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Beyond the optimisation trap: redefining AI as maladaptation sentinels for resilient agro-ecosystems

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Abstract

Across the Global South and beyond, Agriculture 4.0 has rapidly gained prominence as a cornerstone of climate-resilient development, promising higher precision, adaptive decision-making, and improved resource efficiency. Yet the accelerating climate crisis reveals a more complex reality: artificial intelligence (AI) embedded in digital agriculture not only supports adaptation but may unintentionally generate new forms of maladaptation. This analytical review addresses this underexamined tension by synthesizing insights from agrarian political economy, digitalisation studies, resilience theory, and the emerging literature on algorithmic governance. Our aim is to clarify how AI-driven decision systems—when deployed in ecologically fragile and socially heterogeneous agro-ecosystems—can lead adaptation trajectories in directions that heighten long-term vulnerability. The review identifies several interlocking mechanisms of risk. First, efficiency-driven algorithms can intensify resource extraction through rebound effects, as seen in irrigation technologies that inadvertently accelerate water depletion. Second, AI’s reliance on standardised models and training data tends to homogenize practices, thereby reducing agrobiodiversity and narrowing the scope of adaptive responses. Third, data infrastructures underpinning digital agriculture often encode political biases: “weak data,” exclusionary classifications, and the marginalisation of local and Indigenous knowledge. Fourth, the concentration of digital platforms among a small number of corporations reinforces algorithmic lock-in, limiting farmers’ autonomy and constraining alternative adaptation pathways. Together, these dynamics produce structural conditions in which AI does not merely misguide individual decisions but reshapes entire socio-ecological systems toward maladaptive lock-ins. In response, this paper advances a theoretical reorientation of AI’s role: from a tool of optimisation to a potential “maladaptation sentinel.” Rather than proposing operational frameworks, we articulate a conceptual lens through which AI can be used to detect emerging vulnerabilities by integrating diverse data ecologies, tracing long-term feedback, and foregrounding plural knowledge systems. This shift emphasises that the contribution of AI to climate resilience depends not on technological advancement alone, but on whether its design and governance follow principles of responsible innovation, enabling AI to widen rather than constrain the horizon of adaptive futures.

Keywords: Agriculture 4.0; Algorithmic Lock-in, Agrobiodiversity, Artificial Intelligence, Data Politics, maladaptation, Rebound Effects, Resilience

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