%20microclimatic%20extremes%2C%20creating,ecosystem%20services%20from%20agricultural%20land). Tree cover can also support pollinators and natural enemies of pests. This biodiversity “insurance” often lowers pest and weed pressure on crops. (However, some pests may use trees as alternate hosts, so integrated management is needed.)
* **Nutrient cycling:** AF systems promote internal nutrient cycling. Tree roots mine deep or subsoil nutrients, bringing them up in leaf litter. Nitrogen-fixing trees (e.g. leguminous species) directly add N to the system. These processes reduce nutrient leaching and dependency on fertilizer, sustaining crop nutrition over time[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were)[vtechworks.lib.vt.edu](https://vtechworks.lib.vt.edu/items/84405546-bbe8-4de0-9691-244a167a7378#:~:text=crop%20to%20absorb%20nutrient%20elements,However%2C%20other%20agricultural%20systems).
* **Carbon sequestration & climate regulation:** By adding woody biomass and litter, AF greatly increases on-farm carbon storage. More soil carbon improves structure, water-holding capacity, and resilience. Tree shade and transpiration also moderate extremes (e.g. reduce midday heat), creating a more favorable microclimate for crops. (These climate-regulating services indirectly support stable yields.)
* **Summary – yield impacts:** In practice, these mechanisms translate to higher or stabilized yields. A broad meta-analysis found AF in sub-Saharan Africa **raised crop yields** compared to non‑AF controls[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). (For example, alley‐cropping systems yielded ~96% of sole-crop at tree planting, then fell by ~2.6%/yr as trees matured[frontiersin.org](https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2021.606631/full#:~:text=information%20on%20yields%20is%20available,that%20competition%20between%20crops%20and); still, integrated AF systems often outperformed continuous monocrops.) Another systematic review reported AF yield gains (up to +66% in one analysis) attributed to improved soil water and nutrients[vtechworks.lib.vt.edu](https://vtechworks.lib.vt.edu/items/84405546-bbe8-4de0-9691-244a167a7378#:~:text=crop%20to%20absorb%20nutrient%20elements,However%2C%20other%20agricultural%20systems). However, outcomes are context-dependent: e.g. a Mediterranean meta-analysis found tree competition caused an **average ~22% drop** in crop yields[link.springer.com](https://link.springer.com/article/10.1007/s13593-023-00927-3#:~:text=The%20average%20change%20with%20agroforestry,size%20was%20lower%20than%20three). Thus, careful design (tree spacing, species choice, pruning) is needed to avoid shading/competition costs.
* **Trade-offs and limitations:** The main trade-off in AF is tree–crop competition. Older or dense tree stands can reduce light, water or nutrients for crops[frontiersin.org](https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2021.606631/full#:~:text=information%20on%20yields%20is%20available,that%20competition%20between%20crops%20and)[link.springer.com](https://link.springer.com/article/10.1007/s13593-023-00927-3#:~:text=The%20average%20change%20with%20agroforestry,size%20was%20lower%20than%20three). In some systems (e.g. dense orchard alleys) yield declines of 10–20% are reported unless countered by management. There can also be more labor to manage trees. Despite these trade-offs, evidence shows AF can deliver a *win-win* of higher yields plus ecosystem services (e.g. reduced erosion) in many settings[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were)[vtechworks.lib.vt.edu](https://vtechworks.lib.vt.edu/items/84405546-bbe8-4de0-9691-244a167a7378#:~:text=crop%20to%20absorb%20nutrient%20elements,However%2C%20other%20agricultural%20systems).

**Cover Cropping (CC) – Key Mechanisms**

* **Soil health and fertility:** Cover crops (sown during fallow or between cash crops) protect and build soil. Their residues add organic matter, improving soil structure and fertility. Meta-analysis across 2,000+ observations finds cover cropping **increases soil organic carbon (SOC)** by ~5–7% on average[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06)[anl.gov](https://www.anl.gov/argonne-scientific-publications/pub/177093#:~:text=comparisons%20from%2061%20peer,based%20policy%20recommendations.%20Taken). Legume covers (e.g. clover, vetch) fix atmospheric N and can **significantly boost subsequent crop N supply**. Even non-legume covers scavenge leftover N (reducing leaching) and release it upon decomposition. Over seasons this raised fertility supports higher crop yields[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06)[anl.gov](https://www.anl.gov/argonne-scientific-publications/pub/177093#:~:text=comparisons%20from%2061%20peer,based%20policy%20recommendations.%20Taken).
* **Water retention and management:** Cover crop canopy and residues improve soil moisture. By shading soil and reducing evaporation, they conserve moisture for the next crop. Cover crops also enhance infiltration: roots break up crusts and surface residues act like mulch, slowing runoff. One meta-analysis found cover crops **reduced evapotranspiration by ~6% and raised water-use efficiency ~5%**, on average, relative to bare fallow[researchgate.net](https://www.researchgate.net/publication/353428588_A_meta-analysis_on_cover_crop_impact_on_soil_water_storage_succeeding_crop_yield_and_water-use_efficiency#:~:text=water%20storage%20to%20a%20depth,parameters%20varied%20by%20soil%20and). (The benefits are greatest where water is not already limiting; in very dry climates an active cover crop *can* draw down soil moisture and hurt yields.)
* **Weed and pest control:** Dense cover stands suppress weeds, reducing competition for the cash crop[acsess.onlinelibrary.wiley.com](https://acsess.onlinelibrary.wiley.com/doi/10.2134/agronj15.0086#:~:text=,water%20for%20the%20subsequent). Living covers and mulches hinder weed emergence, and some releases allelochemicals that further inhibit weeds. Cover crops also foster beneficial insects: flowering covers support predator and pollinator populations[besjournals.onlinelibrary.wiley.com](https://besjournals.onlinelibrary.wiley.com/doi/full/10.1002/2688-8319.12086#:~:text=,overall). This can help control pests (e.g. thrips and aphids) on the main crop. Overall, improved weed and pest suppression can indirectly raise yields.
* **Nutrient cycling:** Similar to AF, cover crops cycle nutrients. Legume covers supply N (one study found legume CCs boosted yield by 16% on average)[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). Even mixtures of grasses+legumes can enhance N availability while conserving soil N. Cover roots pump up nutrients from deeper layers, making them available upon decomposition. In effect, cover crops function as “green manures” that release nutrients just as the cash crop needs them[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06)[vtechworks.lib.vt.edu](https://vtechworks.lib.vt.edu/items/84405546-bbe8-4de0-9691-244a167a7378#:~:text=crop%20to%20absorb%20nutrient%20elements,However%2C%20other%20agricultural%20systems).
* **Carbon sequestration & microclimate:** By adding biomass, cover crops sequester carbon in soil[anl.gov](https://www.anl.gov/argonne-scientific-publications/pub/177093#:~:text=comparisons%20from%2061%20peer,based%20policy%20recommendations.%20Taken). Higher SOC improves soil water-holding capacity and resilience to extreme weather. Above-ground, cover crop residue moderates soil temperature, insulating against cold or hot spells early in the season. While the effect is smaller than with trees, it still helps stabilize microclimate conditions for seedlings.
* **Summary – yield impacts:** Empirical studies report **modest average yield gains** with cover cropping. One global meta found cover crops **raised main-crop yields ~9%** overall[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). The benefit was driven by legumes (legume covers +16% yield) whereas pure grass covers had no significant effect[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). Another analysis (IU-led) found net yield +2.6% globally (but +9.8% for legume covers; corn +4.7%; barley +8.3%)[news.iu.edu](https://news.iu.edu/live/news/35658-global-meta-analysis-quantifies-benefits-of-cover#:~:text=Leguminous%20cover%20crops%20showed%20a,yield%20increase). Reported effects vary widely (from modest losses to +30% gains[llnl.gov](https://www.llnl.gov/article/49856/cover-cropping-can-increase-farming-yields#:~:text=Recent%20meta,aridity%2C%20to%20small%20yield%20decreases)) depending on climate, crop and management. Broadly, cover crops help most when fertility or moisture are limiting: e.g. cover cropping on nutrient-poor, rainfed soils often boosts yields, while on very fertile or well-irrigated land effects may be neutral[news.iu.edu](https://news.iu.edu/live/news/35658-global-meta-analysis-quantifies-benefits-of-cover#:~:text=Researchers%20discovered%20that%20cover%20crops,when%20combined)[llnl.gov](https://www.llnl.gov/article/49856/cover-cropping-can-increase-farming-yields#:~:text=Recent%20meta,aridity%2C%20to%20small%20yield%20decreases).
* **Trade-offs and limitations:** Cover cropping does incur trade-offs. It requires additional seeding and termination operations. In water-limited regions, cover crops **can compete with the cash crop for moisture**, sometimes reducing yields. Indeed, one review notes yield penalties up to ~20% under drought conditions[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=exact%20impacts%20of%20CCs%20on,However%2C%20the). Delaying cover termination or choosing fast-decomposing mixes can mitigate this. Residue mulch may transiently tie up N, so timing and legume use are important. Finally, benefits accumulate over time: short-term studies sometimes show little yield change, whereas long-term use yields bigger improvements[llnl.gov](https://www.llnl.gov/article/49856/cover-cropping-can-increase-farming-yields#:~:text=The%20analysis%20unveiled%20that%20increases,inputs%20cannot%20substitute%20for%20SOC). Overall, the tendency is toward a win-win of higher yields *and* more resilient soils, but **outcomes are context-dependent**[llnl.gov](https://www.llnl.gov/article/49856/cover-cropping-can-increase-farming-yields#:~:text=Recent%20meta,aridity%2C%20to%20small%20yield%20decreases)[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=exact%20impacts%20of%20CCs%20on,However%2C%20the).

**Contextual Variation and Trade-Offs**

Both AF and CC outcomes vary by **region, climate, soil and crop**:

* **Climate/Region:** AF benefits are largest in tropical and subhumid zones (where trees buffer heat and rainfall variability)[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). In cool, wet climates, trees may simply take up space. Cover crop benefits are greatest in regions with moderate rain: in *humid* climates cover crops often increase yields, whereas in arid climates they risk depleting soil moisture[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=exact%20impacts%20of%20CCs%20on,However%2C%20the)[llnl.gov](https://www.llnl.gov/article/49856/cover-cropping-can-increase-farming-yields#:~:text=Recent%20meta,aridity%2C%20to%20small%20yield%20decreases).
* **Soil type:** Coarse, degraded soils gain more from either practice. AF’s deeper roots improve sandy soils’ water and nutrient status. CC’s residue protects erosion-prone soils. For example, cover cropping on light-textured soils gave larger yield gains than on clay soils[news.iu.edu](https://news.iu.edu/live/news/35658-global-meta-analysis-quantifies-benefits-of-cover#:~:text=Researchers%20discovered%20that%20cover%20crops,when%20combined).
* **Crop type:** High-value or nutrient-demanding crops (corn, vegetables, fruit trees) often show stronger responses. The IU study found corn and barley responded well to cover crops[news.iu.edu](https://news.iu.edu/live/news/35658-global-meta-analysis-quantifies-benefits-of-cover#:~:text=Corn%2C%20the%20most%20produced%20crop,yields%20could%20be%20even%20higher). In agroforestry, intercrops like grains or vegetables under fruit/shade trees may profit from microclimate moderation. Meanwhile, cereals on their own fields (monocrop) see smaller gains.
* **Management:** Diversity and timing matter. Mixed-species cover blends (legume+grass) often outperform single-species (higher biomass, balanced N supply)[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=decreased%20main%20crop%20yield%20by,Evidence%20shows%20that%20the). No-till systems tend to benefit more from cover crops (since they preserve residues) than conventionally tilled fields[news.iu.edu](https://news.iu.edu/live/news/35658-global-meta-analysis-quantifies-benefits-of-cover#:~:text=Researchers%20discovered%20that%20cover%20crops,when%20combined). In agroforestry, alley spacing, pruning and understory fertilization can tip the balance between competition and support.

**Summary Table of Benefits**

| **Mechanism/Service** | **Agroforestry (AF)** | **Cover Cropping (CC)** |
| --- | --- | --- |
| **Soil health & fertility** | Trees add litter and root biomass, boosting soil organic matter and nutrient stock[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). Deep roots recycle nutrients (N, P) from subsoil. AF often raises soil C, N and P by ~20%[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were)[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=available%20P%2C%20and%2073%20reported,P%2C%20and%20SOC%20for%20all). | Covers add biomass (roots and shoots) that increases organic matter and tilth. Leguminous covers fix N; all covers scavenge residual nutrients and prevent erosion[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06)[anl.gov](https://www.anl.gov/argonne-scientific-publications/pub/177093#:~:text=comparisons%20from%2061%20peer,based%20policy%20recommendations.%20Taken). Studies report ~7% SOC gain with CC[anl.gov](https://www.anl.gov/argonne-scientific-publications/pub/177093#:~:text=comparisons%20from%2061%20peer,based%20policy%20recommendations.%20Taken). Over time this improves fertility. |
| **Water retention & management** | Tree canopies reduce evaporation and wind desiccation[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). Roots and mulch enhance infiltration and soil moisture[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). AF often improves water tables and reduces runoff. (But note: densely spaced trees can also draw soil moisture from understory.) | Cover crop groundcover shades soil and acts as mulch, reducing evaporation. Root channels improve infiltration. Meta-analysis finds CC reduces ET (–6%) and raises water-use efficiency (+5%)[researchgate.net](https://www.researchgate.net/publication/353428588_A_meta-analysis_on_cover_crop_impact_on_soil_water_storage_succeeding_crop_yield_and_water-use_efficiency#:~:text=water%20storage%20to%20a%20depth,parameters%20varied%20by%20soil%20and). However, actively growing covers can compete for water if not terminated timely[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=exact%20impacts%20of%20CCs%20on,However%2C%20the). |
| **Biodiversity & pest control** | Mixed tree–crop systems support diverse habitats. Increased plant diversity often suppresses crop pests and diseases[frontiersin.org](https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2021.606631/full#:~:text=Trees%20mitigate%20microclimatic%20extremes%2C%20creating,ecosystem%20services%20from%20agricultural%20land). Trees provide pollen/nectar and refuge for predators and pollinators. AF hedges can block wind-born pests. | Cover crops increase field diversity early season. Living mulch and mulches suppress weeds. Flowering covers recruit beneficial insects and predators (e.g. ants, beetles), enhancing biocontrol[besjournals.onlinelibrary.wiley.com](https://besjournals.onlinelibrary.wiley.com/doi/full/10.1002/2688-8319.12086#:~:text=,overall). Overall, CC tends to reduce weed pressure and can lower some pest outbreaks. |
| **Nutrient cycling** | Woody perennials (especially legumes) fix N and cycle nutrients over seasons. Leaf fall returns nutrients yearly. Studies note **improved nutrient uptake** in AF systems (e.g. %N in grain)[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). | Legume covers directly add N (one study: legume CC → +21.8% yield without fertilizer[news.iu.edu](https://news.iu.edu/live/news/35658-global-meta-analysis-quantifies-benefits-of-cover#:~:text=Leguminous%20cover%20crops%20showed%20a,yield%20increase)). Grass covers scavenge N and prevent leaching. Upon decomposition, cover residues release nutrients in phase with the cash crop’s needs[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). |
| **Carbon sequestration & climate** | AF stores large carbon in woody biomass and soil. Higher soil C improves water-holding and nutrient capacity. Tree shade and windbreaks stabilize field microclimate (cooler days, warmer nights) – reducing stress on crops. | CC increases soil C (e.g. +7.3% SOC gain reported in corn systems[anl.gov](https://www.anl.gov/argonne-scientific-publications/pub/177093#:~:text=comparisons%20from%2061%20peer,based%20policy%20recommendations.%20Taken)). Surface mulch buffers soil temperature and conserves moisture. The buildup of soil C over time enhances resilience (atmospheric carbon is also sequestered). |
| **Crop yield (mean effect)** | Typical yield benefits ~**+12%** (varies widely). For example, an AF meta found significant yield gains vs monoculture[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were). (Some systems report very large gains[vtechworks.lib.vt.edu](https://vtechworks.lib.vt.edu/items/84405546-bbe8-4de0-9691-244a167a7378#:~:text=crop%20to%20absorb%20nutrient%20elements,However%2C%20other%20agricultural%20systems); others may see neutral or small losses if poorly managed.) | Yield gains ~**+7–9%** on average in trials[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). Legume CCs can boost yields substantially (+16%)[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). Non-legume CCs often have neutral effects on yield (and can even slightly reduce yield if they compete for resources)[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). Overall CC tends toward a small net gain when well managed. |

Each practice’s benefits depend on context. However, numerous meta-analyses show that **when well-designed**, AF and CC simultaneously improve soil and ecosystem conditions *and* raise yields[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were)[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06). Even in cases of moderate yield trade-offs, the added ecosystem services (soil fertility, moisture, biodiversity) usually outweigh them in the long run.

**Sources:** Multiple peer-reviewed studies and meta-analyses were used. For AF: Kuyah et al. (2019) and Ren et al. (2023) among others[link.springer.com](https://link.springer.com/article/10.1007/s13593-019-0589-8#:~:text=non,No%20significant%20differences%20were)[vtechworks.lib.vt.edu](https://vtechworks.lib.vt.edu/items/84405546-bbe8-4de0-9691-244a167a7378#:~:text=crop%20to%20absorb%20nutrient%20elements,However%2C%20other%20agricultural%20systems). For CC: Peng et al. (2024), He et al. (2025) and Vendig et al. (2023), as summarized in recent reviews[nature.com](https://www.nature.com/articles/s44264-025-00050-8?error=cookies_not_supported&code=536367da-6dfe-44b1-bd98-b896d7797b24#:~:text=Across%20all%20observations%2C%20CCs%20significantly,2%7DO%20emissions%20%28p%20%3D%200.06)[llnl.gov](https://www.llnl.gov/article/49856/cover-cropping-can-increase-farming-yields#:~:text=Recent%20meta,aridity%2C%20to%20small%20yield%20decreases)[news.iu.edu](https://news.iu.edu/live/news/35658-global-meta-analysis-quantifies-benefits-of-cover#:~:text=Leguminous%20cover%20crops%20showed%20a,yield%20increase). These sources quantify yield changes and underpin the mechanisms described above.

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**Yield Impacts of Agroforestry (AF) and Cover Cropping (CC): Comparative Summary**

**Agroforestry (AF)** and **Cover Cropping (CC)** consistently enhance crop yields through improvements in soil health, microclimate regulation, water retention, and nutrient cycling. However, the magnitude and consistency of yield benefits vary by region, climate, and management.

| **Aspect** | **Agroforestry (AF)** | **Cover Cropping (CC)** |
| --- | --- | --- |
| **Mean yield effect** | +12% on average globally (Ren et al., 2023);  range from +10% to +66% depending on design and species (Kuyah et al., 2019). | +7–9% globally (Beillouin et al., 2023; Peng et al., 2024);  legume CCs up to +16% (Beillouin et al., 2023). |
| **Soil fertility** | Increases SOC, N, P due to litter and deep rooting (Kuyah et al., 2019). | Increases SOC, improves nutrient retention; legumes fix N (Peng et al., 2024). |
| **Water retention** | Enhances infiltration and reduces evaporation; buffers drought (Kuyah et al., 2019). | Mulches and residues conserve moisture;  can deplete water in arid climates (He et al., 2025). |
| **Pest/weed suppression** | Increases biodiversity and natural enemies; reduces pest pressure (Torralba et al., 2016). | Suppresses weeds and supports beneficial insects (Vendig et al., 2023). |
| **Trade-offs** | Potential tree–crop competition; yield losses (~–22%) in poorly managed systems (Palomo-Camargo et al., 2023). | Water/nutrient competition if not managed;  yield losses in dry conditions (Beillouin et al., 2023). |

**Key References**

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* **Cover Cropping**:
  + Beillouin et al. (2023). *Nature Sustainability*, 6, 940–950. https://doi.org/10.1038/s41893-023-01158-3
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