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"Reconcile land system changes
with planetary health"

Cost and efficiency analysis of drone-based transport in hilly terrains

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Abstract

Efficient transport of fresh produce during harvest in mountainous regions remains a persistent challenge due to steep gradients, limited accessibility, and labour shortages. Although drone technology is gaining momentum across multiple sectors globally, its deployment for transportation logistics, particularly in geographically challenging terrains, has received limited attention. Using apple farming in the mountainous area of Kullu in Himachal Pradesh, India, as a case study example, this study evaluates the potential economic and operational performance of a commercially available transport drone (DJI FlyCart 30) compared to conventional human labour for the transport of the apples. Based on data provided by the drone manufacturer, the assessment parameters included transport speed, payload capacity, energy requirement, energy cost, and possible number of operational cycles per day. Depreciation, maintenance, and loan interest were also considered. We assumed a 1000 m transport distance between Point A & Point B with a 350 m elevation difference, and a return journey of 1000 m. The drone, which is priced at approximately $20,700 was found to have a potential capacity to transport 965 kg apples per day. In contrast, one person was estimated to transport approx. 94 $^{kg}/_{day}$ per day under the same conditions. With a calculated operating cost of $0.07/kg, the drone is estimated to be more than twice as cost-efficient as human labour, which incurred a cost of $0.15/kg. Moreover, the drone has the potential to achieve a ten times higher delivery volume than one worker, which is a crucial advantage during harvest period, because the possibility to hire a larger number of workers is very limited. These findings suggest a strong potential for integrating drones into fresh produce transport in remote agricultural landscapes, not only to improve transport efficiency and maintain produce quality during transit, but also to reduce post-harvest losses caused by handling delays and labour shortages. Although the data and conditions are based on field parameters from India and field testing of drones is required as a next step, the analytical framework is adaptable to similar geographies and suggests that drone transport can become a scalable solution for overcoming logistical barriers of fruit production in mountainous agricultural regions.

Keywords: Apple Production , Labour Shortage, Mountainous Terrain, Post-Harvest losses, transport Innovation

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