

Precision Farming in the UK

Technological Advances towards Zero Pesticide Crop Protection

Virtual Mobility Synthesis Report

COST Action CA21134

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September 2026

Executive Summary

Precision farming can reduce unnecessary pesticide use by improving the timing, location and choice of crop-protection actions. It cannot, by itself, guarantee zero-pesticide production.

The strongest UK pathway combines Earth observation, in situ sensing, decision support, process-based modelling and targeted control technologies. Each component addresses a different part of the decision chain.

UK examples already span weed mapping, integrated pest management platforms, electrical weed control and early pest detection. Research infrastructures such as the North Wyke Farm Platform support system-level evaluation.

Wider uptake still depends on cost, usability, digital skills, data interoperability and trust. Policy support is strengthening, but technologies need field-scale validation and farmer participation before routine deployment.

1 Purpose and Scope

This report is a detailed companion to the Virtual Mobility outcomes report for COST Action CA21134. It synthesises UK evidence relevant to lower-input crop protection.

The review covers current technologies, research and commercial initiatives, adoption barriers, policy support and future collaboration priorities. It uses the North Wyke Farm Platform as an integration case study.

Evidence was selected for its relevance to UK practice, decision support or the integration of observations and models. The examples are illustrative rather than exhaustive.

Zero-pesticide crop protection is treated as a long-term direction. The immediate and evidence-based goal is to avoid unnecessary applications while maintaining effective protection and agricultural productivity.

2 Technology Pathways for Targeted Crop Protection

2.1 Sensing and Mapping

Precision farming begins with observations that resolve variation within and between fields. Satellite, UAV and proximal sensors can detect changes in crop condition, soil properties, weeds and environmental stress.

These observations become useful when they support a defined action. Machine readable maps can guide scouting, treatment zones, variable-rate application or a decision to withhold treatment (Alexopoulos et al., 2023).

UK research demonstrates this pathway in both grassland and arable systems. Precision technologies can improve nutrient management, while UAV imagery can map black-grass in cereal fields (Higgins et al., 2019; Cox et al., 2023).

A detection map does not create a reliable treatment decision on its own. Field calibration, economic thresholds and compatible application equipment remain necessary.

2.2 Process Based Modelling

Process-based models represent causal relationships among crop development, soil, water, carbon and the atmosphere. They can test scenarios beyond the period or location of available observations.

JULES-crop extends the Joint UK Land Environment Simulator with a generic representation of annual crops. It has been evaluated for wheat, maize, soybean and rice (Osborne et al., 2015).

Its contribution to crop protection is mainly contextual. It can represent crop condition and environmental response, but it does not replace pest-specific surveillance or intervention thresholds.

2.3 Model Data Fusion and Machine Learning

Model-data fusion combines observations with process models and estimates uncertainty. CARDAMOM provides a Bayesian framework for constraining ecosystem carbon dynamics with field and Earth observation data (Bloom and Williams, 2015).

Applications in Great Britain have estimated grassland carbon dynamics and management effects across fields and mixed-use landscapes (Myrriotis et al., 2021, 2022; Milodowski et al., 2023).

UFLUX uses machine learning to link eddy-covariance measurements, satellite vegetation observations and meteorological drivers. It supports gap filling and spatial upscaling across several resolutions (Zhu et al., 2023a, 2023b, 2026).

These frameworks improve environmental context, anomaly detection, scaling and uncertainty analysis. Their direct crop-protection value must still be demonstrated through decisions and measured field outcomes.

2.4 Targeted and Non Chemical Intervention

Remote sensing can define treatment zones for site-specific weed management. The black-grass study by Cox et al. (2023) shows how UAV imagery and machine learning can support this step.

RootWave offers electrical weed-control systems as a chemical-free alternative to herbicides (RootWave, n.d.). TomatoGuard combines volatile-organic-compound sensors and machine learning for earlier detection of tomato stress and pest pressure (UK Agri-Tech Centre, 2025).

These examples move beyond monitoring towards intervention. Their performance still depends on crop type, operating conditions, detection accuracy and comparison with established management.

3 UK Initiatives and Relevant European Programmes

The PANGEOS COST Action links remote sensing with field phenotyping, precision agriculture and sustainable land management. It supports knowledge exchange among researchers, end users and policy stakeholders (COST Association, n.d.).

The UK-coordinated IPM Decisions platform gives farmers, advisers and researchers access to weather data and decision-support systems for pests, weeds and diseases (IPM Decisions, n.d.).

The LINKDAPA project illustrates a different route to adoption. Its cloud platform combines soil, historic yield and satellite data while addressing affordability and adaptability (Latherow et al., 2024).

Collectively, these initiatives connect research networks, decision support and farm implementation. Their combined value lies in translating observations into decisions that users can understand and test.

4 Case Study North Wyke Farm Platform

The North Wyke Farm Platform is a 63 ha, farm-scale research infrastructure in southwest England. It combines commercial farming conditions with intensive environmental monitoring (Orr et al., 2016; Takahashi et al., 2018; Rothamsted Research, 2026).

The platform was established in 2010. One farmlet began transitioning to arable production in April 2019, extending the infrastructure beyond its original grassland focus (Hawkins et al., 2023).

A central strength is the connection between environmental observations and recorded field events. These records include spraying, fertiliser application, cultivation, grazing and harvesting (Hawkins and Harris, 2023).

The datasets have supported process-based modelling, model-data fusion and machine-learning research. Examples include farm-scale system modelling, inferred management events and fine-resolution flux estimates (Wu et al., 2016; Myrriotis et al., 2021; Zhu et al., 2023a, 2023b).

Continuous eddy-covariance measurements also reveal how management and pasture type affect carbon exchange (Cardenas et al., 2022). This evidence helps separate management effects from background environmental variability.

Precision pesticide application is not yet a routine platform operation. NWFP is therefore best viewed as a test bed for linking detection, prediction, management records and verified outcomes.

5 Farmer Engagement and Adoption Requirements

Technical performance is only one condition for adoption. Cost and adaptability have limited precision-farming uptake among arable farmers in the UK and Germany (Latherow et al., 2024).

The VM discussions also identified digital skills, trust, data ownership, privacy and system integration as practical concerns (Yang, 2026). These issues influence both willingness and capacity to adopt.

Farmers and advisers should therefore participate in tool design, validation and evaluation. Interfaces must show the basis of a recommendation, its uncertainty and the action expected from the user.

Interoperable systems are equally important. Farmers should not need to rebuild the same field record across incompatible platforms, and they require clear control over access and reuse.

6 UK and England Policy and Funding Context

The UK Pesticides National Action Plan 2025 promotes integrated pest management and sets a national direction for reducing pesticide risks and impacts (Defra et al., 2025).

England's Farming Roadmap 2050 anticipates wider use of AI-enabled decision support, interoperable data platforms, Earth observation and automation (Defra, 2026a).

The Sustainable Farming Incentive 2026 includes payments for variable-rate nutrient application, sensor-guided herbicide spraying and mechanical robotic weeding (Defra, 2026b).

The Farming Innovation Programme and its ADOPT fund provide routes for farmer-led trials and demonstrations (UK Research and Innovation, 2025). These mechanisms can reduce the risk of testing new approaches under commercial conditions.

The policy landscape is therefore supportive, but its geographical scope matters. The pesticides plan is UK-wide, while the roadmap and incentive scheme described here apply to England.

7 Research and Collaboration Priorities

Future systems should connect observation, prediction and intervention in one auditable workflow. Hybrid modelling can combine process knowledge with the flexibility of machine learning.

Validation should focus on outcomes that matter to crop protection. These include detection accuracy, treatment-zone reliability, avoided applications, yield, cost and any change in resistance risk.

NWFP can support controlled integration and long-term evaluation. Commercial farms remain essential for testing transferability, operating constraints and economic value across different crops and business models.

The VM follow-up plan proposes collaboration around JULES, LPJ-GUESS, CLM, CARDAMOM and UFLUX. A useful next step is to compare uncertainty and decision value across these modelling approaches.

Research should also address governance. Clear rules for data access, model updates, accountability and farmer consent are necessary when automated recommendations influence crop-protection decisions.

8 Conclusion

The UK now has many components required for more targeted crop protection. They include fine-scale sensing, decision support, modelling, data fusion and non-chemical intervention.

The strongest near-term contribution is better integrated pest management and lower unnecessary pesticide use. Whole-system zero-pesticide production remains crop specific and cannot be inferred from monitoring capability alone.

Progress will depend on validated decision chains, interoperable data, affordable tools and farmer participation. NWFP offers a strong environment for integration, while commercial trials must establish practical and economic value.

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