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Effectiveness and feasibility of regenerative agricultural practices in the root vegetable sector in the UK

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Regenerative agriculture (RA) offers a holistic framework for restoring soil health, enhancing biodiversity, and increasing the resilience of food systems. While RA principles have gained traction globally, their adoption in root vegetable systems, especially within the UK, remains limited and fragmented. Root crops like potatoes and sugar beet pose unique challenges for RA due to their intensive soil disturbance and high input demands. This research aimed to investigate the effectiveness and feasibility of regenerative practices in root crop production in the UK, with a focus on identifying barriers to adoption and context-specific adaptations. A mixed-methods approach was employed, combining a survey of 57 RA practices and semi-structured interviews with root crop experts, including farmers, agronomists, and industry stakeholders. Practices such as nutrient budgeting, diversified rotations, hedgerows, and legume-rich leys were consistently rated high in both effectiveness and feasibility, whereas no-till systems, agroforestry, and biostimulants showed high variability or limited applicability in the root crop context. Findings from the interviews highlighted major barriers, including high transition costs, yield risks, insufficient or inconsistent government support and lack of market rewards. However, opportunities were also identified in supportive policy payments, supermarket-led sustainability pricing and assurance schemes, technological innovation, farmer-led experimentation, and knowledge transfer. The study concludes that RA holds substantial potential in the root vegetable sector, but widespread adoption will require targeted interventions at farm, market, and policy levels. By bridging empirical knowledge with farmers' experiences, the research provides insights that can contribute to the discussion on the UK's agricultural policy and guide initiatives such as Waitrose and Partners' *Farming for Nature* programme towards practical, scalable sustainability in agriculture.

KEYWORDS
regenerative agriculture, root crops, sustainable agriculture, UK agriculture, UK farmers

1 Introduction

Agriculture is both a large source and a sink of environmental damage. Conventional agriculture has been criticised for its role in the climate crisis, loss of biodiversity, declining soil health and reduced nutritional capacity in the food we eat today (Schreefel et al., 2020; Giller et al., 2021). Some alternative agricultural approaches have been suggested as solutions, such as organic farming, conservation agriculture, agroforestry, etc., that improve on the existing paradigm. However, these practices present their own shortcomings; while organic systems eliminate synthetic inputs, they do not necessarily minimise soil disturbance or enhance biodiversity. Conservation agriculture addresses soil disturbance by focusing heavily on reducing tillage, but falls short in capturing practices like diversified rotations or livestock integration. All of the above approaches focus on minimal environmental harm, but regenerative agriculture is an approach that seeks to ameliorate the existing natural systems (Cusworth and Garnett, 2023).

Regenerative agriculture (RA) does not have a fixed definition, and can be best described by its objectives and processes according to Newton et al. (2020). The objective of RA is to improve existing resources, like restoring soil health, enhancing biodiversity and sequestering carbon (DEFRA, 2023a, 2023b). Khangura et al. (2023) described RA as a culmination of practices that reduce the use of synthetic chemicals, keep soil covered, minimise tillage, and integrate diverse species (including crops, livestock, and soil biodiversity) in the field.

The UK agricultural policy is undergoing a significant transition towards RA. Following Brexit, the post-subsidy agricultural policy has shifted from yield-oriented, high-input production toward models emphasising environmental stewardship and rural sustainability (Beacham et al., 2023). The Environmental Land Management (ELM) Schemes, such as the Sustainable Farming Incentives (SFIs), Local Nature Recovery strategies, and Countryside Stewardship grants reward farmers for delivering nature-based public goods rather than area-based handouts (DEFRA, 2023a, 2023b). Although the term "regenerative agriculture" is not explicitly mandated in these policies, they strongly align with RA principles through emphasis on sustainable, nature-based, and restorative farming practices.

Root crops present unique and underexplored challenges in the implementation of RA. The classification of "root vegetables" in this study follows common market and consumer usage, which includes crops such as potatoes and onions, despite their botanical classification as tubers and bulbs. Root vegetables, involving sugar beet, potatoes, carrots, onions, turnips, parsnips, beetroot, radishes and swedes, make up a significant segment of the UK's agricultural economy and warrant deeper investigation. Sugar beet generated over 370 M GBP in revenue in 2023 (DEFRA, 2024) and about 3% of the total cropped land in the UK is engaged in potato production (DEFRA, 2025). Potatoes require extensive tilling for seed-bed preparation before sowing (Djaman et al., 2022) and heavy application of synthetic inputs (Pieterse, 2025) to support growth. Harvesting root crops not only disturbs the soil but also prevents the farmer from leaving roots in the soil (one of the fundamental principles of RA). They also present complications in being involved in rotations because they require Grade 1 or 2 land (excellent to good land with few physical limitations) (Leake, 2024). These biophysical constraints mean that regenerative practices developed for cereals or pastoral systems cannot be directly transferred to root crop production and need to be studied separately. The literature on the effectiveness and feasibility of RA practices for root vegetable systems remains fragmented and scarce.

In addition to these challenges, the evidence of the environmental and economic benefits of RA has been highly context-dependent, which can confuse and deter farmers. Rotations with herbal leys are deemed excellent for soil fertility but could lead to increased herbicide use during the arable crop phase (Cooledge et al., 2022). In almost all practices of RA (except livestock integration), soil carbon had improved as per Burgess et al. (2024), but according to Cai et al. (2022), this finding was consistent only at the surface level (first 10 cm), and at 10-60 cm, this reduction gets offset. There is also speculation for lack of on-field applicability of academic research papers based on RA. Jordon et al. (2022) claimed that while RA practices do contribute to an increase in soil organic carbon (SOC), the evidence of maintaining agricultural productivity remained limited.

This research addresses these knowledge gaps by systematically evaluating 57 regenerative practices specifically within the context of the UK's root vegetable production system. This study prioritises practices aligned with root crop agronomic constraints and identifies the barriers that can be economic, institutional, market-based, and knowledge-related that impede adoption. In doing so, it provides insights contributing to discussions on the UK agricultural policy as well as initiatives such as the *Farming for Nature* programme by Waitrose and Partners towards practical, scalable sustainability in agriculture.

2 Methods

This research employed a mixed-methods approach, combining expert assessment surveys with qualitative interviews with farmers to evaluate the effectiveness and feasibility of practices. Integrating these approaches provides triangulated insights into practice performance and adoption barriers.

2.1 Expert assessment survey

57 RA practices relevant to root vegetable production in the UK were identified through a literature review and validated by agricultural scientists at the University of Reading (Available in Table A1). These practices were organised under five core RA principles: minimising soil disturbance, enhancing crop diversity, enhancing biodiversity, livestock integration, and reducing synthetic inputs. An online survey administered via Qualtrics presented each practice for structured expert assessment across two dimensions: effectiveness (how well each practice achieves desired agricultural and environmental outcomes) and feasibility (practical applicability, both financially and technically). Both dimensions used 5-point Likert scales (1 = strongly disagree, 5 = strongly agree). A three-level confidence rating (Low, Medium, High) captured respondent familiarity with each practice. Additional comments on the influence of soil type and weather were captured to understand context-specific applicability.

The survey was completed by 11 respondents (farmers, agronomists, academics, and agricultural consultants) with experience across diverse root crop production systems. Descriptive statistics (mean, median, standard deviation, and coefficient of variation) were calculated for the effectiveness and feasibility scores. To generate an integrated ranking, confidence levels were converted to numerical weights (Low = 1, Medium = 2, High = 3) and incorporated in the overall score given by the formula below:

$$\text{Overall Score} = \left(\text{Effectiveness} + \text{Feasibility}\right) \times \text{Confidence}$$

This weighting acknowledges that assessments with lower confidence have a minimised bearing on final rankings. The means of the overall scores from each participant were used for analysis. Two complementary visualisations were created: a bar chart ranking all 57 practices by overall score, and a scatter plot positioning practices by effectiveness (y-axis) and feasibility (x-axis), with point colours indicating confidence levels (white = high, grey = medium, black = low). The scatter plot identifies four zones: high-effectiveness/high-feasibility (optimal adoption candidates), high-effectiveness/low-feasibility (practices requiring support), low-effectiveness/high-feasibility (easily implemented with modest benefits), and low-effectiveness/low-feasibility (limited applicability). This multi-dimensional approach reveals trade-offs between practice effectiveness and feasibility that linear rankings may obscure.

2.2 Farmer interviews

Nine semi-structured interviews were conducted with root crop farmers across the UK during June–August 2025. Participants were recruited through LinkedIn, Waitrose's supply chain contacts, and professional networks. Eligibility required direct experience with UK root crop production. The sample was intentionally diverse, spanning geographic regions, crop types, farm sizes, production approaches (conventional, organic, regenerative), and years of experience. Interviews lasting roughly 60 min were conducted remotely via video call, audio-recorded with consent, and transcribed verbatim. The protocol comprised five thematic sections: (1) farm context and management history; (2) direct experience with regenerative practices (successes and failures); (3) information sources and support systems; (4) barriers and enablers to practice adoption; and (5) future perspectives and policy views.

Interview transcripts underwent thematic analysis following Braun and Clarke protocols using NVivo 14. Analysis began with repeated transcript reading for familiarisation, followed by systematic coding using both deductive codes (derived from the interview protocol) and inductive codes (emerging from the data). Codes were organised into broader themes capturing recurring patterns, tensions, and insights across farmer perspectives. Themes were cross-referenced with expert assessment survey findings to identify convergence and divergence.

3 Results

3.1 Expert assessment survey

The general trend observed was that most practices were deemed effective with scores higher than 3 on the 5-point scale (mean = 3.7). Over 21 practices scored as high as 4 for effectiveness. Nutrient budgeting of soil and crops achieved the highest effectiveness score (4.91), with Nutrient analysis, hedgerows and diversified rotations being the next highly ranked practices at 4.73. The lowest scores were given to practices like the use of biostimulants and adding stones and branches to the landscape.

Scores for feasibility (mean = 2.8) were generally low compared to effectiveness, and only 10 practices scored above 4.0. The most highly ranked practices remained the same as in effectiveness; i.e., nutrient budgeting of soil and crops (4.82), nutrient analysis (4.64) and diversified rotation (4.45). Lowest scorers were also consistent with effectiveness, along with practices like delayed residue incorporation, narrow herbicide strip and rainwater harvesting were also rated low in feasibility, with a score of 2.64 for each. This effectiveness-feasibility gap suggests that while experts recognise the agronomic value of regenerative practices, significant implementation barriers exist.

Confidence levels were consistently high except for agroforestry practices and topographical ploughing, suggesting lower popularity of these approaches in root crop contexts. High coefficients of variation (CV) for several practices revealed substantial disagreement among respondents. No-till showed 54% variation, delayed residue incorporation 71%, and narrow herbicide strips 53%. Similarly, feasibility assessments displayed high variation for practices such as nutrient recycling in fertigation (67%), rainwater harvesting (69%), and livestock integration (61–67%).

The scoring formula generated weighted overall scores; the mean of the overall scores from all participants for each practice has been presented in Figure A1. The overall scores were highest for practices such as conducting nutrient budgeting and analysis of soil and crops, hedgerows and biodiversity, diversified rotations, and legume-rich leys. The practices scoring the fewest points were agroforestry practices, contour farming, use of biostimulants and intercropping. A snippet of Figure A1, showcases the top 10 and bottom 10 ranked practices, presented below in Figure 1.

3.1.1 Effectiveness-feasibility scatter plot analysis

The scatter plot analysis (Figure 2) revealed distinct strategic positions for RA practices. Most practices (n = 46) clustered in the high-effectiveness/high-feasibility quadrant, representing optimal adoption candidates. Five practices occupied the low-effectiveness/low-feasibility zone (including biostimulants and landscape features). High-effectiveness/low-feasibility practices (biopesticides, water management) represent opportunities where targeted support could improve adoption. Only minimum-till occupied the high-feasibility/low-effectiveness quadrant.

Practices such as conducting nutrient budgeting and analysis of soil and crops came out on top again; at the same time, the plot deferred from the overall score rankings, in the case of practices like diversified rotation, which was positioned more desirably than hedgerows and biodiversity. Similarly, multispecies leys and crop residue incorporation also switched positions in the two plots, allowing for nuanced insights in the scatter plot vis-à-vis Figure A1.

3.1.2 Practices affected by soil types

Respondents indicated that soil type influenced the perceived effectiveness or feasibility of certain practices. Tillage practices like no till and controlled traffic farming were cited as subject to change in response to the soil type and properties. The survey recorded that no-till was an ineffective practice in light spongy soils. Respondents mentioned the effectiveness of practices like companion cropping, intercropping, living mulch, etc., was also heavily dependent on soil and choice of crop species. Biofertilisers, biopesticides and biostimulants showed a great deal of variation in performance in different farming systems.

Figure 2 presents a scatter plot displaying the relationship between effectiveness and feasibility scores for all 57 regenerative agricultural practices evaluated by root crop experts (n = 11 respondents). Each point represents one practice, with the x-axis showing mean effectiveness score (1–5 scale) and the y-axis showing mean feasibility score (15 scale). Respondents indicated confidence (low, medium, high) in each assessment; confidence levels are reflected in point coloration. A diagonal reference line (y = x) represents the boundary where effectiveness equals feasibility; practices plotted below this line have higher effectiveness than feasibility ratings and vice versa.

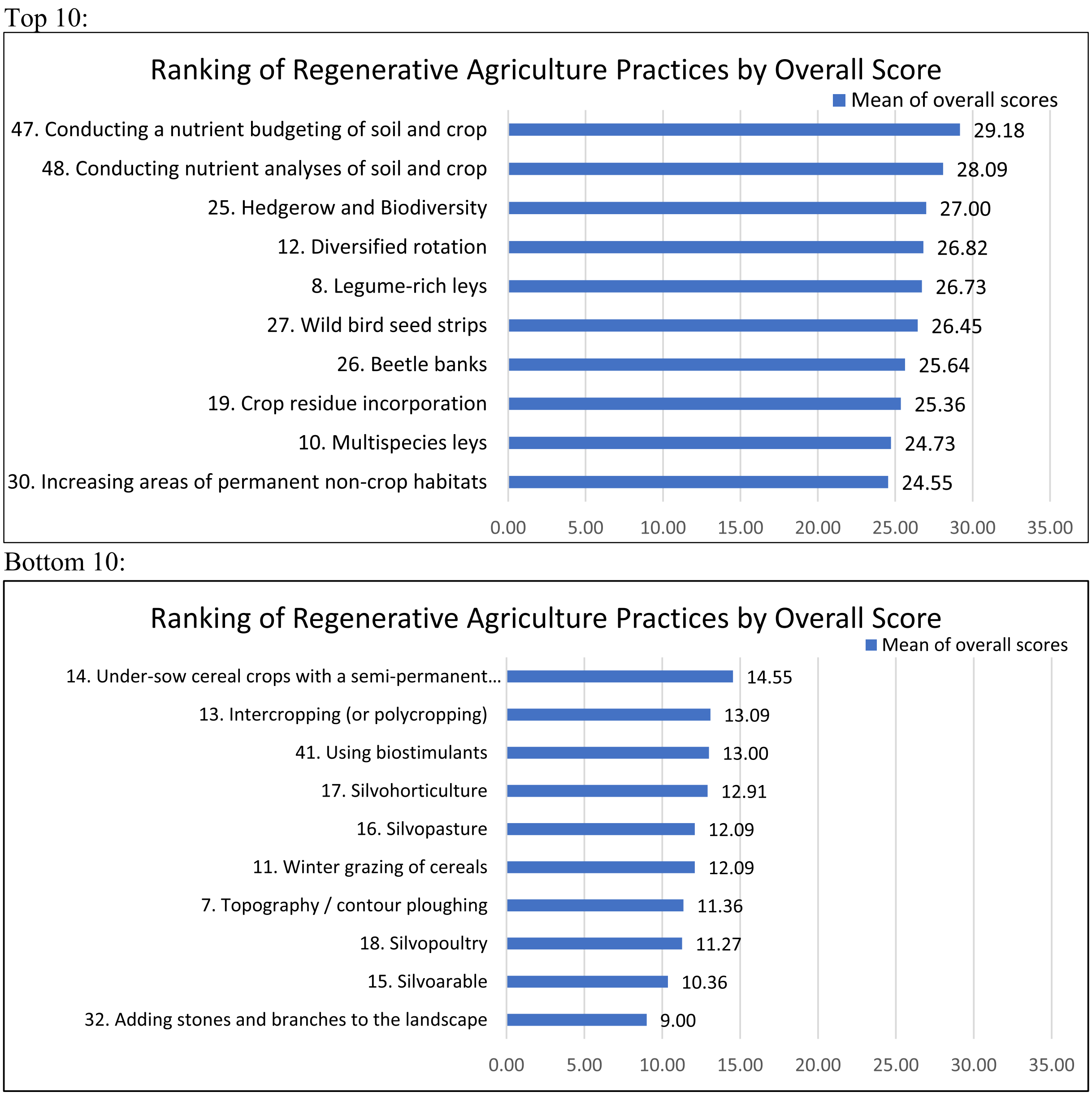

FIGURE 1
Snippets of Figure A1 Ranking RA practices by Overall Scores (Top10 and Bottom10). Top 10 and bottom 10 ranked regenerative agricultural (RA) practices for UK root vegetable production, extracted from Figure A1. Practices are ranked by weighted overall score = (Effectiveness + Feasibility) × Confidence, derived from expert assessments (n = 11). Higher scores indicate practices with strong combined performance and expert confidence; lower scores indicate limited perceived applicability in root crop contexts.

3.2 Interview results

Table 1 below describes the characteristics of the anonymised root crop experts (n = 9) involved in the qualitative interviews. This comprises the region of operation, years of experience, crops managed, farm size and production style.

Data collected from these interviews underwent thematic analysis to explore the adoption barrier for RA practices and interventions associated with these barriers. The themes and subthemes are covered briefly in Figures 3, 4.

Figures 3, 4 present thematic analysis diagrams from semi-structured interviews with UK root crop experts (n = 9). Figure 3 organizes five barriers to RA adoption: Economic and Resource Constraints, Policy and Institutional Barriers, Agronomic and Technical Constraints, Knowledge and Perception Barriers, and Market and Supply Chain Barriers. Figure 4 presents corresponding interventions across five themes: Policy and Market Incentives, Innovation and Technology, Knowledge and Experimentation, Social and Cultural Drivers, and Future-proofing and Market Trends

3.2.1 Barrier to RA adoption

3.2.1.1 Theme B1: Economic and resource constraints

Financial limitations represent the most fundamental barrier to RA adoption, particularly for smaller operations. Upfront transition costs accrue immediately while benefits materialise gradually, creating cash flow pressures. As one farmer stated: "Cost is the biggest

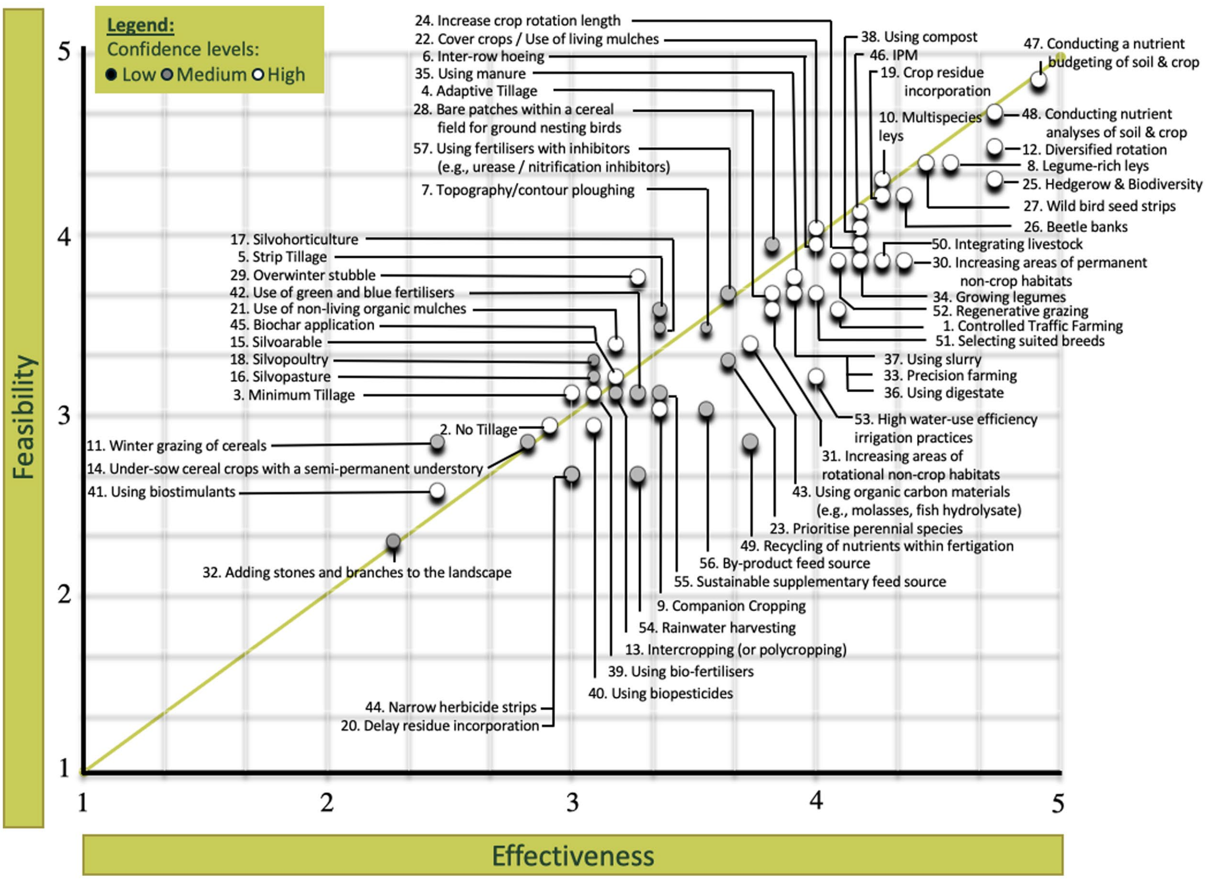

FIGURE 2
Effectiveness–feasibility scatter plot.

TABLE 1 Respondent characteristics.

S. no	Region	Years of experience	Crops grown	Land/operation size	Production style
1	Cambridgeshire	20	Onions, Potatoes	Large Scale >200 ha	Reduced chemical use
2	North England	28	Onions	Small Scale <50 ha	No till
3	Multiple location within England and Scotland	16	Potatoes	Large Scale >200 ha	Conventional and organic
4	Norfolk	13	Carrots and Potatoes	Large Scale >200 ha	Conventional and organic
5	Multiple location within England and Scotland	22	Carrots and Parsnips	Large Scale >200 ha	Conventional and organic
6	Ireland and UK	25	Potatoes	Large Scale >200 ha	Conventional
7	Across UK	30	Potatoes	-	-
8	Norwich	7	Sugar Beet and beetroot	Large Scale >200 ha	Regenerative
9	Cirencester	17	Carrot, potato, parsnips and beetroot	Medium Scale > 50 ha	Regenerative with agroforestry

barrier… to go down more regenerative, it comes down to finances" (Respondent 5). For smaller farms, the challenge is acute: "If I'm a small farmer with only a couple of hundred hectares, I do not want to lose 10–20% of my farming land" to regenerative features such as wild bird seed strips or hedgerows that reduce productive area (Respondent 1).

Labour and machinery present specific cost barriers. Drip irrigation systems, while improving water use efficiency, can be "very labour heavy because the drips get damaged easily. You get a lot of leaks" (Respondent 1). Similarly, "you need to have specialised machinery, like in the case of potatoes (*planters, cultivators, haulm toppers, and harvesters*) that need to be replaced" (Respondent 2). Equipment costs

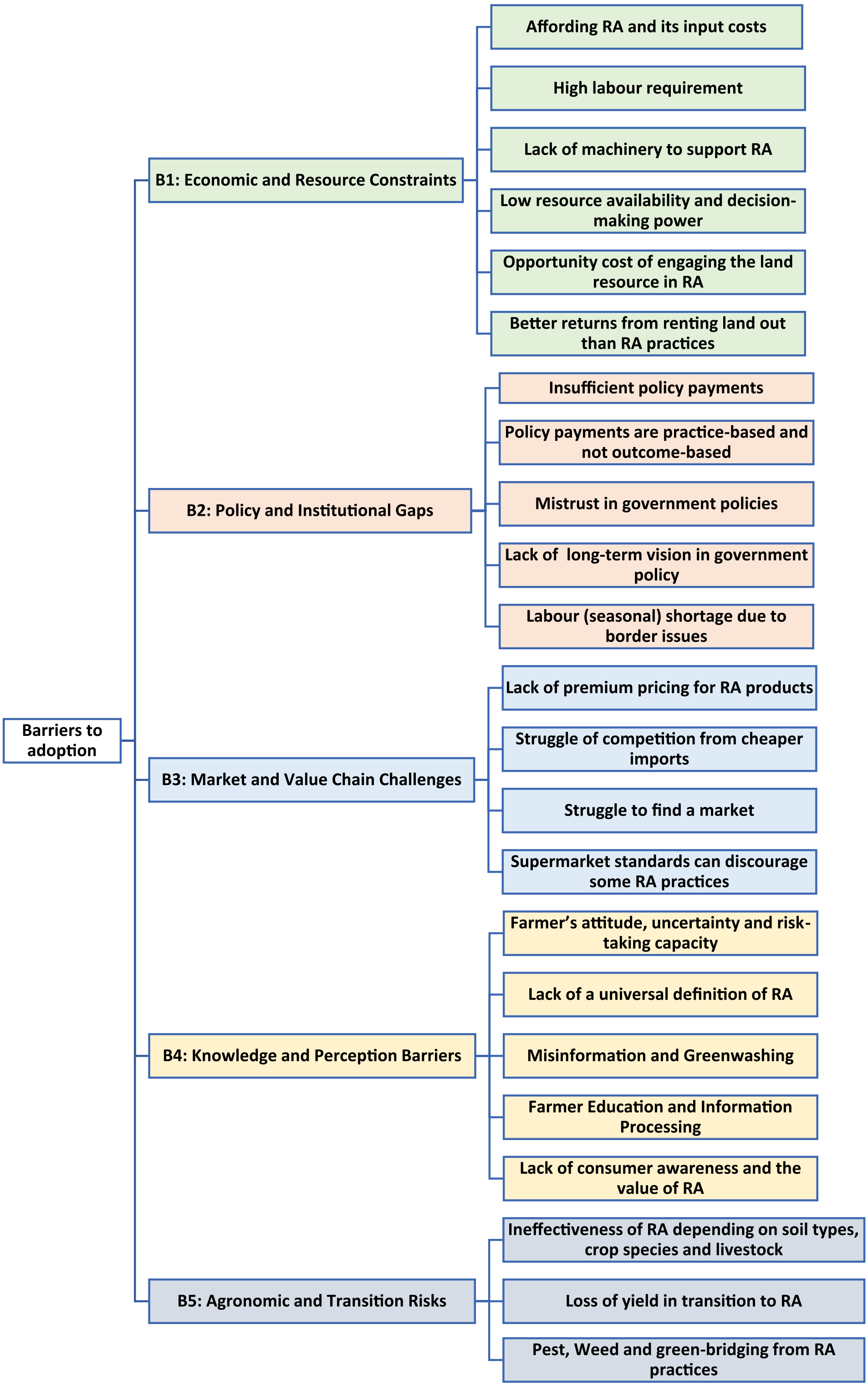

FIGURE 3
Barriers to adoption of RA practices: themes and subthemes.

are prohibitive: a 2-metre laser-weeder costs £550,000, and a 6-metre model costs £1.25 million (Respondent 4), prices far exceeding most farm budgets.

Land tenure constrains long-term planning. Many operations depend on rented land, preventing rotation-based transitions: "Operations operate on rented land. So, we do not have control of the full rotation ourselves; we have to coordinate with landlords and other tenants" (Respondent 4). Opportunity costs further discourage adoption: productive land dedicated to hedgerows or leys generates no direct revenue, yet "rent money can actually be more profitable than losing land to hedgerows" (Respondent 1).

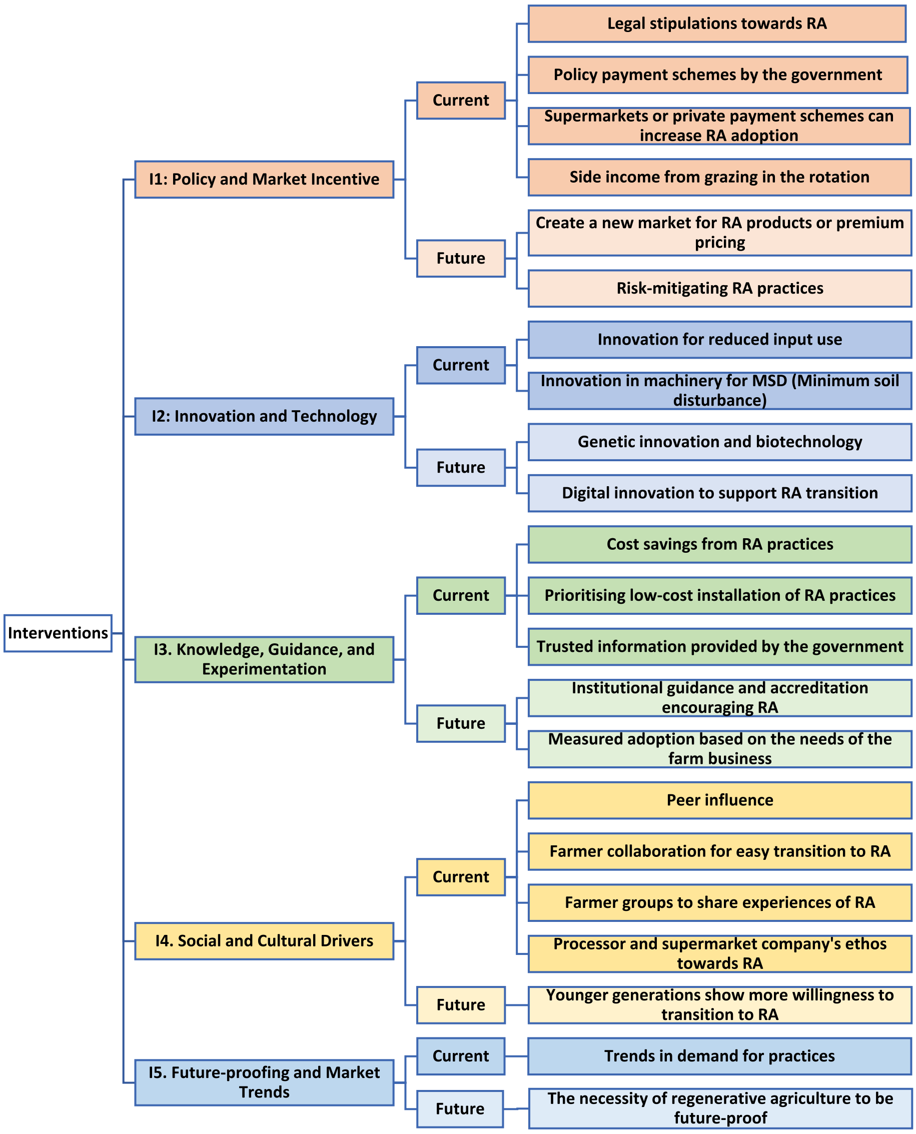

FIGURE 4
Interventions to address RA adoption barriers: themes and subthemes.

3.2.1.2 Theme B2: Policy and institutional gaps

Government support structures fail to adequately incentivise RA adoption. Farmers report that schemes like the Sustainable Farming Incentive (SFI) exist, but claim these payments do not match up to previous EU subsidies: "The amount of subsidy UK farmers receive compared to that received from the EU is a lot less than it was; it has not been a like-for-like"(Respondent 3).

Policy design favours prescriptive practices over measurable outcomes, reducing flexibility for farm-specific innovation. Respondent 3 emphasised: "It has to be tangible… how do we measure it, how do we manage it, how do we improve it? We cannot do that without numbers." This puts root crop farmers at a disadvantage as it does not allow them to compensate for practices difficult to incorporate (For eg. No-till) with enhanced outcomes from others.

Inconsistent policy creates severe uncertainty. Respondent 9 described how "the government took a complete U-turn on its previously made promises regarding Inheritance tax and Employer's National Insurance Contributions, which significantly affected our bottom line by over 20%." The sudden closure of SFI applications compounds farmer hesitancy: "Last year you could get 50% grant funding… and this year you cannot. So there's a definite barrier to entry there" (Respondent 4). Beyond direct payments, labour policy failures constrain adoption. Respondent 1 noted: "We had labour shortage because seasonal workers were not allowed in… for us as a business, one of the biggest issues we have is labour and immigration."

3.2.1.3 Theme B3: Market and value chain challenges

Premium pricing for RA products remains absent despite environmental claims. As one farmer explained: "Organic potatoes have a slight premium, but here there's a big risk (but not enough reward)… so I think farmers are always looking at risk and reward" (Respondent 3). Competition from cheaper imports, particularly from the Netherlands and New Zealand, undercuts domestic prices, making higher-cost RA systems economically unviable.

Supermarket standards create direct conflicts with regenerative principles. Strict grading and sizing requirements force farmers to prioritise appearance over sustainability. For onions: "Markets set sizing limits, anything below 50 mm or above 90 mm, you cannot sell" (Respondent 1), forcing deeper ploughing to achieve desired bulb sizes. Strip-till beetroot demonstrates this tension: "We tried strip tillage and the beetroot came up almost rectangular because of how narrow the tilled area was, and it just squished them" (Respondent 8).

Market volatility further discourages adoption. Organic onions "do not last very long, so you have to be very quick with selling them. It's not really a big market for them" (Respondent 1), making regenerative conversion too risky.

3.2.1.4 Theme B4: Knowledge and perception barriers

Risk aversion dominates farmer decision-making, particularly given weather uncertainties: "There's enough inherent risks in producing crops in the UK… we are all very averse to risk because the weather conditions put enough risk" (Respondent 3). The absence of a universal RA definition exacerbates this uncertainty. One farmer expressed: "I'm personally not bought into the concept that regenerative is reparative. If you are using glyphosate, how can it be?" (Respondent 5). Another noted: "We're not fully regenerative because I do not think any of us really know what that means yet with regards to vegetables" (Respondent 4).

Commercial interests fuel misinformation around biological products. Respondent 2 noted that biostimulants "are so pushed, but that's from commercial interest," while Respondent 8 observed: "You can put 'bio' in front of anything these days to sell it." These concerns are legitimate: many products lack robust evidence for root crops.

Educational limitations reduce farmers' capacity to evaluate claims critically. Respondent 8 stated: "There is too much information out there, and choosing the relevant and trustworthy knowledge is difficult. They often lack the education to interpret the data or a paper, and they do not have the critical thinking skills."

Consumer awareness remains insufficient to drive market demand. Without consumer willingness to pay premiums, farmers see little incentive to bear adoption risks: "The big question is: if input costs are going to be slightly higher by being regenerative, ultimately, is the consumer willing to pay for it?" (Respondent 3).

3.2.1.5 Theme B5: Agronomic and transition risks

Practice effectiveness varies substantially across contexts. Controlled traffic farming "is good but not on every soil type. Some of it is very spongy, like the black thin soils we have here. It's very easy to move and blow around" (Respondent 1). Crop species respond differently: "Strip tilled sugarbeets may be just not quite the right species of plant to grow, as they grow rectangularly without proper seedbed preparation, and become difficult to harvest." (Respondent 7).

Livestock integration can generate unintended consequences: "We've had pigs. The downside is that they dig wallows, which can take the oxygen out of the soil and then you get disease issues when you put carrots in" (Respondent 5).

Reduced-tillage practices inadvertently create pest and disease problems. Respondent 4 noted: "Where there's been reduced tillage, we have seen increased wireworm numbers, increased thistle numbers… min-till, low-till have been failures there." Cover crops create "green bridges" for pest survival: "Cover crops like Red Clover can host nematodes that feast on carrots when grown right after it in the rotation" (Respondent 4), and "Brassica cover crops can be a big problem for nematodes affecting sugar beet" (Respondent 8).

3.2.2 Interventions to address adoption barriers

3.2.2.1 Theme I1: Policy and market incentives

Government payment schemes reward the early adopters of RA. Respondent 9 described how the SFI "rewards sustainable practices… we get more money now and without changing anything that we do." Another farmer confirmed: "The SFI is generally a good thing… you have to do very little and you are going to earn 8 or 900 pounds per hectare" (Respondent 8).

Private sector initiatives complement public payments. Respondent 8 noted: "British Sugar offer a yield assurance scheme; if your crop fails, as long as you drilled it at the right time, you get 80% of your yield." Supermarkets too can create additional incentives: "I think we'll see the likes of the big supermarkets actually incentivising regeneration somehow, whether that's selling a premium or establishing a sustainable standard" (Respondent 8).

Some RA practices can open up new markets and additional income streams. Livestock grazing arrangements generate revenue: "There's a financial incentive from the grazier that wants somewhere to put their sheep in the winter" (Respondent 8). Integrated systems in the right crop rotation phases allow the soil to naturally replenish nutrients (like potassium and phosphorus essential for root and tuber development): "The easiest way in a true regenerative style would be to have leys that you graze with livestock, so you are adding fertility while making money" (Respondent 9).

Future interventions should establish a niche for RA products in the market and design clear standards, certification and labelling to allow for premium pricing. "The better way is to create a market where you are paid for what you do more progressively. So you are rewarded, that probably needs to be developed." (Respondent 5).

3.2.2.2 Theme I2: Innovation and technology

Precision technologies reduce input dependencies while maintaining productivity. Laser-weeders exemplify this: "We now have a laser weeder machine that works 24 h, and it just kills weeds with the laser" (Respondent 1). Gas burners and targeted chemical reduction offer alternatives: "Avoid soil disturbance not only from tilling but also from spraying. With proper management, we do burn off weeds" (Respondent 3).

Farmers adopt creative machinery adaptations. Respondent 6 noted: "The technology is there. Manufacturers are producing ring rollers, and eventually, you'll come across something that will work in several soil conditions. At the moment, we have got a local guy who welded an old ring roller." Modern equipment is also emerging: "One of our growers has got a new minimal-till potato planter" (Respondent 3).

Biological product development expands options. Respondent 5 uses biopesticides: "We use the equivalent of a soap to kill aphids in carrots. They're expensive, but in an organic system, they are the only option we have." Advancements in genetic technology also offer long-term potential: "Gene editing is probably a massive win because it will suddenly bring to market a whole range of varieties with resistance" (Respondent 8).

Digital tools improve decision-making. Respondent 3 uses the Land App "to map the farm at no cost and identify areas that can receive funding that we do not currently access." Respondent 5 deployed "in-field weather data systems which measure soil moisture capacity, rainfall, irrigation inputs at different depths," enabling data-driven management.

3.2.2.3 Theme I3: Knowledge, guidance, and experimentation

Low-cost entry points facilitate trials. Respondent 9 emphasised: "Harness the existing nature and wildlife, especially predatory insects. We do not see biodiversity as a charitable activity. We see it as a really effective tool for sustainable crop production. Agroforestry, wildflower strips, and intelligent cover crop management all boost biodiversity and provide biological control. "Visible cost savings encourage such experimentation. Respondent 8 described how reducing tillage eliminated one full-time ploughing position: "We used to have one man who would plough from September through March… he retired. There was no need to replace him."

Context-specific guidance matters. Respondent 5 emphasised: "Manage every field on its own merit and ask why. Why are we putting on? Do we need to put that on? Because in my experience, less is more."

Trusted government-backed information drives adoption. Respondent 8 stated: "We are getting all our soils carbon tested as part of the SFI. If the government were not paying us, I would not be doing it." Farmer-led research proves persuasive: "Making sure a lot of the research is done on the farm by farmers rather than just by scientists" (Respondent 7).

Formal accreditation systems would strengthen confidence. Respondent 5 noted: "If you go organic, you are certified, you can put it on your packaging." A comparable RA certification scheme, validated for root crops specifically, would address knowledge gaps. Similarly, Respondent 7 suggested: "More interaction between farmers and the public, and LEAF's education through open farm sunday can create awareness and value for an RA label."

3.2.2.4 Theme I4: Social and cultural drivers

Peer influence powerfully motivates adoption. Respondent 9 explained: "Farmers like to see it in practice on a farm and like to hear from a farmer who's done it and made it work or learnt from their mistakes." Respondent 4 concurred: "It definitely helps if you have other colleagues or farmers who want to farm in the same way. Our no-till potatoes trials encourage many."

Farmer collaboration addresses machinery and knowledge barriers specific to root crops. Respondent 1 described: "Swap fields with other farmers, rent out one field and grow something else. Neighbouring farms can work together." Respondent 8 noted: "Rotation in collaboration, where one of our neighbours, a big livestock farmer, grazes most of the farms in the region. For expensive equipment like laser-weeders or minimal-till planters, shared ownership among root crop neighbours reduces capital barriers."

Structured networks accelerate adoption. Respondent 9 highlighted: "Cluster groups, farm trials, the Adopt project, the Innovative Farmers project are the big ones we get involved in."

BBRO (British Beet Research Organisation) and the British Carrot Grower's association were some groups listed by respondents.

Industry commitments create cultural momentum. Respondent 1 observed: "Bigger farmers definitely do it. Smaller ones will follow up because they have to." Respondent 7 noted: "Tesco, Aldi etc. insist on schemes like LEAF from suppliers, which encourages RA."

Generational change promises future acceleration. Respondent 1 noted: "Younger farmers are all more innovative and looking forward to getting new technology involved."

3.2.2.5 Theme I5: Future-proofing and market trends

Market signals increasingly favour sustainability. Respondent 1 observed: "I hope organic produce will grow. It's a very visual trend, chemical use is going down, and they are not as heavy as they were." Respondent 4 added: "Through supermarkets, a lot of guidance steering towards RA has been coming from customers."

All nine respondents anticipate that RA will transition from voluntary participation to the norm. Respondent 1 predicted: "In 10 years, every single farmer will do something about it because they'll realise they have to preserve the land's fertility to grow root crops." Respondent 4 emphasised: "For the next generation, we cannot keep using finite resources, pesticides, and artificial nitrogen. We cannot keep polluting waterways, like nitrate leaching from potatoes. Regeneration ticks that box."

This shift reflects recognition that RA represents the only viable long-term sustainability pathway in an era of tightening environmental regulations and increasing climate volatility.

4 Discussion

4.1 Assessment survey analysis

Clustering of 46 practices in the high-effectiveness/high-feasibility quadrant challenges the assumption that soil-disturbing cropping systems are inherently incompatible with regenerative approaches. This finding aligns with the post-productivist agricultural paradigm shift documented by Beacham et al. (2023), where farmers, taking diverse pathways, worked towards identifying as regenerative, even within intensive production systems.

Nutrient budgeting and analysis of soil and crop ranked highest, reflecting their role as essential entry points for RA transitions. These practices provide measurable baselines and align with Newton et al.'s (2020) emphasis on RA being process as well as outcome driven, where systematic assessment precedes practice implementation. Diversified rotations and legume-rich leys performed strongly, consistent with literature demonstrating their effectiveness in building soil health and reducing synthetic input dependence. In particular, potato-wheat-peas with grass-clover rotations increased soil organic carbon (SOC) by 2.3 tons/ha/year, by restoring the large macroaggregates (that house SOC) destroyed by potato crops (Guest et al., 2022). Legume-based rotations reduced nitrogen fertiliser requirements by up to 30% (Reckling et al., 2016), validating expert assessment of their environmental impact and feasibility.

However, water management and livestock integration practices scored lower on feasibility despite high effectiveness ratings. Livestock integration, while improving nutrient cycling and reducing pest pressure through herbicide-resistant weed control (Schut et al., 2021; BES, 2025), still requires substantial upfront investment and skilled management (Asai et al., 2018; BES, 2025). Modelled analysis substantiated that regenerative systems with livestock yielded lower commodity income (214 GBP) than conventional systems (247 GBP), but profit was recovered with policy payments and carbon credits (Teanby and Cackett, 2023). This highlights that policy interventions are essential to close the economic feasibility gap.

Agroforestry practices showed notably low confidence levels, likely reflecting limited familiarity with root crop applications. These results were significantly different from the trials at Tolhurst organic, which displayed agroforestry as having promising results in the context of root crops like sugarbeet (Kanzler et al., 2018). The lower confidence scores may be due to the longer-term nature of agroforestry benefits, which can take years to manifest, and are especially problematic to witness on leased farmland. The lack of specialised knowledge and machinery required for the successful cultivation of root vegetables in understoreys also hinders the adoption of agroforestry practices.

4.2 The effectiveness-feasibility gap

Effectiveness scores substantially exceeded feasibility scores across most RA practices. Only 10 of 57 practices scored above 4.0 for feasibility, compared to 21 for effectiveness. This gap suggests that while root crop experts recognise the value of regenerative practices, significant barriers exist to their implementation. The interviews clarify that these barriers are not simply technical but fundamentally economic and institutional. Literature on reduced-tillage systems in root crops demonstrates this clearly: while reduced tillage and controlled traffic farming offer multiple benefits [erosion control, fuel efficiency, improved water retention, enhanced soil biota; Drakopoulos et al., 2018 (potatoes); Mondal and Chakraborty, 2022], yield penalties [Koch et al., 2009 (sugar beet); NIAB, 2014 (sugar beet)] and high machinery investment requirements (Vermeulen et al., 2007; Hefner et al., 2019) (carrots) limit farmer adoption.

4.3 Variability in expert assessment

4.3.1 Context-specificity

Some practices showed a high coefficient of variation, no-till: 54%; delayed residue incorporation: 71%; narrow herbicide strips: 53%. This variability likely reflects the context-dependent nature of agricultural practices, where effectiveness and feasibility can vary significantly based on factors such as soil type, climate, farm size, market conditions, and management experience. The small-scale farmers (less than 50 ha) reported higher acceptance of practices like no-till in comparison to large-scale farms over 200 ha. Similarly, effectiveness also varies across soil type. In the case of a German study, no-till sugar beet yields fell by 15% on sandy soils but increased 13.8% on silty-loamy soils (Tebrügge and Böhrnsen, 2003). Such practices, influenced by soil type, local climate or size, warrant caution during transition, creating a need for decision-support tools enabling farm-specific practice selection.

4.3.2 Anchoring effect

Another reason for the variability was identified as an anchoring effect among root crop experts. In the interviews, the respondents tended to favour one of the regenerative principles (minimum soil disturbance, crop diversity, enhanced biodiversity, reduced synthetic input, etc.) as the central tenet of their farming philosophy. This often leaned towards either reduced synthetic inputs, as in organic farming (5 out of 9), or towards conservative tillage practices (3 out of 9). Their endorsement for other practices were dependent on their central tenet principle. Respondents with an organic focus rated practices such as legume-rich leys and biofertilizers highly due to the chemical requirements of the soil, and rated no till practices lower because tillage was essential in weed removal when herbicides cannot be used. At the same time, the conservative tillage farming approaches found it less effective to have diversified rotations and cover crops due to the difficulty of clearly defining growth phases and ley phases without tillage. Therefore, practices like no-till and narrow herbicide strips had such varied answers. This demonstrated that RA encompasses internally contrasting approaches, where the selection and prioritisation of 'core principles' can lead to fundamentally different production systems.

4.4 Interpreting multi-dimensional analysis

Overall score rankings and scatter plot positions showed different ranks for certain practices. Diversified rotation ranked below hedgerows in overall scores, but appeared equally feasible and more effective in scatter plots. Hedgerows, while effective for biodiversity and carbon sequestration (131 tonnes carbon per hectare annually according to Organic Research Centre (2021)), impose edge-effect costs, i.e., yield loss from shading and root competition, soil compaction, weed/pest pressure (Pywell et al., 2015) that can lead to malformed roots and reduced sugar accumulation. Conversely, diversified rotations offer yield benefits, e.g., alfalfa rotations increased sugar beet yield by 20–30% over monocultures in trials by Götze et al. (2017). These differences also highlighted why multi-dimensional analysis is essential, as linear rankings obscure critical trade-offs.

4.5 Barriers and interventions

The scoring exercise identified practices with relatively high perceived effectiveness and feasibility, while the qualitative insights add more nuance by revealing the contextual constraints and uncertainties that hinder adoption.

Practices such as controlled traffic farming (CTF) and water-use irrigation efficiency have been identified as highly effective but low in feasibility. They received high scores for effectiveness due to the benefits in soil health and ecosystem resilience. In past research on root crop tillage practices, CTF emerged as a productive practice under the principle of minimising soil disturbance to counter soil compaction as well as improve yield and profitability (Hefner et al., 2019; Farmer's Weekly, 2025; Vermeulen et al., 2007). However, interviewees highlighted that their feasibility was constrained by the inability to afford adjustments for machinery, which is often specialised and fixed-width in the case of sugar beet and potatoes. Interventional farmer-led machinery adaptations, such as modified potato planters and locally fabricated solutions (Respondent 6) demonstrate creative problem solving and incremental innovation. However, DIY solutions are temporary workarounds and need to be addressed at the manufacturing level with scalable and affordable equipment. Other technological interventions, like precision technologies for input reduction, particularly laser-weeding and targeted application systems, were cited by respondents as ways to overcome both economic and environmental constraints simultaneously. Respondent 1 still pointed out the high labour requirements and maintenance in practices like drip irrigation, slowing the momentum down.

On the other hand, enhanced biodiversity practices like hedgerows, wild bird seed strips and beetle banks were scored highly in both effectiveness and feasibility. Respondents confirmed their establishment was easy and low-cost, despite the edge effects and green bridges hindering productivity. SFI and countryside stewardship grants make the incorporation of biodiversity profitable. This aligned with a CPRE (Campaign to Protect Rural England) study demonstrating a return of 1.73GBP (from reduced input requirement) on every 1GBP spent on hedgerows (Organic Research Centre, 2021).

Few other practices supported by current payment schemes scored higher for feasibility in comparison to their effectiveness in this study, e.g., multispecies leys, cover crop/living mulch, over-winter stubble and agroforestry practices. At the same time, interviewees stressed that the payments were insufficient (when compared to prior EU subsidies) and the inconsistency of policy incentives deterred long-term adoption. A sentiment commonly shared by the Bradshaw (2025), which calls for more coherent policy frameworks in response to the sudden closure of SFIs (Bradshaw, 2025). The mismatch of high feasibility and low effectiveness can also be attributed to lapses in agricultural policy planning, including DEFRA's prescriptive, process-based payments rather than outcome-based ones. Respondent 9 reported receiving increased income from SFIs "without changing anything that we do." demonstrates how incentives reward implementing practices and not delivering measured results. Outcome-based payment approach has been advocated in Europe by Poeplau et al. (2015). A practice-based system does not allow root crop systems to compensate higher positive outcomes from applicable practices for practices difficult to implement (such as no till).

The intervention analysis revealed a sophisticated understanding and identification of government payment schemes as enabling factors among all 9 respondents. This reaffirmed the importance of financial incentives in the successful transition of root crop systems, as also documented by The Potato News Today on regenerative potato farming (Pieterse, 2025), stressing how farmers need to strategically leverage multiple support mechanisms simultaneously and hedge risks like scheme closure. Digital innovations in land monitoring systems and decision-support tools represent a fundamental shift toward data-driven uptake of scheme benefits.

While incentives and policy payments work as symptom-control for the absence of fair farmer income, the root cause is the ineffective market establishment and fair pricing. When choosing a central RA tenet as an anchor, 5 out of 9 respondents chose organic root crop farming over minimising soil disturbance due to the premium pricing available in this segment. Market and value chain challenges further explain the low uptake of practices such as strip tillage and the use of legumes. Such practices can fail to meet size, shape and appearance standards for commercial sale, especially in onions and carrots, where appearance is paramount (e.g., clovers in rotation can stimulate harmless, superficial scabs on potatoes, beets, radishes and parsnips). The interviewees also revealed that competition from cheaper subsidised imports diminished profitability, making the RA transition in high-value crops like potatoes a riskier proposition against Irish and Dutch imports (Respondent 8).

The private sector initiatives, particularly supermarket-led schemes and corporate sustainability commitments, represent a market-based solution that can potentially address fair pricing and protection for RA root crops. Respondent 8 mentioned the British Sugar yield assurance schemes which provide cover for yield protection and against virus yellows (2021–23), demonstrating an example of support from the private sector, mitigating risk for sugar beet farmers. Extension of such intervention strategies to other crops can prove beneficial in managing risk.

Concepts like premium pricing become complicated in the absence of a proper definition of RA, as mentioned earlier in the introduction (Newton et al., 2020). Lack of definitions and fixed metrics of RA practices creates misinformation among both farmers and consumers, giving way to greenwashing. Similar to many respondents, claiming that commercially sold biological inputs (especially biostimulants) advertised as in line with RA principles were ineffective on field. The research by Schütz et al. (2018) had similar results with biofertilizer, where root crops like potatoes and sweet potatoes exhibited the least improvement in both Phosphorus Use Efficiency (PUE) and Nitrogen Use Efficiency (NUE). The scepticism expressed by multiple respondents about commercial bias in biological product promotion suggests that technological solutions require credible evaluation and endorsement systems. Interviewees emphasised that farmers value information from the government, as it is seen as impartial and backed by on-farm trials. They desired more institutional guidance and accreditation from organisations like LEAF, similar to an organic certification, which would validate RA practices and build consumer trust.

This resonates with literature that stresses the role of farmer learning, peer influence, and trusted advisory systems in overcoming resistance to change, especially in IPM practices (Pretty and Bharucha, 2015), livestock integration (Asai et al., 2018), and enhancing biodiversity (Cottney et al., 2025), etc. The practices with high confidence and high mean feasibility scores often correlated with those already visible either on field or among farming peers, acting as "proof of concept." These practices were cover cropping, diversified rotations, and organic matter enhancement, which also suggests that regenerative approaches in root crop systems may focus more on compensatory practices (aimed at reversing the soil damage) rather than eliminating soil disturbance entirely.

Overall, the integration of results suggested that while RA practices were widely recognised as effective, adoption depended less on their agronomic potential and more on economic viability, institutional support, and market structures. This was similar to Lemke's findings on organic agriculture, where the main drivers of adoption were demand in the market and profits. (Lemke et al., 2024). The interventions highlighted that increasing adoption rates required a multi-level approach: reducing transition costs and risks, building institutional trust, aligning market incentives and governmental policy. Respondents were in consensus that shifting consumer expectations and tightening regulations would make RA adoption unavoidable and not optional, echoing in the literature on sustainability transitions in agri-food systems (Beacham et al., 2023; Schreefel et al., 2020; Cusworth et al., 2022). Table 2 presents a strategic framework to directly link each identified barrier to specific interventions at three different levels: individual farm, market, and policy.

The excess use of blue font denoting future/potential interventions highlights opportunities for improvement in making RA easy to adopt in the root crop sector.

4.6 Sample size limitations

This research is limited by a small sample size of expert respondents ($n = 11$ for survey, $n = 9$ for interviews) and purposive

TABLE 2 Mapping identified barriers with intervention.

Barriers	Individual Level Interventions	Market Level Interventions	Policy Level Interventions
Economic & Resource Constraints			
Affording RA and input costs	• Cost-saving RA practices adoption • Prioritizing low-cost installations (wildflower strips, hedgerows) • Measured adoption based on farm business needs	• Side income from grazing rotations • Carbon credit markets • Premium pricing for RA products • Supermarket sustainability premiums	• Risk-mitigating: SFI and countryside stewardship payments • Farming Equipment & Technology Fund grants • Long-term policy certainty
High labour requirements	• Farmer collaboration for easy transition • Innovation in machinery for minimum soil disturbance	NA	• Policy reform for seasonal workers • Support for mechanisation investments
Machinery barriers	• Peer machinery sharing arrangements • Innovation in machinery for minimum soil disturbance • Innovation for reduced input use	• Processor companies' ethos: Equipment leasing and financing schemes	•Farming Equipment & Technology Fund grants • Capital grants for precision equipment
Land tenure insecurity	• Farmer Collaboration: Long-term tenant agreements • Collaborative rotations with landlords	• Digital innovation: for land management	• Policy: Landscape recovery scheme: Funding for tenant farmer- landowner cooperation
Market & Value Chain Challenges			
Lack of premium pricing	• Trends in demand: some forms like organic farming receive premiums • Accreditation: Apply for labels and certifications	• Supermarket sustainability standards and commitments • RA certification and labelling schemes	• Standards and certification framework • Create a market: Consumer awareness campaigns
Import competition	• Trends in demand: Product differentiation strategies • Create a market: Local market development	• Processor ethos: Supply chain standards and transparency	• Trade policy supporting domestic production • Policy payments that can support competitive pricing in global markets
Supermarket standards	• Innovation in machinery and genetic varieties: Crop planning for market specifications • Create a market: Local market development	• Revised grading standards for RA products especially like no till root crops • Waste reduction initiatives	• Trusted information provided by the government • Institutional guidance and accreditation encouraging RA
Knowledge & Perception Barriers			
Risk aversion & uncertainty	• Peer learning and demonstration • Incremental and measured adoption	• Institutional guidance and accreditation encouraging RA •Risk-mitigating: yield assurances and private payment schemes	• Trusted information provided by the government • Policy payment schemes by government
Lack of RA definition	NA	• Institutional guidance and accreditation encouraging RA	• Trusted information provided by the government • Legal stipulation: reduced synthetic input to shape farmer understanding of RA
Misinformation & greenwashing	• Accreditation: Apply for labels and certifications	• Processor ethos: Supply chain standards and transparency	NA
Limited farmer education	• Peer influence and learning • Farmer groups to share experiences • Younger workforce show more critical thinking	• Institutional guidance and accreditation encouraging RA	• Trusted information provided by the government
Agronomic & Transition Risks			
Soil type limitations	• Measured adoption based on the needs of the farm business	• Digital innovation to plan and implement RA transition	NA
Yield loss during transition	• Prioritising low-cost installation of RA practices • Farmer collaboration • Genetic innovation and biotechnology	• Risk-mitigating: yield assurances • private payment schemes	• Policy payment schemes by government

(Continued)

TABLE 2 (Continued)

Barriers	Individual Level Interventions	Market Level Interventions	Policy Level Interventions
Pest & disease risks	• Innovation for reduced input use • Genetic innovation and biotechnology	• Risk-mitigating: yield assurances	• Policy payment schemes by government
Policy & Institutional Gaps			
Insufficient payments	• Digital innovation such as land management apps prescribing planning around incentive schemes	• Supermarkets or private payment schemes can increase RA adoption	•Policy: Long-term policy commitments
Practice-based vs outcome-based payments	• Measured adoption based on the needs of the farm business • Digital innovation to measure baseline and current impacts from practices	• Institutional guidance and accreditation: based on outcomes	• Policy reform toward outcome-based payment schemes
Policy uncertainty	NA	NA	• Trusted, well-researched information provided by the government • Policy: Long-term policy commitments

Table maps identified barriers to regenerative agriculture adoption against corresponding interventions at three operational levels: farm, market, and policy. Black font colour indicates current interventions, while blue font colour indicate future/recommended interventions.

sampling from UK root crop stakeholders. While appropriate for exploratory qualitative research and expert elicitation, these numbers preclude statistical generalisation to the broader UK farming population or other geographic contexts. The findings represent expert opinion and farmer experiences from this specific sample rather than empirically established outcomes applicable universally. Practitioners and policymakers should treat these findings as experiences and insights requiring validation through larger-scale surveys, multi-year field trials, and regional comparative studies before implementing at scale. The identified barriers and interventions reflect the views of respondents in this study and may not capture all perspectives within the diverse root crop sector in the UK.

5 Conclusion

This study evaluated 57 regenerative agricultural practices in the UK's root vegetable production system. Nutrient budgeting, diversified rotations, and hedgerows emerged as high-effectiveness/high-feasibility candidates, whilst agroforestry and no-till showed limited applicability. The effectiveness-feasibility gap revealed that adoption barriers were fundamentally economic and institutional rather than technical. Economic constraints, policy inconsistency, absent market premiums, and knowledge gaps collectively suppressed the uptake despite recognised practice effectiveness. The barrier-intervention framework identified solutions across farm, market, and policy levels, with substantial opportunity for policy and market innovation.

In conclusion, RA in root crop systems is agronomically viable and institutionally necessary. Widespread adoption requires coordinated intervention across farm, market, and policy domains, underpinned by trusted information systems and financial instruments that mitigate transition risk. This research provides exploratory and experience-informed insights for practitioners and policymakers in the root crop sector.

Future research to aid various stakeholders in choosing the right RA practices for root crops should prioritise: (1) long-term field trials validating effectiveness rankings across diverse UK agroecological contexts; (2) economic analysis of transition pathways accounting for policy payments and market premiums; and (3) policy analysis optimising incentive structures for RA adoption.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

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Supplementary material

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