Cover crops and their benefits to specific following crops

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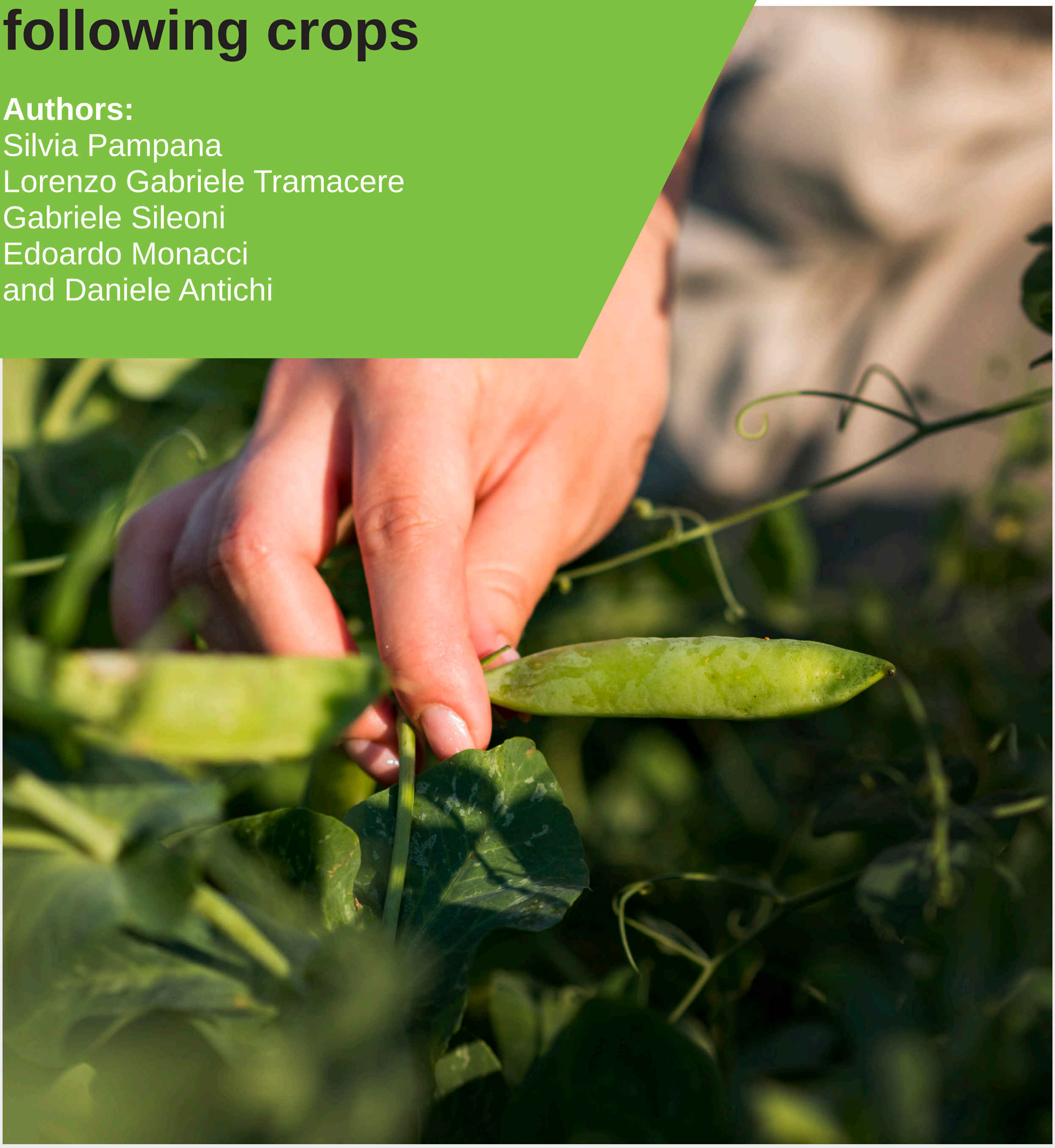

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Summary

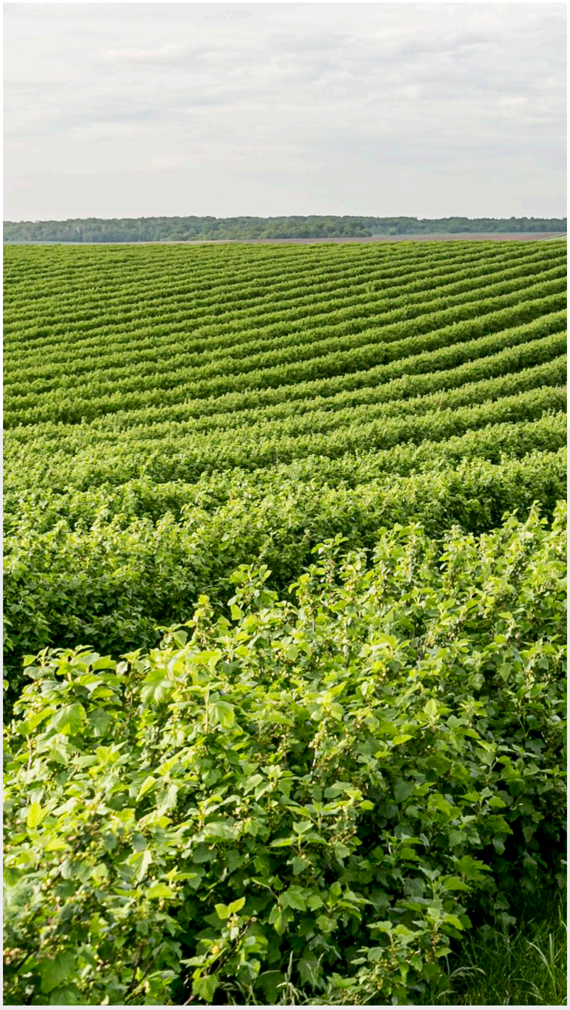
Cover crops—plants grown without the intention of harvesting, typically planted between or alongside cash crops—provide numerous agronomic, environmental, and economic benefits. This white paper examines the influence of key legume cover crops on subsequent plantings of winter (such as wheat and barley) and spring (i.e., maize, and sorghum) cereals, spring crops (sunflower), vegetables (like tomato, and eggplant), and legumes (such as soybean and common bean). We integrated findings from scientific research, farmer experiences, and extension services to provide practical recommendations tailored to each crop sequence.

INTRODUCTION

Rotated crops that are grown not as the primary cash crop but to offer benefits to the cropping system are called "cover crops" (CCs); they can also be named "catch crops", "green manures", "dead mulch" or "living mulch" to more specifically distinguish among their different functions and management: i.e., catch crops are grown to absorb available nitrogen in the soil and prevent nutrient loss; green manures improve soil by incorporation of fresh biomass (organic matter, OM) and nutrients; dead mulches originated from not incorporating dead cover crop material into the soil provide season-long soil cover and protect from weed infestation and excessive water evaporation; living mulches grow together the main crop at least for part of its cycle. According to the Basic Payment Scheme's (BPS) greening rules, catch crops must be planted by 31st August and kept until 1st October, while cover crops should be planted by 1st October and retained until 15th January of the following year. Although cover crops have traditionally been viewed as an ancient practice, their integration into contemporary cropping systems is increasingly recognized as a valuable ecological intensification strategy to enhance soil health, facilitate nutrient cycling, control erosion, suppress weeds and pests, and support biodiversity. The benefits of using cover crops in crop rotations depend on the cover crop type, the timing and the method of termination, with legume cover crops (LCCs) providing an additional advantage thought biologically fixed atmospheric nitrogen (N). This white paper explores the agronomic, economic, and environmental benefits of integrating LCCs into crop rotations, with a specific focus on how they enhance the productivity and resilience of subsequent cash crops.

Which are the most common LCCs and what benefits do they bring?

LCCs can supply additional N through biological nitrogen fixation (BNF) from the atmosphere.



The most used LCCs can be included into different types and are summarized in Table 1 and their characteristics and management reported in Figure 1. Their benefits depend on factors such as species, field conditions, and the duration of cover crop growth. LCCs enhance agricultural systems by fixing atmospheric nitrogen, generating organic matter, enhancing soil structure through their taproot systems, reducing erosion, attracting beneficial insects, and improving soil health. This includes raising organic carbon levels by 0.3–1.5% over 3–5 years, enhancing aggregate stability, and reducing compaction. They also reduce nitrate leaching by up to 60%, mobilise soil P through acid rhizodeposition and acting as mycorrhizal fungi host plants, and sequester significant amounts of carbon (approximately 0.3–1 t C ha^{-1} year-1). Additionally, cover crops offer economic benefits, such as decreased fertilizer and herbicide requirements, yield increases of around 4–8%, and improved resilience (Table 2). However, the sowing and establishment of small-seeded legumes require careful planning, and certain species may interfere with other legumes used in the rotation with negative effects, such as increased pest and disease presence, rotational conflicts, weed issues, and higher costs.

Do the above benefits from LCCs translate into increased crop yields?

The direct economic benefits can be simply evaluated through enhancements in the yield of subsequent crops, as the following examples show (Figure 2). However, it is important to note that yield improvements may sometimes become apparent later in the crop rotation cycle, requiring repeated use of cover crops and that cover crops offer further advantages for both the farm and the environment as well (see previous paragraph).

✓ Winter Cereals (Wheat and Barley)

Positive impact on wheat crop yield while a negative impact on barley crop yield was observed.

Cover crops: hairy vetch

Benefits:

- Vetch adds ~40–80 kg N/ha to-soil, reducing N-fertilizer need.
- Hairy vetch mulch can increase main crop disease resistance and prolong leaf photosynthesis of the following crop.
- No effect on the grain or N yield of the subsequent barley crop, but reduced N leaching.

Risks:

Excessive biomass may delay planting; careful management of termination. Overwinter mortality, regrowth following mechanical termination resulting in competition with subsequent crops, and rapid mineralization of residues resulting in N losses prior to crop N uptake.

✓ Spring Cereals (Maize and Sorghum)

Various positive effects of LCCs on soil health and subsequent summer crop yields have been observed. These benefits are primarily associated with the quantity of biologically fixed nitrogen supplied, particularly when the following cash crops are grown using no-tillage methods.

For example, hairy vetch can supply biologically approximately 70 to 100 kg ha^{-1}fertilizer N annually to the corn and 125-135 to grain sorghum.

Cover crops: hairy vetch, crimson clover, squarrosum clover, faba bean

Benefits:

Vetch adds on average 40–80 kg N ha-1 to-soil, reducing N-fertilizer need

Risks:

Excessive biomass may delay planting; careful management of termination.

Spring Crops (Sunflower)

In France sunflower's performances were negatively affected by LCCs, because of competition for water and poor weed control due to no hoeing.

Cover crops: alfalfa, purple vetch and legumes mixture

Benefits:

average amount of nitrogen returned to soil after cover crops destruction was of 40 kg N/ha for purple vetch, 18 kg N/ha for alfalfa and 19.5 kg N/ha for legumes mixture

Risk:

sunflower suffered of reduced water availability and weed control.

Vegetables (Tomato and Eggplant)

In Italy, squarrose clover was a suitable winter cover crop for tomato, especially in no-till systems.

Cover crops: crimson clover, squarrose clover

Benefits:

Clovers provide nitrogen, boosting early-season growth.

The yield, fruit, and straw nitrogen uptake of eggplant were higher after using a hairy vetch cover crop, possibly due to the high residual nitrogen in the soil. A no-tillage strategy is recommended with legume cover crop residues to minimize the risk of nitrogen loss.

Cover crop: hairy vetch

Benefits:

residual N in soil.

Risk:

The nitrogen released from the hairy vetch cover crop in conventional tillage can be lost if not captured by the next crop. Leaving residues as mulch on the soil surface can delay this process.

Legumes (Soybean)

Farmers can expect a 4.9% increase in soybeans after five consecutive years of cover crop use., which can be even higher (+11.6%) in drought years.

Cover crops: winter pea, hairy vetch, mixtures.

Benefits:

- Peas and vetch fix up to ~80 kg N/ha; boost yield potential of soybean by ~5–10%
- Biomass moderates soil moisture and suppresses early-season weeds
- Winter pea cover improved spring biomass and soil N at planting, yielding ~0.3 t/ha more soybean.

Anyway, mixtures of cereals and legumes enhance nitrogen retention, disrupt pest cycles, and diversify microorganism activity. Studies indicate that due to their complementary N acquisition strategies and aboveground structures, these mixtures can outperform monocultures (overyielding). The increased biomass production of these mixtures also improves ecosystem services like weed suppression and nitrogen retention compared to single-species cover crops.

IMPLEMENTATION GUIDELINES

Extension programs, cost-sharing arrangements, and carbon incentive initiatives may encourage the use of cover crops through. Besides, provision of training, region-specific guidelines, and support may be convenient to address management complexity.

Specific useful hints are the following:

1. Cover Crop Selection:

match growth habit and termination timing with cash crop schedule.

- Use regionally recommended cover crops and seeding rates.
- For delayed sowing, choose early maturing varieties or terminate earlier.
- Late sowing of summer species is not a concern due to the mulch's high moisture retention.
- Mix legumes and grasses for nitrogen fixation and residue cover.

2. Termination Techniques:

- Schedule termination to reduce negative effects on soil moisture or planting window.
- In case of green manure, ideal termination 2–3 weeks before cash crop planting to allow for residue breakdown (e.g., allelochemicals), minimum tillage sufficient for incorporation to save soil water.
- Roller-crimping at flowering (e.g., vetch, see Photo 1).
- Mowing or herbicide application but more rapid degradation of the dead mulch

3. Integrated Nutrient Management:

- Sample soil mid-season after cover crop termination.
- Adjust fertilizer N based on cover crop contribution.

4. Monitoring & Adaptive Management:

- Track yields, soil health, and pest/disease presence over time.
- Rotate cover species annually or grow in mixtures to avoid trait fatigue and responsiveness loss.
- Inoculate with Rhizobia in case of first/rare cultivation of legume crops

Conclusion

LCCs are a versatile and sustainable instrument within contemporary cropping systems to achieve with four primary aims: enhancing soil fertility, improving soil structure, managing weeds and pests, and contributing to environmental management.

When tailored to specific crop sequences, they offer substantial agronomic, environmental, and economic returns. The best cover crop species and management depend on the grower's goals; by optimizing selection, timing, and management, their adoption can help farmers in maintaining soil health, high yields, reduce input dependence, and contribute to climate resilience.

Evidence from academic literature and on-farm studies shows that LCCs can significantly reduce fertilizer inputs, improve soil structure and enhance yields, thereby contributing to long-term farm profitability and sustainability.

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ANNEXES

Type	Examples	Main Characteristics and management
Winter annuals	crimson clover	It relatively quickly establishes compared to some longer-term clovers but should be sown early for autumn cover as it does not thrive in cool and heavy soils. Sowing: August; Rate: 30 kg ha^{-1}
	berseem clover	It quickly establishes and forms a dense cover for effective weed suppression; it also regrows rapidly after mowing or grazing. Drought-tolerant, can be grown also as a summer annual in colder climates.
	hairy vetch	Hairy vetch thrives even in hard frost areas, producing ample vegetation and fixing significant nitrogen. Its residues decompose fast when green manured, releasing nitrogen quickly, which benefits high-nitrogen-demand crops. Suitable also to be managed as dead mulch in mixture with grass species. It performs well even on sandy soils, given adequate soil potassium for optimal productivity. Sowing: August-September; Rate: 80-100 kg ha^{-1}
	common vetch	Primarily used for fertility building and grazing. Less suited to drought-prone soils and frost areas than other legumes. Sowing: August-September; Rate: 80-100 kg ha^{-1}
	field peas	Establishes quickly and thrives in cool, moist climates, producing high residue. Primarily used for fertility building, either alone or in mixtures. Suitable for late sowing. Sowing: Late August- mid-September; Rates: 200–400 kg ha^{-1}
	field beans	Most used to increase fertility both as a single species or part of mixtures. They can be sown later than many legumes. Sowing: Late August to September; Rate: 100–200 kg ha^{-1}
Perennials	crown vetch	Suited for well-drained soils and low fertility, providing permanent ground cover but establishing slowly. Best for perennial use.
	red clover	Biannual species, vigorous, shade-tolerant, winter-hardy, and quick to establish. Often inter-seeded with small grains in relay intercropping, its slow initial growth minimizes competition and ensure forage production or green manures in post-harvest season of intercropped cereals.
	white clover	Perennial species, primarily utilized for fertility enhancement, this legume does not exhibit as much growth as many others and has a lower tolerance for drought conditions. Despite its shorter stature, it has better shading tolerance compared to many other legumes. This makes it suitable as permanent living mulch. Sowing: August; Rate: 10-15 kg ha^{-1}
	Sainfoin	A perennial species lasting over four years. It enriches low-nutrient soils and is commonly used in grazing mixtures. It thrives in poor soil and drought conditions. Sowing: August; Rates: 70 kg ha^{-1}
Biennials	Alfalfa	Ideal for well-drained, fertile, near-neutral soils, alfalfa grows quickly and can enhance soil structure over several years. Often inter-seeded with oats, wheat, or barley, it continues to grow after grain harvest. Sowing: August; Rates: 20 kg ha-1
	sweet clover	Winter-hardy and vigorous crop that can help break up compacted subsoils. It withstands high temperatures and drought conditions better than many other cover crops. However, it performs poorly in wet, clayey soils. It requires a near-neutral soil pH and a high calcium level, but it can grow well on low-fertility soils if the pH is high. The plant usually flowers and completes its life cycle in the second year. When used as a green manure crop, it is incorporated into the soil before full bloom. Sowing: August; Rates: 10–15 kg ha^{-1}
Summer annuals	annual species grown in the summer or colder climates	E.g., cowpeas (*Vigna unguiculata*) or sunn hemp (*Crotalaria juncea*), perform better in mixture with grass species (E.g., sudangrass, foxtail millet or grain millet) or other short cycle forbs (e.g., buckwheat). Require irrigation after sowing and early phases in dry climates.

Table 1.

Examples and characteristics of LCCs grouped by different types.

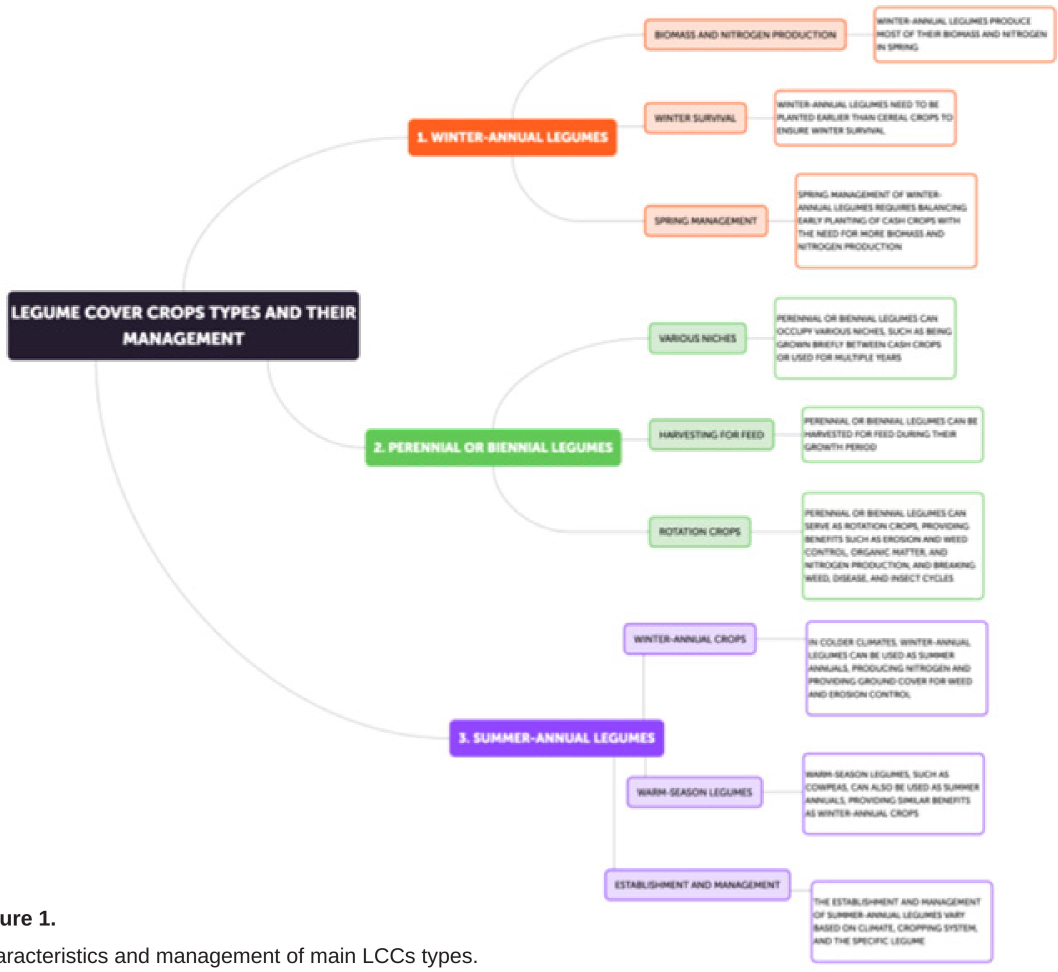

Figure 1.

Characteristics and management of main LCCs types.

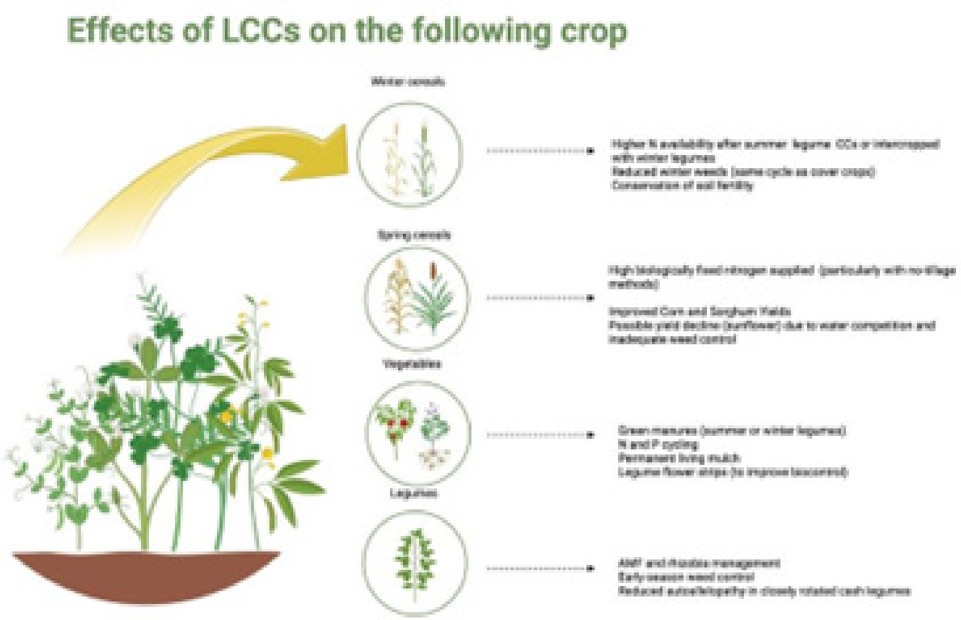

Figure 2.

Effects of LCCs on the following crops. Created in https://BioRender.com

Benefit	Description
Agronomic	
Atmospheric nitrogen fixation, uptake and release	Convert atmospheric N_2 into plant-available nitrogen through symbiosis
Weed suppression	Allelopathic effects (release compounds that inhibit weed germination) and physical competition
Nematode suppression	Generally sensible to nematodes, some cultivars can reduce nematodes populations (e.g., cowpea for root-knot nematode species (*Meloidogyne incognita*); sunn hemp for *Rotylenchulus reniformis*.
Environmental	
Reduce/prevent erosion	Reduced water runoff Improved soil aggregate stability
Soil health and fertility	Soil chemical properties: increasing soil organic matter (+0.3–1.5% C, over 3–5 years); C and nutrient cycling
	Soil physical properties: increased organic matter improves aggregate formation and stability and reduces compaction
	Soil biological properties: increased microbiological and mesofauna biodiversity, promoted microbial activity
Climate Mitigation	Deliver biomass for soil carbon sequestration (~0.3–1 t C/ha/yr) Reduction of CO_2 emissions
Climate Resilience	Increase water infiltration into soil
Biodiversity and habitat provision	Attract beneficial insects (pollinators) and wildlife
Economic	
Forage	Cover crops as additional source of forage (e.g., by grazing on regrowth after mowing)
Economic Gains	Reduced herbicide and fertilizer requirements
	Subsequent crop yield increase (approximately 4–8%) and stability
	Risk reduction (through enhanced resilience)

Table 2.

Potential benefits of LCCs use, with a short description of mechanisms.

Photo 1.

One of the most used LCCs is Vetch

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