Spot farming: A novel concept for sustainable and climate-resilient crop production

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Prof Dr Jens Karl Wegener from the Julius Kühn Institute in Braunschweig, Germany, discusses Spot Farming, which he considers a novel concept for sustainable and climate-resilient crop production

Modern agriculture faces mounting challenges: climate change, biodiversity loss, soil degradation, resource scarcity, and shifting societal expectations. At the same time, farmers are expected to produce food that is both affordable and abundant – a demand that becomes even more difficult due to increasingly unpredictable climatic conditions. These evolving pressures are not only intensifying but also fundamentally altering the operating environment for crop production.

Addressing this complexity requires more than incremental change. One widely accepted approach is Integrated Pest Management (IPM), which promotes site-specific, knowledge- driven, and preventive strategies to reduce inputs and environmental impact. Spot Farming builds on the core principles of IPM and extends them into a comprehensive, systems- level concept. It aims to optimise crop production by aligning crop management with spatial variability, ecological functionality, and long-term resilience.

Unlike IPM, which primarily focuses on maintaining yield stability while minimising environmental harm, Spot Farming also targets yield increases and an expansion of ecosystem services – including biodiversity support, erosion control, and climate resilience.

Developed by the Julius Kühn Institute (JKI) in collaboration with the Thünen Institute and TU Braunschweig, Spot Farming redefines the relationship between crops, land, and technology. The goal: a more sustainable, efficient, and climate-resilient agriculture that remains economically viable and socially acceptable.

The concept: From uniformity to spatial precision

Spot Farming recognises that agricultural fields are inherently heterogeneous in terms of soil properties, water availability, yield potential, microclimate, and erosion risk. These spatial differences, now digitally mappable, can be integrated to define so-called “spots” – subfield zones that are internally homogeneous and suitable for tailored management.

This spatial differentiation forms the basis for more precise and efficient crop production. In its simplest form, Spot Farming enables zone-specific seeding and fertilisation. In its more advanced application, it involves assigning distinct crop rotations to each spot,

matching crops to site-specific conditions for optimal resilience and resource use. Such complexity, however, exceeds the capabilities of conventional large-scale machinery.

Plant-level optimisation and reduced input demand

A key element of Spot Farming is equidistant planting, where every individual crop is positioned to maximise access to light, water, and nutrients while minimising competition. Compared to conventional drilling, this approach reduces seed and seed treatment usage by more than 50%, while improving crop health and uniformity. Moreover, JKI has developed a seeding technique for the digital mapping of each individual seed, which can be utilised in subsequent processes.

Sparse, evenly spaced crops are more aerated and less susceptible to disease, thereby aligning with core IPM objectives. In such systems, mechanical weeding in multiple directions becomes viable, reducing herbicide dependency without requiring expensive plant recognition sensors. These advantages, however, hinge on extremely precise planting and weeding, which current machinery struggles to deliver.

Breeding and variety selection for resilience

Modern crop varieties have been bred for dense sowing under uniform conditions. But in equidistant systems, the ideal plant architecture may differ significantly. Ongoing field trials, focusing on wheat, are investigating optimal seed densities and varietal traits. Initial findings suggest that even with existing varieties, yield is maintained or even significantly increased under stressful conditions compared to conventional drill sowing.

As new insights emerge, breeding programs may develop varieties specifically suited for equidistant planting, increasing both productivity and resilience under changing climate conditions.

Feeding and protecting crops more precisely

In the domain of nutrient management, Spot Farming envisions micro-dosed fertiliser applications delivered directly to the root zone – improving uptake efficiency and minimising nitrogen leaching into groundwater. Crop protection is integrated from the outset through diverse crop rotations, reduced crop density, mechanical weed control, and spot spraying. Chemical interventions can be minimised and resistance management improved. Ultimately, the goal is plant-level precision that balances productivity with environmental integrity.

Rethinking landscape structure for climate adaptation

Decades of land consolidation and machinery-driven design have reduced the presence of functional elements, such as hedgerows, ditches, and buffer zones – structures that once protected fields from wind and water erosion.

Spot Farming incorporates these insights into field planning, reintroducing structural diversity to reduce landscape- level vulnerability. In doing so, the approach enhances ecological connectivity, biodiversity, and resilience to extreme weather – a core requirement in climate-adapted agriculture.

Enabling technology: Autonomous agricultural robotics

The ambitions of Spot Farming cannot be fulfilled with today's conventional machinery. The spatial complexity, need for plant-level actions, and demand for ultra-precise operations necessitate a new class of technology. Small, autonomous robots working in coordinated swarms may provide the answer.

Challenges such as energy infrastructure, safety, and legal frameworks remain, but are not unique to agriculture. As with autonomous vehicles in transport, these are societal challenges to be addressed alongside technological progress.

Conclusion: From plant to system: Rethinking crop production methodologically

Spot Farming demonstrates that sustainable intensification is not only possible but can also be methodically derived. The approach begins by thinking from the crops, rather than from existing machinery. It consciously detaches from the current paradigm of "bigger, faster, wider" to ask: What does the crop need, and how can we shape management systems accordingly?

The method behind Spot Farming considers three interrelated levels:

1. The individual plant, where spatial arrangement, nutrient access, and resilience matter most.
2. The field and farm scale, where variability is managed and resources are optimised.
3. The landscape and market interface, where ecological functionality, public acceptance, and economic viability converge.

Based on these levels, Spot Farming pursues four strategic goals:

- Improved allocation of crops to site-specific conditions.
- Optimised spatial and temporal use of natural resources.
- More efficient and reduced use of agrochemicals.
- Reinforcement of functional landscape elements to enhance resilience.

This method has been developed for typical German arable farming conditions, where the Spot Farming concept emerged as a promising solution. However, the same logic is transferable to perennial systems or other types of landscapes. What matters is not the specific crops or regions, but the principle: rethinking plant production from the biological and ecological needs of the crop, and designing farming systems accordingly.

Of course, Spot Farming will not fix the systemic challenges agriculture faces on its own. However, as a methodologically grounded concept, it offers a forward- looking framework for designing resilient, efficient, and ecologically sound production systems, suitable for a changing climate and society.

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