



Uncovering the potential of cover cropping for regenerative horticulture

Matthew Smee^a, Nicholas T. Girkin^{a,b}, Robert Simmons^a, Natalia Falagán^{a,*}

^a Faculty of Engineering and Applied Sciences, Cranfield University, Bedford, UK

^b Agricultural and Environmental Sciences, School of Biosciences, University of Nottingham, UK

ARTICLE INFO

Keywords:

Climate change
Greenhouse gas emissions
Soil health
Nutrient cycling
Soil erosion

ABSTRACT

Cover cropping is increasingly promoted as a tool for enhancing sustainability and resilience in horticultural systems. This review synthesises the outcomes of 79 studies on cover cropping in temperate European horticulture, focusing on agronomic and ecological impacts. The evidence demonstrates that cover crops can improve yield and quality, enhance soil health indicators, increase nutrient density in follow on cash crops, suppress weeds, reduce synthetic chemical inputs, and improve nitrogen (N) availability. Tomato, cabbage, pepper, courgette, lettuce, baby leaf, and onion were the most frequently studied crops, with positive outcomes most consistently reported in yield, soil health, and nutrient density. However, outcomes were highly context-dependent, with negative effects, such as reduced yield, lower quality, increased weed pressure, or decreased N availability, occurring regularly. Conflicting results were influenced by species, composition, sowing dates, termination methods, crop type, and local agroecological conditions. For instance, legume cover crops increased N availability for some crops but led to N immobilisation or competition in others. Termination strategies also affected subsequent crop performance and soil health indicators. Farmer adoption remains limited, driven by perceived risks, management complexity, and knowledge gaps. Few studies examined ecological outcomes, multi-cropping strategies, or nutritional benefits, highlighting priorities for future research. This review demonstrates that cover cropping can be an important component of wider regenerative practices in horticulture, but success requires careful, site-specific management, iterative testing, and monitoring. Strategic integration of cover crops, informed by species selection, sowing and termination timing, and crop priorities, is essential to maximise benefits while minimising trade-offs.

1. Introduction

In Europe, the frequency and intensity of droughts and heatwaves are projected to increase, with associated impacts on land degradation and food insecurity (Reidsma et al., 2010; Medina et al., 2017; Hermans and McLeman, 2021). Climate change is also expected to exacerbate soil erosion through more frequent and intense storm events (Baxter et al., 2013; IPCC, 2022; Routschek et al., 2014).

Agriculture contributes nearly one-quarter of global anthropogenic greenhouse gas (GHG) emissions, driven by fertiliser use, agrochemical application, monoculture cropping, and intensive tillage. These practices reduce ecosystem services, undermine ecological functions essential for production, and limit the regenerative capacity of soils (Houser and Stuart, 2020; McLennon et al., 2021; Schwarz et al., 2022). Collectively, these practices result in production systems that are unsustainable and exhibit low climate resilience i.e. have limited capacity to absorb or recover from disturbances under climate change (Anderson

and Rivera-Ferre, 2021; Merino, 2020; Valenzuela, 2016).

Regenerative agriculture is increasingly defined as a principles based approach aimed at restoring soil health, enhancing biodiversity, improving ecosystem services, and increasing agroecosystem resilience while maintaining productivity. Core principles commonly associated with regenerative agriculture include minimising soil disturbance, maintaining living roots, increasing diversity, protecting soil cover, and adapting practices to site specific ecological conditions (Newton et al., 2020). Within this framework, cover crops contribute to regenerative outcomes by supporting multiple principles simultaneously, although such outcomes depend strongly on context and management.

Previous studies have proved how these regenerative agricultural practices, including minimal tillage, cover cropping, mob grazing, and diverse crop rotations, improve soil health, enhance biodiversity, maintain yields, reduce GHG emissions, and increase system resilience, although precise benefits are context specific (Sherwood and Uphoff, 2000; Rhodes, 2017). Support for regenerative agriculture is growing

* Corresponding author.

E-mail address: natalia.falagan@cranfield.ac.uk (N. Falagán).

<https://doi.org/10.1016/j.eja.2026.128243>

Received 26 January 2026; Received in revised form 15 June 2026; Accepted 21 June 2026

Available online 27 June 2026

1161-0301/© 2026 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

among researchers, policy makers, and practitioners as a strategy to mitigate land degradation, reduce climate impacts, and strengthen food security (Ingram, 2008; Montgomery, 2017; Defra, 2021). The principles most associated with regenerative agriculture include protecting the soil surface from erosive rainfall, maintaining living roots, minimising soil disturbance, increasing agricultural diversity, integrating livestock, and recognising site-specific context (Cherry, 2020; Ritz, 2021; Khangura et al., 2023; Cusworth and Garnett, 2023).

Cover crops are widely considered central to regenerative agriculture (LaCanne and Lundgren, 2018; Giller et al., 2021; Cusworth and Garnett, 2023; Khangura et al., 2023). Their use in horticultural systems addresses three core principles: protecting the soil surface from erosive rainfall, maintaining living roots, and minimising soil disturbance, often achieved in association with reduced tillage (Wortman et al., 2012; Chapagain et al., 2020; Nordblom et al., 2023). Cover crops, also referred to as living mulches, green manures, catch crops, or agroecological service crops, are grown outside the main cash crop cycle and can be annual or biennial, either as single species or mixtures (Abdalla et al., 2019). They can provide multiple agronomic and environmental benefits, including improvement of soil structure, enhanced nutrient cycling, suppression of weeds and pests, and increased system biodiversity (Wortman et al., 2012; Chapagain et al., 2020; Nordblom et al., 2023). In addition, cover crops can reduce nitrate leaching, improve water infiltration, and contribute to soil carbon (C) sequestration, supporting both productivity and environmental sustainability.

Cover crops can also remediate compacted soils by creating biopores through a bio-drilling effect, which has been shown to increase yields of subsequent cash crops (Seymour et al., 2012). Plant roots contribute to soil structure directly by penetrating and displacing soil and depositing adhesive compounds, and indirectly by providing energy and nutrient sources that support soil biota. These processes enhance soil aggregation and macro porosity. Additionally, the canopies, stems, and root systems of cover crops reduce soil erosion. Consequently, cover crops are a key component of regenerative horticultural systems. Termination methods include grazing, incorporation via tillage, roller-crimping, flail mowing, or herbicide application (Bergtold et al., 2017), while living mulches are maintained as a continuous ground cover alongside the cash crop (Nakamoto and Tsukamoto, 2006; Westbrook et al., 2021). Cover crops are typically classified as grasses, brassicas, legumes, or small cereals (Singer et al., 2007; Abdalla et al., 2019). The use of diverse cover crop mixtures is debated: while monocultures may not deliver multiple benefits, some studies suggest mixtures may not consistently achieve specific functional outcomes (MacLaren et al., 2019; Chapagain et al., 2020; Saleem et al., 2020; Florence & McGuire, 2020). More broadly, cover crops can be associated with yield trade-offs, for example in a study on organic kale following different cover crops, yield (leaf biomass) varied widely: when preceded by perennial ryegrass the kale yield reached $\sim 42.8 \text{ t ha}^{-1}$, but when preceded by a winter-pea cover crop, it dropped to $\sim 16.2 \text{ t ha}^{-1}$ (Thavarajah et al., 2019). Employing cover crops can also increase costs and labour for seed, planting and termination (Thavarajah et al., 2019; MacLaren et al., 2019).

Horticultural systems face additional challenges from climate change, necessitating adoption of strategies that mitigate ecological pressures. Practices such as excessive N fertiliser application, pesticide misuse, intensive irrigation, and poor waste management contribute to environmental degradation and threaten food security through denitrification, soil erosion, ground and surface water contamination, biodiversity loss, elevated GHG emissions, emergence of new plant virus strains, and increased nitrate concentrations in crops (Bourn and Prescott, 2002; Castro et al., 2019; Aznar-Sánchez et al., 2020; Sakrabani et al., 2023). These impacts are particularly pronounced in light-textured soils, which are more prone to compaction, leaching, and erosion, especially under intensive tillage, destoning, and repeated mechanical disturbance (Rickson, 2015). Light-textured soils are well suited for horticultural crops; however, intensive tillage operations reduce aggregate stability, promote surface sealing and crust formation,

and can substantially decrease seed emergence, infiltration, and increase runoff and erosion risk. Growing cover crops in rotation as part of a regenerative approach may reduce erosion risk.

This paper addresses the research question: Do cover crops in horticultural systems support regenerative outcomes, and should their adoption be promoted to improve soil health, restore ecosystem services, enhance biodiversity, and support food security? The study aims to achieve regenerative outcomes by evaluating the effects of cover cropping in horticulture and identifying the agronomic and ecological factors involved. Current research on regenerative agriculture has largely focused on arable and livestock systems, with horticultural production primarily examined through agroecology and permaculture frameworks (Hathaway, 2016; Newton et al., 2020; Muhie, 2022). There is a clear need to include horticultural systems in regenerative agriculture research, as all production sectors face challenges from climate change, ecosystem degradation, and food security pressures (Webb et al., 2017; Medina et al., 2017; Schwarz et al., 2022). This study contributes by providing evidence-based recommendations on the suitability of cover cropping for horticultural systems in the context of relevant crops for European agriculture specifically, but with findings that are widely applicable to global agricultural systems. Ultimately, this study seeks to assess whether regenerative agriculture can deliver the comprehensive benefits often claimed by its proponents. Specifically, the objectives of this study are: i) to evaluate the agronomic and ecological outcomes associated with cover cropping in European horticultural systems; ii) to identify the agroecological and management factors driving positive outcomes, trade-offs and conflicting results; and iii) to assess under what conditions cover cropping may contribute to regenerative horticultural goals and identify priorities for future research.

2. Methodology

2.1. Study design

A Rapid Evidence Assessment was conducted to examine the use of cover cropping in horticultural systems. The assessment followed systematic review principles in a streamlined format and was guided by the standards of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (Fig. 1; Sarkis-Onofre et al., 2021). The review was completed in August 2023.

2.2. Search strategy

A structured search was carried out using the Scopus database to identify relevant peer-reviewed literature. Search terms for peer-review articles combined key concepts for cover cropping and horticultural production: “cover crops”, “cover cropping”, “cover crop”, “living mulches”, “living mulch”, “vegetables”, “horticulture”, “vegetable production”. Keywords were linked using Boolean operators ‘OR’ and ‘AND’, and were searched within article titles, abstracts, keywords, and/or topics. These words were selected as they are the usual terms used in the scientific community. No date restrictions were applied. An initial search revealed that no publications using the combined search terms appeared before 1997, thus the review spanned approximately 25 years of research. Detailed records were maintained throughout the review process to document search results, exclusions, and methodological decisions, ensuring transparency and reproducibility.

2.3. Eligibility criteria and scope

The geographical scope of the review was restricted to Europe. This limitation ensured that all studies were conducted in temperate climates, allowing for fair comparison of impacts and effects and the generation of regionally relevant agronomic recommendations for horticultural practitioners in a pan-European context (Fig. 1).

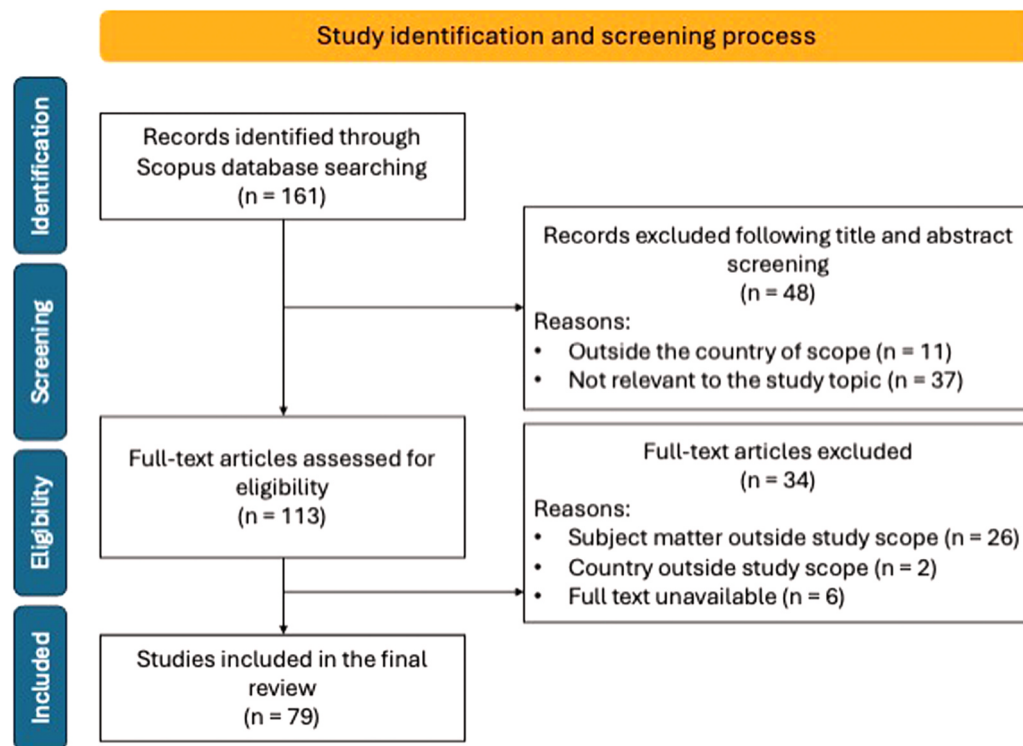


Fig. 1. Approach taken to perform systematic review in to cover cropping in horticulture systems, directed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (adapted from Schreefl et al. 2020).

Studies were included if they:

- Reported empirical data on cover cropping or living mulches within horticultural or vegetable production systems, and
- Were based within European countries.

Studies were excluded if they:

- Focused on non-European regions,
- Were grey literature, editorials, or conference papers,
- Were not directly related to cover cropping in horticultural systems, or
- Were unavailable in full text.

While restricting the review to European studies reduced broad climatic heterogeneity compared with a global synthesis, we recognise considerable variation exists among Mediterranean, Atlantic, and continental systems. Because many primary studies did not report climatic descriptors consistently, formal stratification by climatic zone was beyond the scope of this review. Nevertheless, climate is recognised as an important driver of context dependent outcomes and is considered in interpretation of findings.

2.4. Screening and selection process

The initial Scopus search identified 161 articles. After screening titles and abstracts, 48 articles were excluded because they were either unrelated to the subject matter or conducted outside the defined European scope. A total of 113 articles were then assessed at the full-text screening stage. Of these, a further 34 articles were excluded: 26 for being unrelated to the review topic, two for being based outside Europe, and six because full texts were non-retrievable. Following this process, 79 peer-reviewed articles met all inclusion criteria and were retained for detailed analysis (Fig. 1).

All references and screening records were managed in a structured

database. Detailed notes were kept at each review stage to document inclusion and exclusion decisions, allowing reassessment of excluded studies if necessary and ensuring transparency in data handling.

3. Results

The reviewed studies revealed a range of both positive and negative agronomic and ecological outcomes (Table 1). Among the cash crops examined, tomato, cabbage, pepper, courgette, lettuce and baby leaf, onion, carrot, and cauliflower were the most frequently studied. Positive outcomes were most reported and included increased yield and quality, reduced weed pressure, enhanced soil health indicators, decreased reliance on synthetic inputs (e.g. mineral fertilisers, pesticides, herbicides), improved N availability, higher nutrient density, reduced pest and disease incidence, and greater soil C-sequestration. In contrast, the most frequently cited negative outcomes were reductions in yield and quality, increased weed pressure, and decreased N availability. The prevalence of tomato-focused studies may reflect the geographic distribution of the research: 34 studies were conducted in Italy, globally one of the largest tomato producing countries. This highlights a potential bias in the literature towards crops of regional economic importance, which may influence the generalisability of the results.

3.1. Agronomical and ecological outcomes

3.1.1. Yield and quality

The most frequently reported beneficial outcome of cover cropping in horticultural systems was increased yield and quality, with 49 studies reporting this effect across more than 80% of the crops reviewed. For example, Lenzi et al. (2015) reported that courgette yields increased from 7.9 t ha⁻¹ to 9.2 t ha⁻¹, and lettuce yields increased from 19.9 t ha⁻¹ to 23.7 t ha⁻¹ following cover crop introduction. Similarly, Radicetti et al. (2013) observed a significant increase in pepper yield from 15.3 t ha⁻¹ on bare soil to 45.6 t ha⁻¹ when grown following a pure strand of common vetch (*Vicia sativa*, variety not specified).

Table 1

Matrix of crop type and associated effect of cover cropping in horticultural production. No studies were identified that reported reduced carbon sequestration, increased synthetic inputs, increased levels of pests and disease, decreased levels of beneficial insects, decreased soil health indicators, or declines in water management, and have therefore been omitted).

	Increased yield and quality	Reduced yield and quality	Increased weed burden	Reduced weed burden	Increase nitrogen availability	Reduced nitrogen availability	Increased carbon sequestration	Reduced inputs (synthetic)	Increased nutrient density	Reduced levels of pests & disease	Increased levels of beneficial insects	Improved soil health indicators	Improved water management	TOTALS
Tomato	8	2	2	1	3	1	2	5	2	1	1	4	1	37
Cabbage (savoy, white, red)	6	7		3	3	2		2	4	1		3		34
Pepper (sweet)	5	3		5	2	1	2	4		1		4		30
Courgette	6	4	1	2		1	1	2		1	1	5		29
Lettuce & baby leaf	3	2	3		1		2	3	1	1	1	5		26
Cauliflower	2	3	1	3	1	2	1	4		2	1	3	1	26
Carrot	3	2		1	1			2	1	1		2		13
Aubergine	2	1		1	1			1				2		9
Onion & Shallot	3	1			1			1	1			2		9
Artichoke	1			1			1	2				2		7
Melon		1		1				1		2				5
Olive	1				1				1			1	1	5
Fennel	1	1		1				1						4
Leek	1			1	1									4
Beetroot	1	1		1	1									4
Endive & root chicory	1							1				1		4
French beans	1						1					1		3
Kohlrabi		1									1	1		3
Kale & collards	1		1	1										3
Potatoes	1			1										2
Celery	1											1		2
Celeriac		1												2
Hamburg parsley (root)	1													1
Broccoli				1										1
Turnip		1												1
TOTAL	49	31	8	24	16	7	10	29	10	10	5	37	3	

Yield and quality responses were influenced by both biotic and abiotic factors. Biotic factors included weed pressure (Radice et al., 2013) and insect pressures (Ciaccia et al., 2019), while abiotic factors included temperature extremes (Kumar, 2020) and drought conditions (Morel and Cartau, 2023). The use of cover crops appears to mitigate some of these stressors, which may drive farmer adoption of regenerative agriculture practices.

Conversely, reductions in yield and quality were reported in 31 instances across 60% of crops. Cabbage (Kristensen and Thorup-Kristensen, 2007; Übelhör et al., 2014; Pinto et al., 2016; Antichi et al., 2019; Hefner et al., 2020b, 2022), courgette (Magagnoli et al., 2018; Ciaccia et al., 2019; Di Bene et al., 2022), cauliflower (Canali et al., 2015, 2016; Di Bene et al., 2022), and peppers (Adamczewska-Sowińska et al., 2022; Campiglia et al., 2014; Persiani et al., 2021) were the most frequently cited crops experiencing yield reductions, in some cases up to 100%. In addition to yield responses, several studies reported effects of cover cropping on crop quality characteristics, although these outcomes were less consistently measured than productivity metrics. Reported quality improvements included increased nutrient density, enhanced mineral composition, improved marketable quality and reductions in physiological or pest related damage. For example, some studies observed improved nutrient concentrations in leafy vegetables and enhanced fruit quality in tomato systems associated with improved nutrient cycling and soil function. However, quality responses were highly variable and depended strongly on crop type, cover crop species, management practices and environmental conditions. In several cases, quality improvements occurred alongside stable or reduced yields, highlighting the importance of evaluating cover cropping beyond productivity alone.

Crucially, many studies did not provide detailed information on the cover crop species, whether they were grown in monoculture or mixtures, or whether they were used as rotational crops versus companion crops. Termination strategies were also not consistently reported. This limits the ability to draw specific recommendations regarding which cover crop strategies are most likely to increase yield or quality for horticultural crops. There is therefore a clear need for more detailed reporting and comparative studies, potentially summarised in a matrix format (cover crop species/type × horticultural crop × outcome), to guide practical cover cropping strategies (Table 1).

3.1.2. Soil health indicators

Improvement of soil health indicators was the second most frequently reported beneficial outcome, with 37 studies reporting this across 60% of the horticultural crops examined. Reported benefits included increased soil microbial activity (Patkowska and Konopinski, 2013), improved soil structure (Adamczewska-Sowińska et al., 2022), enhanced water retention (Diacono et al., 2021), increased fertility (Ciaccia et al., 2019), reduced populations of soilborne pests (Djian-Caporalino et al., 2019), improved soil pH (Domagała-Świątkiewicz and Siwek, 2022), reduced soil erosion (Stein et al., 2022; Salata et al., 2022), increased soil organic matter (Deligios et al., 2017; Domagała-Świątkiewicz et al., 2019), and higher levels of beneficial fungi and root interactions with mycorrhizal networks (Trinchera et al., 2016; Patkowska et al., 2018).

For example, soil bulk density was reported to be 2.5% lower in aubergine crops grown with a cover crop (white clover and perennial ryegrass) compared to those without cover crops (Adamczewska-Sowińska et al., 2022). Similarly, Steenwerth and Belina (2008) observed a 1.4-fold increase in soil organic matter under a rye cover crop system, though it was unclear whether this was grown as a living mulch or prior to the horticultural crop. These gaps in reporting highlight the need for more detailed contextual information.

3.1.3. Reduced chemical inputs

Cover cropping was reported to reduce the need for chemical inputs, including mineral fertilisers, herbicides, and pesticides, in 29 studies

covering 48% of crops examined. Examples include reduced N fertiliser requirements (Campiglia et al., 2012, 2014; Galieni et al., 2017), lower herbicide application (Tittarelli et al., 2018), and decreased pesticide interventions (Magagnoli et al., 2018; Depalo et al., 2020). Reduced chemical inputs are a common objective in regenerative systems, suggesting that cover cropping can support more sustainable horticultural practices. However, details of the cover crop species, monoculture versus mix, and management strategy were often missing, limiting practical guidance for growers.

3.1.4. Weed burden

Cover crops were associated with reduced weed pressure in 24 studies across 60% of crops evaluated. Some of these studies also reported reduced chemical inputs (Tittarelli et al., 2018), while others involved organic systems where chemical inputs were not applied (Lenzi et al., 2015; Antichi et al., 2019; Sportelli et al., 2022). Weed control is a key agronomic consideration, as practices to reduce weeds can sometimes negatively impact ecological factors (e.g. soil disturbance, biodiversity; Cai and Gu, 2016; Singh et al., 2017; Mia et al., 2020).

In contrast, increased weed burden was reported in eight studies across 20% of crops, with lettuce showing the highest number of cases (Mennan et al., 2006; Diacono et al., 2019; Antichi et al., 2019). Increased weed pressure often correlated with reduced yields (Ciaccia et al., 2016) and can influence farmer decisions regarding cover crop adoption (Jiri et al., 2015; Table 1).

3.1.5. Nitrogen availability

Increased N availability (NO_3^- and NH_4^+) was reported in 16 studies covering 44% of crops, notably in tomatoes (Campiglia et al., 2010; Galieni et al., 2017; Diacono et al., 2021), peppers (Campiglia et al., 2014; Persiani et al., 2021), and cabbages (Kristensen 2006; Hefner et al., 2020b; Stein et al., 2022). Higher N availability was linked to increased yield and quality and allowed reductions in synthetic N inputs (Campiglia et al., 2014; Persiani et al., 2021; Galieni et al., 2017).

Reduced N availability was reported in seven instances across 20% of crops, particularly in cabbage, pepper, and courgette (Übelhör et al., 2014; Persiani et al., 2021; Hefner et al., 2022). Causes included N immobilisation from incorporated cover crops and competition with living cover crops (Hiltbrunner et al., 2007; Antichi et al., 2019). These findings underscore the importance of considering cover crop species, growth method, and local soil conditions when managing N (Table 1).

3.1.6. Carbon sequestration

When reported, integration of cover crops was seen to increase C-sequestration in 10 instances and across 28% of crops. This occurred twice as often in tomato (Mancinelli et al., 2019; Domagała-Świątkiewicz and Siwek, 2022), pepper (Mancinelli et al., 2019; Persiani et al., 2021), and lettuce (Domagała-Świątkiewicz and Siwek, 2022; Diacono et al., 2019), compared to courgette (Mancinelli et al., 2019), cauliflower (Diacono et al., 2019), artichoke (Deligios et al., 2021) and French beans (Domagała-Świątkiewicz and Siwek, 2022). Increased C-sequestration is seen as an important outcome in regenerative systems (Elevitch et al., 2018; Newton et al., 2020; Giller et al., 2021; Cusworth and Garnett, 2023) and often highlighted as a benefit of adopting regenerative agriculture, which can reduce the levels of synthetic N required (Almaraz et al., 2021).

3.1.7. Pest and disease

Reduced levels of pests and disease were reported for crops grown with cover crops in 10 instances and across 32% of the horticultural crops covered in the literature review. This includes reduced levels of root-knot nematodes (Collange et al., 2014; Djian-Caporalino et al., 2019), reduced abundance of *Sclerotinia sclerotiorum* (Patkowska et al., 2018), decreased aphid populations (Magagnoli et al., 2018) and the reduced viability of *Verticillium longisporum microscerotia* (França et al., 2013). These pest and disease reductions were seen to improve yield and

quality (Patkowska et al., 2018; Patkowska, 2021), improve soil health indicators (Patkowska et al., 2018; Ciaccia et al., 2019) and reduce the need for synthetic inputs (Magagnoli et al., 2018; Depalo et al., 2020). The importance of reduced pest and disease levels are considered a critical agronomic and ecological factor across horticultural production and are seen as a major driving factor in farmer adoption (Euriga et al., 2021).

3.2. Agroecological factors driving conflicting outcomes

The literature demonstrates multiple instances where the outcomes of cover cropping vary widely depending on agroecological context. Factors such as geographic location, climatic conditions, soil type, cover crop species, and horticultural crop type all interact to influence yield, nutrient availability, weed pressure, and pest suppression. For example, Depalo et al. (2020) highlighted that cauliflower crops under the same cover crop management showed contrasting outcomes between Denmark and Italy: aphid numbers were reduced in Denmark but increased in Italy. Similarly, (Xie and Kristensen, 2016) reported that N uptake in cauliflower decreased in Denmark under cover cropping but increased in Italy under the same cover crop system. These discrepancies underscore the importance of local environmental conditions in determining the efficacy of cover cropping strategies.

Crop-specific responses are also notable. Adamczewska-Sowińska & Kolota, (2008) demonstrated that white clover used as a living mulch reduced pepper yield, while tomato yields remained largely unaffected. Di Bene et al. (2022) observed that lettuce yields increased by 10% under a system with cover crops, whereas courgette yields decreased by 55% under the same management. These examples illustrate that not only crop species but also cover crop selection and management strategies are critical determinants of outcomes.

Furthermore, conflicting outcomes are influenced by cover crop species traits, including N mineralisation rates, biomass production, rooting density and depth, and competitiveness with cash crops. For instance, hairy vetch and white clover rapidly mineralise N, providing benefits to subsequent crops (Isik et al., 2009), while crimson clover and sweet clover have slower mineralisation rates, which can delay N availability. Mixed cover crop systems, such as vetch-barley mixtures, can balance nutrient release and reduce N leaching (Farneselli et al., 2018). Hefner et al. (2022b) found that adding vetch to a pure clover stand enhanced N management in cabbage, leek, and lettuce systems (Table 2).

Overall, these examples highlight the need for context-specific management. Timing, species selection, and crop rotation practices interact with local agroecological conditions to produce variable outcomes, and blanket recommendations for cover cropping are likely to be ineffective. A structured reporting framework, such as a matrix of cover crop $\times$ horticultural crop $\times$ outcome, would aid practitioners in making informed decisions.

3.3. Termination strategies

Termination approaches significantly affect the performance of subsequent horticultural crops and the sustainability of the system. The

two most reported termination strategies are ploughing/incorporation and roller crimping. Thorup-Kristensen (2006) demonstrated that ploughing legume and grass cover crops enhanced N availability, rooting depth, and yield in follow-on cabbage, carrot, onion, and lettuce crops. Ploughing appeared particularly beneficial for legume cover crops due to improved N release and reduced competition with the subsequent crop.

In contrast, roller crimping generally provided lower immediate yield benefits. Franczuk et al. (2009), (2010) and Manici et al. (2018) showed that ploughing increased mean yields in cabbage and other crops compared to roller crimping, though roller crimping has potential long-term benefits for soil organic matter and C-sequestration. Diacono et al. (2019) reported improved yield and soil health in lettuce and courgette under ploughed cover crops compared with roller-crimped systems, though it was unclear whether cash crops were transplanted into the crimped residue or if additional soil preparation occurred. Hefner et al. (2020a) found that cabbage yields were reduced under roller crimping across multiple countries but noted that the practice could enhance soil organic matter over time.

These findings suggest that termination strategy must be carefully aligned with cover crop species, cash crop requirements, and production goals. Legume species benefit from ploughing to maximise N release, whereas grass-dominated cover crops may tolerate roller crimping with fewer negative yield consequences. Timing of termination, in combination with sowing dates, further interacts to influence weed suppression, soil moisture retention, and nutrient cycling.

3.4. Farmers and growers adoption

Farmer adoption of cover cropping in horticultural systems remains relatively limited, despite demonstrated benefits. Only three of the 79 reviewed studies explicitly addressed adoption, but they reveal key insights into drivers and barriers. Morel and Cartau (2023) found that climate change concerns motivate farmers to adopt cover crops as part of adaptive strategies to enhance system resilience and productivity. Farmers perceive cover crops to mitigate negative impacts such as yield instability, pest outbreaks, and extreme weather events, although adoption increases farm management complexity and requires additional staff training.

Perceived efficacy is crucial for adoption. De Notaris et al. (2022) reported that Danish farmers were more likely to adopt cover cropping when clear positive outcomes were observed, rather than simply as a mitigation for negative impacts. However, lack of knowledge regarding potential trade-offs or management nuances often limited wider uptake. Canali et al. (2015) found that 75% of respondents accepted cover crop practices, but ongoing adoption was contingent on maintaining yield and quality, highlighting that perceived risk remains a barrier. Conversely, 25% of respondents considered cover cropping ineffective or too risky.

These findings emphasise the importance of extension services, knowledge exchange, and context-specific guidance. Adoption is influenced not only by ecological and agronomic outcomes but also by socioeconomic factors, training, and perceived risk. Strategies to increase adoption should therefore integrate technical advice with clear

Table 2

Outcomes associated with hairy vetch as a cover crop related to different cash crop types (vetch included as a monoculture; Isik et al. 2009; Borowy, 2012; Campiglia et al. 2012; Domagała-Świątkiewicz et al. 2019; Mancinelli et al. 2019; Patkowska and Konopinski, 2013).

Cash crop	Increased available N	Increased nitrogen leeching	Reduced nitrogen leeching	Reduced weed burden	Increased yield and/or quality	Reduced yield and/or quality
Cabbage	4	1	1	3	6	1
Lettuce	2	1	1	1	2	1
Pepper	1			2	2	
Tomato		1		1	1	1
Leek	1	1	1		1	
Turnip						1

demonstrations of cover crop benefits under local conditions, including species selection, termination strategy, and crop rotation compatibility.

4. Discussion

These outcomes are interpreted through a regenerative agriculture lens, recognising that cover cropping may support regenerative goals but is not inherently regenerative in all contexts.

Our review demonstrates that cover cropping in horticultural systems can provide a range of benefits, including improved yield and quality, higher nutritional density in follow on cash crops, reduced weed burden, enhanced soil health indicators, reduced synthetic chemical inputs, and increased N availability (Campiglia et al., 2010; Galieni et al., 2017; Djian-Caporalino et al., 2019). However, the results also show that cover cropping is not inherently a solution; its efficacy depends on careful management of species selection, timing, sowing dates, and termination techniques (Campiglia et al., 2014; Morel and Cartau, 2023). While negative outcomes were less frequently reported than beneficial ones, they occurred regularly, emphasising the nuanced and context-dependent nature of cover cropping in horticultural systems. Rather than viewing cover cropping as inherently regenerative, our synthesis suggests regenerative outcomes emerge when species selection, termination strategy, climatic conditions and cash crop compatibility are aligned. This conditional framework represents a key contribution of this review.

Importantly, the ‘potential’ referred to in this review does not imply that cover cropping delivers universal or previously unrecognised benefits but rather highlights its conditional capacity to support regenerative outcomes when species selection, management practices and agroecological context are appropriately aligned. A key finding emerging from this synthesis is that cover cropping should not be viewed as inherently regenerative, but as a practice whose outcomes depend on how and where it is implemented. This review therefore shifts emphasis from asking whether cover crops are beneficial in general, toward identifying the conditions under which they can optimise soil health, nutrient cycling, resilience and reduced input dependency while minimising trade-offs. In this sense, the potential uncovered lies in recognising cover cropping as a context-dependent management strategy rather than a universally positive intervention. This work also highlights opportunities for improving outcomes through species selection, sowing and termination strategies, multi-species mixtures and integration with wider regenerative practices. Framing cover crops through this conditional and systems-based lens represents a central contribution of this review and provides a basis for more targeted implementation and future research.

Evidence from arable systems suggests parallels that can inform horticultural practice. Studies have shown that cover cropping supports yields under reduced tillage and contributes to ecological intensification (Wittwer et al., 2017). Cover crops in arable systems have also been associated with reduced synthetic input requirements (Wittwer and van der Heijden, 2020) and improvements in soil health, pest suppression, weed control, and wildlife habitat. These findings corroborate the positive outcomes identified in our review and reinforce the potential of cover cropping to contribute to sustainable and regenerative agricultural practices.

The variability of outcomes, particularly the conflicting results reported for yield, N availability, and weed suppression, underscores the importance of context. Agroecological factors such as soil type, climate, cash crop type, and regional management practices interact with cover crop species traits to determine results. For instance, hairy vetch and white clover were associated with rapid N mineralisation benefiting pepper yields (Isik et al., 2009), while the same species had little or even negative impact on lettuce, cabbage, and turnip crops in other studies (Pinto et al., 2016). Timing of cover crop sowing and termination was also critical: early or late sowing influenced weed suppression and crop competition, while termination method (ploughing versus roller

crimping) affected nutrient availability, yield, and soil health outcomes (Franczuk et al., 2009, 2010; Thorup-Kristensen, 2006; Diacono et al., 2019; Hefner et al., 2020a).

In addition to competition for resources and differences in nutrient mineralisation, allelopathic interactions may also help explain some of the contrasting outcomes associated with cover crops. Certain cover crop species, particularly grasses and brassicas, can release bioactive compounds through root exudates or decomposing residues that influence weed emergence, soil microbial communities, nutrient dynamics and, in some cases, subsequent cash crop performance. These effects may contribute to reported weed suppression benefits but may also partly explain occasional negative outcomes where crop establishment or growth is reduced. Despite this potential importance, allelopathy was rarely examined explicitly in the studies reviewed, with most studies reporting agronomic outcomes without isolating underlying biochemical mechanisms (Schulz and Tabaglio, 2025). Greater research attention to allelopathic interactions, particularly in relation to species mixtures, termination strategies and horticultural crop sensitivity, could improve understanding of when cover crops support regenerative outcomes and when trade-offs may emerge.

Farmer adoption of cover crops is influenced by both perceived benefits and risks. Positive economic outcomes such as yield uplift, improved soil health, and reduced chemical inputs can drive adoption (Quintarelli et al., 2022; De Notaris et al., 2022). However, negative outcomes, complexity of management, and risk perception slow uptake (Canali et al., 2015; Morel and Cartau, 2023). Adoption is further limited by the need for technical knowledge regarding species selection, management, and site-specific conditions. This review highlights that only three studies explicitly addressed adoption in horticulture, showing a significant knowledge gap that requires further research and extension support in the sector.

Beyond the agronomic and ecological performance, economic considerations strongly influence whether cover cropping can contribute to regenerative horticulture in practice. While cover crops may reduce expenditure on fertilisers, herbicides or pest control over time, adoption can involve short-term costs associated with seed purchase, sowing, termination, additional labour and management complexity (Francis and Holmes, 2020). In some systems, these costs may be compounded by risks of temporary yield reductions or delayed returns, which can discourage adoption despite potential long-term benefits.

Whether ecological and economic benefits offset implementation costs is likely to depend on context, including crop value, input costs, labour availability, farm scale and the time horizon over which benefits are evaluated. For example, improvements in soil health, nutrient cycling or resilience may generate economic value over multiple seasons, but these benefits may not be immediately captured in short-term farm decision-making. This mismatch may partly explain adoption barriers reported in the literature.

These findings suggest that evaluating cover cropping solely through agronomic performance may underestimate its broader value, while focusing only on ecological benefits may overlook important economic constraints. Future research should therefore integrate agronomic, ecological and economic assessments, including cost-benefit analyses and consideration of economic thresholds, to determine under what conditions cover cropping provides net benefits for horticultural producers.

Collectively, these findings suggest that successful adoption of cover cropping strategies requires iterative on-farm testing and monitoring. Farmers should evaluate combinations of cover crop species, sowing dates, termination strategies, and cash crop interactions to identify approaches that optimise regenerative outcomes on their own farms (Fig. 2). Without monitoring and adaptation, cover cropping could produce suboptimal or even negative results.

This work also identifies priority areas for future research in temperate horticultural systems:

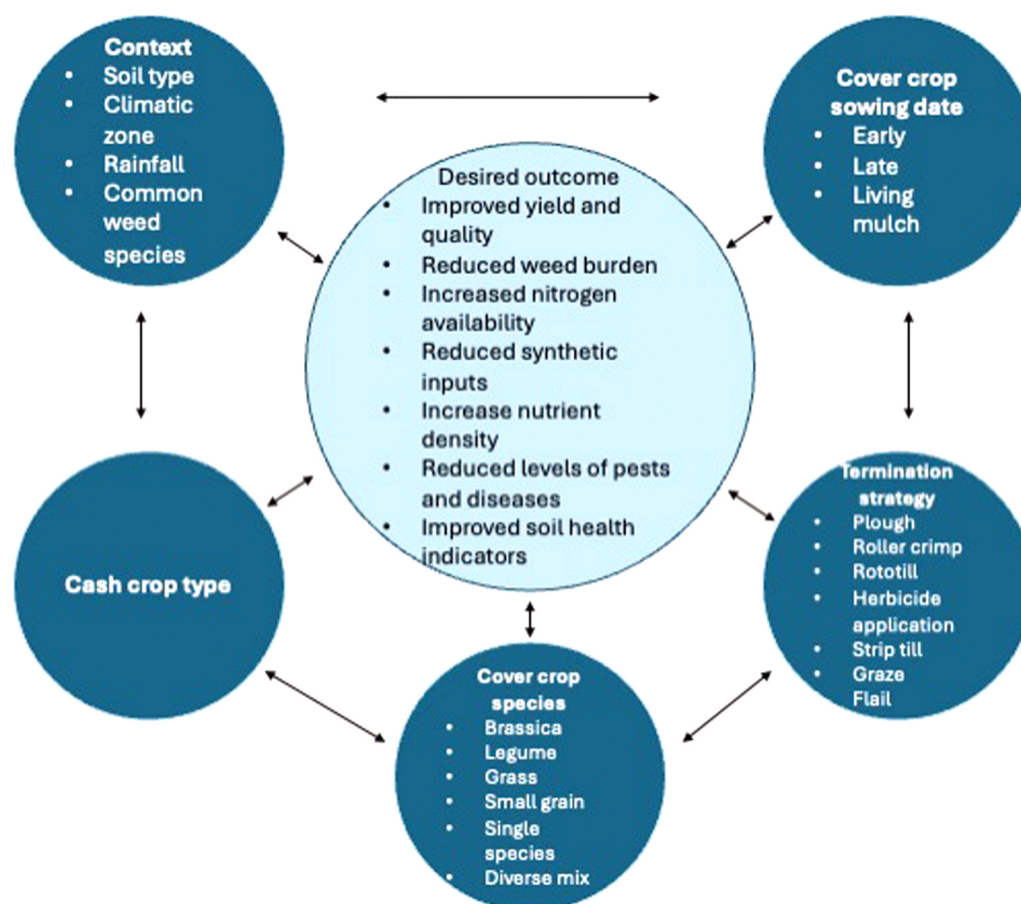


Fig. 2. Factors requiring consideration by practitioners when approaching cover cropping integration in horticultural production systems.

1. Beneficial insects and pollinators: Only two studies explicitly examined these outcomes: [Depalo et al. \(2017\)](#) and [Magagnoli et al. \(2018\)](#). Both yield inconclusive or context-dependent results. Further research is needed to clarify the ecological benefits of cover cropping for pollinator and beneficial insect populations under different management and climatic conditions.
2. Farmer adoption and perception: Only three studies directly addressed adoption and perception of cover cropping in horticultural systems: [Canali et al. \(2015\)](#), [De Notaris et al. \(2022\)](#), and [Morel and Cartau \(2023\)](#). These revealed key social and economic barriers, underscoring the need for more participatory and socio-economic research to complement agronomic studies.
3. Use of cash crops as cover crops: Innovative approaches, such as [Lenzi et al. \(2015\)](#), who tested globe artichoke (*Cynara scolymus* L.) as a multifunctional cash-cover crop, deserve further exploration to integrate productivity and ecosystem service delivery within regenerative systems.
4. Multi-cropping and intercropping strategies: Studies such as [Diacono et al. \(2021\)](#) and [Di Bene et al. \(2022\)](#) illustrate the potential of intercropping and rotational systems with legumes to enhance N use efficiency and system resilience. Expanding such work could help mitigate the yield and quality reductions sometimes observed with cover cropping while improving overall profitability and ecological performance.

5. Conclusion

Cover cropping in European horticultural systems offers substantial potential to enhance sustainability, improve soil health, chemical inputs, and support regenerative practices. This review shows that cover

cropping can provide multiple benefits, including increased yield and quality, higher nutritional density, improved soil structure and fertility, reduced weed pressure, and enhanced N availability. However, outcomes are highly context-specific and influenced by cover crop species, sowing and termination timing, cash crop type, and local agroecological conditions. Negative outcomes, such as reduced yield, quality, or N availability, were observed across several crops, emphasising the need for careful, site-specific management. Farmers are advised to adopt iterative approaches, testing and monitoring cover cropping strategies to optimise both productivity and ecological benefits. Overall, the findings suggest cover cropping can contribute to regenerative horticulture when managed appropriately within site-specific systems. Future research should address gaps in understanding ecological impacts, nutritional outcomes, multi-cropping approaches, and farmer adoption behaviours, ensuring that cover cropping delivers consistent agronomic and environmental benefits while minimising trade-offs.

CRediT authorship contribution statement

Nicholas T. Girkin: Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Investigation, Data curation, Conceptualization. **Matthew Smee:** Writing – original draft, Investigation, Data curation. **Natalia Falagán:** Writing – review & editing, Validation, Supervision, Investigation, Data curation, Conceptualization. **Robert W. Simmons:** Writing – review & editing, Investigation, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

References

- Abdalla, M., Hastings, A., Cheng, K., Yue, Q., Chadwick, D., Espenberg, M., Truu, J., Rees, R.M., Smith, P., 2019. A critical review of the impacts of cover crops on nitrogen leaching, net greenhouse gas balance and crop productivity. *Glob. Change Biol.* 25 (8), 2530–2543. <https://doi.org/10.1111/GCB.14644>.
- Adamczewska-Sowińska, K., Kolota, E., 2008. The Effect of Living Mulches on Yield and Quality of Tomato Fruits. *J. Fruit Ornament. Plant Res.* 69 (1), 31–38. <https://doi.org/10.2478/v10032-008-0018-z>. Sciendo.
- Adamczewska-Sowińska, K., Wojciechowski, W., Krygier, M., Sowiński, J., 2022. Effect of soil regenerative practice on selected soil physical properties and eggplant (*Solanum melongena* L.) yield. *Agronomy* 12 (7), 1686. <https://doi.org/10.3390/AGRONOMY12071686>.
- Almaraz, M., Wong, M.Y., Geoghegan, E.K., Houlton, B.Z., 2021. A review of carbon farming impacts on nitrogen cycling, retention, and loss. *Ann. New. Y. Acad. Sci.* 1505 (1), 102–117. <https://doi.org/10.1111/NYAS.14690>.
- Anderson, M.D., Rivera-Ferre, M., 2021. Food system narratives to end hunger: extractive versus regenerative. *Curr. Opin. Environ. Sustain.* 49, 18–25. <https://doi.org/10.1016/J.COSUST.2020.12.002>.
- Antichi, D., Sbrana, M., Martelloni, L., Chehade, L.A., Fontanelli, M., Raffaelli, M., Mazzoncini, M., Peruzzi, A., Frascioni, C., 2019. Agronomic performances of organic field vegetables managed with conservation agriculture techniques: A study from central Italy. *Agronomy* 9 (12), 810. <https://doi.org/10.3390/AGRONOMY9120810>.
- Aznar-Sánchez, J.A., Velasco-Muñoz, J.F., García-Arca, D., López-Felices, B., 2020. Identification of opportunities for applying the circular economy to intensive agriculture in Almería (South-East Spain). *Agronomy* 10 (10), 1499. <https://doi.org/10.3390/AGRONOMY10101499>.
- Baxter, R., Rowan, J.S., McKenzie, B.M., Neilson, R., 2013. Understanding soil erosion impacts in temperate agroecosystems: Bridging the gap between geomorphology and soil ecology. *Biogeosciences Discuss.* 10, 7491–7520. <https://doi.org/10.5194/bgd-10-7491-2013>.
- Bergtold, J.S., Ramsey, S., Maddy, L., Williams, J.R., 2017. A review of economic considerations for cover crops as a conservation practice. *Renew. Agric. Food Syst.* 34 (1), 62–76. <https://doi.org/10.1017/S1742170517000278>.
- Borowy, A., 2012. Growth and yield of stake tomato under no-tillage cultivation using hairy vetch as a living mulch. *Acta Sci. Pol.* 11 (2), 229–252.
- Bourn, D., Prescott, J., 2002. A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. *Crit. Rev. Food Sci. Nutr.* 42 (1), 1–34. <https://doi.org/10.1080/10408690290825439>.
- Cai, X., Gu, M., 2016. Bioherbicides in organic horticulture. *Horticulturae* 2 (2), 3. <https://doi.org/10.3390/HORTICULTURAE2020003>.
- Campiglia, E., Mancinelli, R., Di Felice, V., Radicetti, E., 2014. Long-term residual effects of the management of cover crop biomass on soil nitrogen and yield of endive (*Cichorium endivia* L.) and savoy cabbage (*Brassica oleracea* var. *sabauda*). *Soil. Tillage Res.* 139, 1–7. <https://doi.org/10.1016/J.STILL.2014.01.003>.
- Campiglia, E., Mancinelli, R., Radicetti, E., Caporali, F., 2010. Effect of cover crops and mulches on weed control and nitrogen fertilization in tomato (*Lycopersicon esculentum* Mill.). *Crop. Prot.* 29 (4), 354–363. <https://doi.org/10.1016/J.CROPRO.2009.12.001>.
- Campiglia, E., Radicetti, E., Mancinelli, R., 2012. Weed control strategies and yield response in a pepper crop (*Capsicum annuum* L.) mulched with hairy vetch (*Vicia villosa* Roth.) and oat (*Avena sativa* L.) residues. *Crop. Prot.* 33, 65–73. <https://doi.org/10.1016/J.CROPRO.2011.09.016>.
- Campiglia, E., Radicetti, E., Brunetti, P., Mancinelli, R., 2014. Do cover crop species and residue management play a leading role in pepper productivity? *Sci. Hortic.* 166, 97–104. <https://doi.org/10.1016/J.SCIEN.2013.12.018>.
- Canali, S., Campanelli, G., Ciaccia, C., Diacono, M., Leteo, F., Fiore, A., Montemurro, F., 2015. Living mulch strategy for organic cauliflower (*Brassica oleracea* L.) production in central and southern Italy. *Ital. J. Agron.* 10 (2), 90–96. <https://doi.org/10.4081/IJA.2015.644>.
- Castro, A.J., López-Rodríguez, M.D., Giagnocavo, C., Gimenez, M., Céspedes, L., La Calle, A., Gallardo, M., Pumares, P., Cabello, J., Rodríguez, E., Uclés, D., Parra, S., Casas, J., Rodríguez, F., Fernández-Prados, J.S., Alba-Patiño, D., Expósito-Granados, M., Murillo-López, B.E., Vasquez, L.M., Valera, D.L., 2019. Six collective challenges for sustainability of Almería greenhouse horticulture. *Int. J. Environ. Res. Public Health* 16 (21), 4097. <https://doi.org/10.3390/IJERPH16214097>.
- Chapagain, T., Lee, E.A., Raizada, M.N., 2020. The potential of multi-species mixtures to diversify cover crop benefits. *Sustainability* 12 (5), 2058. <https://doi.org/10.3390/SU12052058>.
- Cherry, J., 2020. Principles of regenerative agriculture. Groundswell. (<https://groundswellag.com/principles-of-regenerative-agriculture/>).
- Ciaccia, C., Canali, S., Campanelli, G., Testani, E., Montemurro, F., Leteo, F., Delate, K., 2016. Effect of roller-crimper technology on weed management in organic zucchini production in a Mediterranean climate zone. *Renew. Agric. Food Syst.* 31 (2), 111–121. <https://doi.org/10.1017/S1742170515000046>.
- Ciaccia, C., Ceglie, F.G., Burgio, G., Madžarić, S., Testani, E., Muzzi, E., Mimiola, G., Tittarelli, F., 2019. Impact of agroecological practices on greenhouse vegetable production: Comparison among organic production systems. *Agronomy* 9 (7), 372. <https://doi.org/10.3390/AGRONOMY9070372>.
- Collange, B., Navarrete, M., Montfort, F., Maitelle, T., Tavoillot, J., Martiny, B., Tchamitchian, M., 2014. Alternative cropping systems can have contrasting effects on various soil-borne diseases: Relevance of a systemic analysis in vegetable cropping systems. *Crop. Prot.* 55, 7–15. <https://doi.org/10.1016/J.CROPRO.2013.10.002>.
- Cusworth, G., Garnett, T., 2023. What Is. Regen. Agric. ? TABLE Explain. TABLE Univ. Oxf. Swed. Univ. Agric. Sci. Wageningen. Univ. Res. <https://doi.org/10.56661/2D7B8D1C>.
- De Notaris, C., Abalos, D., Mikkelsen, M.H., Olesen, J.E., 2022. Potential for the adoption of measures to reduce N₂O emissions from crop residues in Denmark. *Sci. Total. Environ.* 835, 155510. <https://doi.org/10.1016/J.SCITOTENV.2022.155510>.
- Defra. (2021). Policy paper: Sustainable Farming Incentive: Defra's plans for piloting and launching the scheme - [online document] Retrieved from (<https://www.gov.uk/government/publications/sustainable-farming-incentive-scheme-pilot-launch-overview/sustainable-farming-incentive-defras-plans-for-piloting-and-launching-the-scheme>).
- Deligios, P.A., Farina, R., Tiloca, M.T., Francaviglia, R., Ledda, L., 2021. C-sequestration and resilience to climate change of globe artichoke cropping systems depend on crop residues management. *Agron. Sustain. Dev.* 41 (2), 1–10. <https://doi.org/10.1007/S13593-021-00680-5>.
- Deligios, P.A., Tiloca, M.T., Sulas, L., Buffa, M., Caraffini, S., Doro, L., Sanna, G., Spanu, E., Spissu, E., Urracci, G.R., Ledda, L., 2017. Stable nutrient flows in sustainable and alternative cropping systems of globe artichoke. *Agron. Sustain. Dev.* 37 (6), 1–12. <https://doi.org/10.1007/S13593-017-0465-3>.
- Depalo, L., Burgio, G., Magagnoli, S., Sommaggio, D., Montemurro, F., Canali, S., Masetti, A., 2020. Influence of cover crop termination on ground dwelling arthropods in organic vegetable systems. *Insects* 11, 445. <https://doi.org/10.3390/insects11070445>.
- Depalo, L., Burgio, G., Von Fragstein, P., Kristensen, H.L., Bavec, M., Robačar, M., Campanelli, G., Canali, S., 2017. Impact of living mulch on arthropod fauna: analysis of pest and beneficial dynamics on organic cauliflower (*Brassica oleracea* L. var. *botrytis*) in different European scenarios. *Renew. Agric. Food Syst.* 32 (3), 240–247. <https://doi.org/10.1017/S1742170516000156>.
- Di Bene, C., Diacono, M., Montemurro, F., Testani, E., Farina, R., 2022. EPIC model simulation to assess effective agro-ecological practices for climate change mitigation and adaptation in organic vegetable system. *Agron. Sustain. Dev.* 42 (1), 1–17. <https://doi.org/10.1007/S13593-021-00745-5/TABLES/1>.
- Diacono, M., Persiani, A., Castellini, M., Giglio, L., Montemurro, F., 2021. Intercropping and rotation with leguminous plants in organic vegetables: crop performance, soil properties and sustainability assessment. *Biol. Agric. & Hortic.* 37 (3), 141–167. <https://doi.org/10.1080/01448765.2021.1891968>.
- Diacono, M., Persiani, A., Testani, E., Montemurro, F., 2019. Sustainability of agro-ecological practices in organic horticulture: yield, energy-use and carbon footprint. *Agroecol. Sustain. Food Syst.* 44 (6), 726–746. <https://doi.org/10.1080/21683565.2019.1704961>.
- Djian-Caporalino, C., Maitelle, T., Bailly-Bechet, M., Marteu, N., Fazari, A., Bouteau, P., Raptoupolou, A., Van Duong, L., Tavoillot, J., Martiny, B., Goillon, C., Castagnone-Sereno, P., 2019. Evaluating sorghums as green manure against root-knot nematodes. *Crop. Prot.* 122, 142–150. <https://doi.org/10.1016/J.CROPRO.2019.05.002>.
- Domagała-Świątkiewicz, I., Siwek, P., Bucki, P., Rabiasz, K., 2019. Effect of hairy vetch (*Vicia villosa* Roth.) and vetch-rye (*Secale cereale* L.) biculture cover crops and plastic mulching in high tunnel vegetable production under organic management. *Biol. Agric. & Hortic.* 35 (4), 248–262. <https://doi.org/10.1080/01448765.2019.1625074>.
- Domagała-Świątkiewicz, I., Siwek, P., 2022. Effect of field pea (*Pisum sativum* subsp. *arvense* L. Asch.) and pea-oat (*Avena sativa* L.) biculture cover crops on high tunnel vegetable under organic production system. *Organic. Agriculture* 12 (1), 91–106. <https://doi.org/10.1007/S13165-021-00383-X/TABLES/12>.
- Elevitch, C.R., Mazaroli, N.D., Ragone, D., 2018. Agroforestry standards for regenerative agriculture. *Sustainability* 10 (9), 3337. <https://doi.org/10.3390/SU10093337>.
- Euriga, E., Boehme, M.H., Amanah, S., 2021. Changing farmers' perception towards sustainable horticulture: A case study of extension education in farming community in Yogyakarta, Indonesia. *AGRARIJ Journal Agribusiness Rural Development Research* 7 (2), 225–240. <https://doi.org/10.18196/AGRARIJ.V7I2.11510>.
- Farneselli, M., Tosti, G., Onofri, A., Benincasa, P., Guiducci, M., Pannacci, E., Tei, F., 2018. Effects of N sources and management strategies on crop growth, yield and potential N leaching in processing tomato. *Eur. J. Agron.* 98, 46–54. <https://doi.org/10.1016/J.EJA.2018.04.006>.
- Florence, A.M., McGuire, A.M., 2020. Do diverse cover crop mixtures perform better than monocultures? A systematic review. *Agron. J.* 112 (5), 3513–3534. <https://doi.org/10.1002/AGJ2.20340>.
- França, S.C., Spiessens, K., Pollet, S., Debode, J., De Rooster, L., Callens, D., Höfte, M., 2013. Population dynamics of *Verticillium* species in cauliflower fields: Influence of crop rotation, debris removal and ryegrass incorporation. *Crop. Prot.* 54, 134–141. <https://doi.org/10.1016/J.CROPRO.2013.08.008>.
- Francis, J., Holmes, S., 2020. Regenerative agriculture—quantifying the cost. In: Occasional Paper, 20. Australian Farm Institute: Sydney, Australia.
- Franzcu, J., Jabłońska-Ceglarek, R., Zaniewicz-Bajkowska, A., Kosterna, E., Rosa, R., 2009. The effect of plant mulches on the nutritive value of red cabbage and onion. *Veg. Crops Res. Bull.* 70 (1), 125–134. <https://doi.org/10.2478/V10032-009-0012-0>.

- Franczuk, J., Zaniewicz-Bajkowska, A., Kosterna, E., Rosa, R., 2010. The effect of cover plants on the yield and content of selected components of cabbage varieties. *Acta Sci. Pol. Hortorum Cultus* 9, 23–30.
- Galieni, A., Stagnari, F., Specia, S., D'Edigio, S., Pagnani, G., Pisante, M., 2017. Management of crop residues to improve quality traits of tomato (*Solanum lycopersicum* L.) fruits. *Ital. J. Agron.* 12 (1), 59–62. <https://doi.org/10.4081/IJA.2017.759>.
- Giller, K.E., Hijbeek, R., Andersson, J.A., Sumberg, J., 2021. Regenerative Agriculture: An agronomic perspective. *Outlook Agric.* 50 (1), 13–25. https://doi.org/10.1177/0030727021998063/ASSET/IMAGES/LARGE/10.1177_0030727021998063-FIG4.JPG.
- Hathaway, M.D., 2016. Agroecology and permaculture: addressing key ecological problems by rethinking and redesigning agricultural systems. *J. Environ. Stud. Sci.* 6 (2), 239–250. <https://doi.org/10.1007/S13412-015-0254-8>.
- Hefner, M., Canali, S., Willekens, K., Lootens, P., Deltour, P., Beeckman, A., Arlotti, D., Tamm, K., Bender, I., Labouriau, R., Kristensen, H.L., 2020a. Termination method and time of agro-ecological service crops influence soil mineral nitrogen, cabbage yield and root growth across five locations in Northern and Western Europe. *Eur. J. Agron.* 120, 126144. <https://doi.org/10.1016/J.EJA.2020.126144>.
- Hefner, M., Gebremikael, M.T., Canali, S., Sans Serra, F.X., Petersen, K.K., Sorensen, J.N., De Neve, S., Labouriau, R., Kristensen, H.L., 2020b. Cover crop composition mediates the constraints and benefits of roller-crimping and incorporation in organic white cabbage production. *Agric. Ecosyst. & Environ.* 296, 106908. <https://doi.org/10.1016/J.AGEE.2020.106908>.
- Hefner, M., Sorensen, J.N., de Visser, R., Kristensen, H.L., 2022. Sustainable intensification through double-cropping and plant-based fertilization: production and plant-soil nitrogen interactions in a 5-year crop rotation of organic vegetables. *Agroecol. Sustain. Food Syst.* 46 (8), 1118–1144. https://doi.org/10.1080/21683565.2022.2104419/SUPPL_FILE/WJSA_A_2104419_SM9521.EPS.
- Hermans, K., McLeman, R., 2021. Climate change, drought, land degradation and migration: exploring the linkages. *Curr. Opin. Environ. Sustain.* 50, 236–244. <https://doi.org/10.1016/J.COSUST.2021.04.013>.
- Hiltbrunner, J., Liedgens, M., Bloch, L., Stamp, P., Streit, B., 2007. Legume cover crops as living mulches for winter wheat: Components of biomass and the control of weeds. *Eur. J. Agron.* 26 (1), 21–29. <https://doi.org/10.1016/J.EJA.2006.08.002>.
- Houser, M., Stuart, D., 2020. An accelerating treadmill and an overlooked contradiction in industrial agriculture: Climate change and nitrogen fertilizer. *J. Agrar. Change* 20 (2), 215–237. <https://doi.org/10.1111/JOAC.12341>.
- Ingram, J., 2008. Are farmers in England equipped to meet the knowledge challenge of sustainable soil management? An analysis of farmer and advisor views. *J. Environ. Manag.* 86 (1), 214–228. <https://doi.org/10.1016/J.JENVMAN.2006.12.036>.
- IPCC, 2022. In: Shukla, P.R., Skea, J., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., Malley, J. (Eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press. <https://doi.org/10.1017/9781009157926>.
- Isik, D., Kaya, E., Ngouajio, M., Mennan, H., 2009. Weed suppression in organic pepper (*Capsicum annuum* L.) with winter cover crops. *Crop. Prot.* 28 (4), 356–363. <https://doi.org/10.1016/J.CROPRO.2008.12.002>.
- Jiri, O., Mafongoya, P., Chivenge, P., 2015. Smallholder farmer perceptions on climate change and variability: a predisposition for their subsequent adaptation strategies. *J. Earth Sci. & Clim. Change* 06 (5). <https://doi.org/10.4172/2157-7617.1000277>.
- Khangura, R., Ferris, D., Wagg, C., Bowyer, J., 2023. Regenerative agriculture - A literature review on the practices and mechanisms used to improve soil health. *Sustainability* 15 (3), 2338. <https://doi.org/10.3390/SU15032338>.
- Kristensen, H.L., Thorup-Kristensen, K., 2007. Effects of vertical distribution of soil inorganic nitrogen on root growth and subsequent nitrogen uptake by field vegetable crops. *Soil. Use Manag.* 23 (4), 338–347. <https://doi.org/10.1111/J.1475-2743.2007.00105.X>.
- Kumar, S., 2020. Abiotic stresses and their effects on plant growth, yield and nutritional quality of agricultural produce. *Int. J. Food Sci. Agric.* 4 (4), 367–378. <https://doi.org/10.26855/IJFSA.2020.12.002>.
- LaCanne, C.E., Lundgren, J.G., 2018. Regenerative agriculture: Merging farming and natural resource conservation profitably. *PeerJ* 2, e4428. <https://doi.org/10.7717/PEERJ.4428/SUPP-1>.
- Lenzi, A., Baldi, A., Tesi, R., 2015. Artichoke (*Cynara scolymus* L.) as cash-cover crop in an organic vegetable system. *Acta Agric. Slov.* 105 (1), 53–60. <https://doi.org/10.14720/AAS.2015.105.1.06>.
- MacLaren, C., Swanepoel, P., Bennett, J., Wright, J., Dehnen-Schmutz, K., 2019. Cover crop biomass production is more important than diversity for weed suppression. *Crop. Sci.* 59 (2), 733–748. <https://doi.org/10.2135/CROPCSCI2018.05.0329>.
- Magagnoli, S., Depalo, L., Masetti, A., Campanelli, G., Canali, S., Leteo, F., Burgio, G., 2018. Influence of agro-ecological service crop termination and synthetic biodegradable film covering on *Aphis gossypii* Glover (Rhynchota:Aphididae) infestation and natural enemy dynamics. *Renew. Agric. Food Syst.* 33 (4), 386–392. <https://doi.org/10.1017/S1742170517000175>.
- Mancinelli, R., Radicetti, E., Muleo, R., Marinari, S., Bravo, I., Papetti, P., 2019. Can hairy vetch cover crop affect arsenic accumulation in vegetable crops? *Agriculture* 9 (5), 89. <https://doi.org/10.3390/AGRICULTURE9050089>.
- Manici, L.M., Caputo, F., Nicoletti, F., Leteo, F., Campanelli, G., 2018. The impact of legume and cereal cover crops on rhizosphere microbial communities of subsequent vegetable crops for contrasting crop decline. *Biol. Control.* 120, 17–25. <https://doi.org/10.1016/J.BIOCONTROL.2016.11.003>.
- McLennon, E., Dari, B., Jha, G., Sihi, D., Kankarla, V., 2021. Regenerative agriculture and integrative permaculture for sustainable and technology driven global food production and security. *Agron. J.* 113 (6), 4541–4559. <https://doi.org/10.1002/AGJ2.20814>.
- Medina, A., Akbar, A., Baazeem, A., Rodriguez, A., Magan, N., 2017. Climate change, food security and mycotoxins: Do we know enough? *Fungal Biol. Rev.* 31 (3), 143–154. <https://doi.org/10.1016/J.FBR.2017.04.002>.
- Mennan, H., Ngouajio, M., Isik, D., 2006. The effects of cover crop on weed control in collard (*Brassica oleracea* var. *acephala*) and lettuce (*Lactuca sativa* L.). *Communications in Agricultural and Appl. Biol. Sci.* 71, 709–714.
- Merino, R., 2020. The geopolitics of food security and food sovereignty in Latin America: Harmonizing competing visions or reinforcing extractive agriculture? *Geopolitics* 27 (3), 898–920. <https://doi.org/10.1080/14650045.2020.1835864>.
- Mia, M.J., Massetani, F., Murri, G., Neri, D., 2020. Sustainable alternatives to chemicals for weed control in the orchard – A review. *Hortic. Sci.* 47 (1), 1–12. <https://doi.org/10.17221/29/2019-HORTSCI>.
- Montgomery, D.R., 2017. *Growing a revolution: Bringing our soil back to life*, First edition. W.W. Norton & Company.
- Morel, K., Cartau, K., 2023. Adaptation of organic vegetable farmers to climate change: An exploratory study in the Paris region. *Agric. Syst.* 210, 103703. <https://doi.org/10.1016/J.AGSY.2023.103703>.
- Muhie, S.H., 2022. Novel approaches and practices to sustainable agriculture. *J. Agric. Food Res.* 10, 100446. <https://doi.org/10.1016/J.JAFR.2022.100446>.
- Nakamoto, T., Tsukamoto, M., 2006. Abundance and activity of soil organisms in fields of maize grown with a white clover living mulch. *Agric. Ecosyst. & Environ.* 115 (1–4), 34–42. <https://doi.org/10.1016/J.AGEE.2005.12.006>.
- Newton, P., Civita, N., Frankel-Goldwater, L., Bartel, K., Johns, C., 2020. What is regenerative agriculture? A review of scholar and practitioner definitions based on processes and outcomes. *Front. Sustain. Food Syst.* 4, 577723. <https://doi.org/10.3389/FSUFS.2020.577723/BIBTEX>.
- Nordblom, T., Gurusingham, S., Erbacher, A., Weston, L.A., 2023. Opportunities and challenges for cover cropping in sustainable agriculture systems in Southern Australia. *Agriculture* 13 (3), 688. <https://doi.org/10.3390/AGRICULTURE13030688>.
- Patkowska, E., 2021. Cover crops and soil-borne fungi dangerous towards the cultivation of *Daucus carota* L. *Acta Sci. Pol. Hortorum Cultus* 20 (2), 3–12. <https://doi.org/10.24326/ASPHC.2021.2.1>.
- Patkowska, E., Jamiolkowska, A., Błazewicz-Woźniak, M., 2018. Antagonistic activity of selected fungi of the soil environment of carrot. *Plant. Soil. Environ.* 64 (2), 58–63. <https://doi.org/10.17221/792/2017-PSE>.
- Patkowska, E., Konopinski, M., 2013. The role of oats, common vetch and tansy phacelia as cover plants in the formation of microorganisms communities in the soil under the cultivation of root chicory (*Cichorium intybus* var. *sativum* Bisch.) and salsify [*Tragopogon portifolius* var. *sativus* (Gaterau) Br.]. *Acta Sci. Pol. Hortorum Cultus* 12 (5), 179–191.
- Persiani, A., Montemurro, F., Diacono, M., 2021. Agronomic and environmental performances of on-farm compost production and application in an organic vegetable rotation. *Agronomy* 11 (10), 2073. <https://doi.org/10.3390/AGRONOMY11102073>.
- Pinto, R., Brito, L.M., Coutinho, J., 2016. Organic production of horticultural crops with green manure, composted farmyard manure and organic fertiliser. *Int. J. Sustain. Prod. Syst.* 33 (4), 269–284. <https://doi.org/10.1080/01448765.2017.1347521>.
- Quintarelli, V., Radicetti, E., Allevato, E., Stazi, S.R., Haider, G., Abideen, Z., Bibi, S., Jamal, A., Mancinelli, R., 2022. Cover crops for sustainable cropping systems: A review. *Agriculture* 12 (12), 2076. <https://doi.org/10.3390/AGRICULTURE12122076>.
- Radicetti, E., Mancinelli, R., Campiglia, E., 2013. Impact of managing cover crop residues on the floristic composition and species diversity of the weed community of pepper crop (*Capsicum annuum* L.). *Crop. Prot.* 44, 109–119. <https://doi.org/10.1016/J.CROPRO.2012.10.017>.
- Reidsma, P., Ewert, F., Lansink, A.O., Leemans, R., 2010. Adaptation to climate change and climate variability in European agriculture: The importance of farm level responses. *Eur. J. Agron.* 32 (1), 91–102. <https://doi.org/10.1016/J.EJA.2009.06.003>.
- Rhodes, C.J., 2017. The imperative for regenerative agriculture. *Sci. Progress.* 100 (1), 80–129. <https://doi.org/10.3184/003685017X14876775256165>.
- Rickson, R.J., 2015. Input constraints to food production: the impact of soil degradation. *Philos. Trans. R. Soc. B Biol. Sci.* 370 (1669), 20140366. <https://doi.org/10.1007/s12571-015-0437-x>.
- Ritz, K., 2021. The Groundswell 5 principles and soil sense. Groundswell. (<https://groundswellag.com/karl-ritz-the-groundswell-5-principles-and-soil-sense/>).
- Routschek, A., Schmidt, J., Kreienkamp, F., 2014. Impact of climate change on soil erosion - A high-resolution projection catchment scale until 2100 in Saxony/Germany. *Catena* 121, 99–109. <https://doi.org/10.1016/j.catena.2014.04.019>.
- Sakrabani, R., Garnett, K., Knox, J.W., Rickson, J., Pawlett, M., Falagán, N., Girkin, N.T., Cain, M., Alamar, M.C., Burgess, P.J., Harris, J., Patchigolla, K., Sanders, D., Graves, A., Hannam, J., W Simmons, R., 2023. Towards net zero in agriculture: Future challenges and opportunities for arable, livestock and protected cropping systems in the UK. *Outlook Agric.* 52 (2), 116–125. <https://doi.org/10.1177/00307270231178889>.
- Salata, A., Nurzyńska-Wierdak, R., Kalisz, A., Moreno-Ramón, H., 2022. Impacts of Alexandrian clover living mulch on the yield, phenolic content, and antioxidant capacity of leek and shallot. *Agronomy* 12 (11), 2602. <https://doi.org/10.3390/AGRONOMY12112602>.
- Saleem, M., Pervaiz, Z.H., Contreras, J., Lindenberger, J.H., Hupp, B.M., Chen, D., Zhang, Q., Wang, C., Iqbal, J., Twigg, P., 2020. Cover crop diversity improves multiple soil properties via altering root architectural traits. *Rhizosphere* 16, 100248. <https://doi.org/10.1016/J.RHISP.2020.100248>.

- Sarkis-Onofre, R., Catalá-López, F., Aromataris, E., Lockwood, C., 2021. How to properly use the PRISMA Statement. *Syst. Rev.* 10 (1), 1–3. <https://doi.org/10.1186/S13643-021-01671-Z/METRICS>.
- Schulz, M., Tabaglio, V., 2025. Allelopathy: Mechanisms and applications in regenerative agriculture (2nd Edition). *Plants* 14 (11), 1565. <https://doi.org/10.3390/plants14111565>.
- Schwarz, G., Vanni, F., Miller, D., Helin, J., Prazan, J., Albanito, F., Fratila, M., Galioto, F., Gava, O., Irvine, K., Landert, J., Quero, A.L., Mayer, A., Monteleone, D., Muller, A., Rööös, E., Smyrniotopoulou, A., Vincent, A., Vlahos, G., Zilans, A., 2022. Exploring sustainability implications of transitions to agroecology: A transdisciplinary perspective. *EuroChoices* 21 (3), 37–47. <https://doi.org/10.1111/1746-692X.12377>.
- Seymour, M., Kirkegaard, J.A., Peoples, M.B., White, P.F., French, R.J., 2012. Break-crop benefits to wheat in Western Australia - insights from over three decades of research. *Crop. Pasture Sci.* 63 (1), 1–16. <https://doi.org/10.1071/CP11320>.
- Sherwood, S., Uphoff, N., 2000. Soil health: research, practice and policy for a more regenerative agriculture. *Appl. Soil. Ecol.* 15 (1), 85–97. [https://doi.org/10.1016/S0929-1393\(00\)00074-3](https://doi.org/10.1016/S0929-1393(00)00074-3).
- Singer, J.W., Nusser, S.M., Alf, C.J., 2007. Are cover crops being used in the US corn belt? *J. Soil. Water Conserv.* 62 (5), 353–358. (<https://www.jswnonline.org/content/62/5/353>).
- Singh, S., Kumar, V., Chauhan, A., Datta, S., Wani, A.B., Singh, N., Singh, J., 2017. Toxicity, degradation and analysis of the herbicide atrazine. *Environ. Chem. Lett.* 16 (1), 211–237. <https://doi.org/10.1007/S10311-017-0665-8>.
- Sportelli, M., Frascioni, C., Fontanelli, M., Pirchio, M., Gagliardi, L., Raffaelli, M., Peruzzi, A., Antichi, D., 2022. Innovative living mulch management strategies for organic conservation field vegetables: evaluation of continuous mowing, flaming, and tillage performances. *Agronomy* 12 (3), 622. <https://doi.org/10.3390/AGRONOMY12030622/S1>.
- Steenwerth, K., Belina, K.M., 2008. Cover crops enhance soil organic matter, carbon dynamics and microbiological function in a vineyard agroecosystem. *Appl. Soil. Ecol.* 40 (2), 359–369. <https://doi.org/10.1016/j.apsoil.2008.06.006>.
- Stein, S., Hartung, J., Möller, K., Zikeli, S., 2022. The effects of leguminous living mulch intercropping and its growth management on organic cabbage yield and biological nitrogen fixation. *Agronomy* 12 (5), 1009. <https://doi.org/10.3390/AGRONOMY12051009>.
- Thavarajah, D., Siva, N., Johnson, N., McGee, R., Thavarajah, P., 2019. Effect of cover crops on the yield and nutrient concentration of organic kale (*Brassica oleracea* L. var. acephala). *Sci. Rep.* 9, 10374. <https://doi.org/10.1038/s41598-019-46847-9>.
- Thorup-Kristensen, K., 2006. Root growth and nitrogen uptake of carrot, early cabbage, onion and lettuce following a range of green manures. *Soil. Use Manag.* 22 (1), 29–38. <https://doi.org/10.1111/J.1475-2743.2005.00012.X>.
- Tittarelli, F., Campanelli, G., Leteo, F., Farina, R., Napoli, R., Ciaccia, C., Canali, S., Testani, E., 2018. Mulch based no-tillage and compost effects on nitrogen fertility in organic melon. *Agron. J.* 110 (4), 1482–1491. <https://doi.org/10.2134/AGRONJ2017.09.0529>.
- Trinchera, A., Testani, E., Ciaccia, C., Campanelli, G., Leteo, F., Canali, S., 2016. Effects induced by living mulch on rhizosphere interactions in organic artichoke: The cultivar's adaptive strategy. *Renew. Agric. Food Syst.* 32 (3), 214–223. <https://doi.org/10.1017/S1742170516000119>.
- Übelhör, A., Gruber, S., Claupein, W., 2014. Influence of tillage intensity and nitrogen placement on nitrogen uptake and yield in strip-tilled white cabbage (*Brassica oleracea* convar. *capitata* var. *alba*). *Soil. Tillage Res.* 144 (1), 156–163. <https://doi.org/10.1016/J.STILL.2014.07.015>.
- Valenzuela, H., 2016. Agroecology: A global paradigm to challenge mainstream industrial agriculture. *Horticulturae* 2 (1), 2. <https://doi.org/10.3390/HORTICULTURAE2010002>.
- Webb, N.P., Marshall, N.A., Stringer, L.C., Reed, M.S., Chappell, A., Herrick, J.E., 2017. Land degradation and climate change: building climate resilience in agriculture. *Front. Ecol. Environ.* 15 (8), 450–459. <https://doi.org/10.1002/FEE.1530>.
- Westbrook, A.S., Bhaskar, V., Di Tommaso, A., 2021. Weed control and community composition in living mulch systems. *Weed Res.* 62 (1), 12–23. <https://doi.org/10.1111/WRE.12511>.
- Wittwer, R.A., Dorn, B., Jossi, W., Van Der Heijden, M.G.A., 2017. Cover crops support ecological intensification of arable cropping systems. *Sci. Rep.* 7 (1), 1–12. <https://doi.org/10.1038/srep41911>.
- Wittwer, R.A., van der Heijden, M.G.A., 2020. Cover crops as a tool to reduce reliance on intensive tillage and nitrogen fertilization in conventional arable cropping systems. *Field Crops Res.* 249, 107736. <https://doi.org/10.1016/J.FCR.2020.107736>.
- Wortman, S.E., Francis, C.A., Bernards, M.L., Drijber, R.A., Lindquist, J.L., 2012. Optimizing Cover Crop Benefits with Diverse Mixtures and an Alternative Termination Method. *Agron. J.* 104 (5), 1425–1435. <https://doi.org/10.2134/AGRONJ2012.0185>.
- Xie, Y., Kristensen, H.L., 2016. Overwintering grass-clover as intercrop and moderately reduced nitrogen fertilization maintain yield and reduce the risk of nitrate leaching in an organic cauliflower (*Brassica oleracea* L. var. *botrytis*) agroecosystem. *Sci. Hortic.* 206, 71–79. <https://doi.org/10.1016/J.SCIENTA.2016.04.034>.



DSPACE

<https://dspace.org/>

Uncovering the potential of cover cropping for regenerative horticulture

Smee, Matthew; Girkin, Nicholas T.; Simmons, Robert W.; Falagán, Natalia

2026-09

Elsevier

<https://doi.org/10.1016/j.eja.2026.128243>

Smee M, Girkin NT, Simmons R, Falagán N. (2026) Uncovering the potential of cover cropping for regenerative horticulture. European Journal of Agronomy, Volume 180, September 2026, Article number 128243