4. Precision agriculture adoption in smallholder vegetable farming systems in Developing Countries: A review

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Abstract

Precision Agriculture (PA) technologies have the potential to transform smallholder vegetable farming in developing countries, by improving yields, improving resource use, and enhancing climate change. However, despite these benefits, many farmers have not adopted these technologies. This review examined the main challenges that prevent smallholder vegetable farmers in developing countries from using PA technologies. The study used a systematic approach to analyze 60 peer-reviewed articles, government reports, and case studies published between 2010 and 2025. The review found that several factors limited adoption, including high costs, lack of locally adapted technologies, low digital literacy, weak extension services, and poor policy support. In addition, the results indicate that smallholder farmers also struggle with limited access to modern equipment, financial resources, and training. However, the study found that affordable, simple PA technologies, farmer education and strong collaboration among governments, researchers, and private sectors can improve adoption rates. Practical solutions such as mobile-based advisory services, low-cost soil sensors, and community-based learning programs have shown promising results. For PA to benefit smallholder vegetable farmers, it is crucial to develop policies that support research, provide financial incentives, and strengthen agricultural extension services. This review highlights the need for tailored solutions that fit local conditions and farmers' needs, ensuring that PA contributes to food security, sustainability, and economic growth in developing countries.

Key words: *Barriers, Innovation, Resource efficiency, Climate, Soil Sensors, Yield*