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Drone-captured imagery for visual communication of crop health monitoring to farming communities

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Abstract

Leading crop health experts have long argued that showing farmers what is happening in their fields is more powerful than telling them. This research tested whether drone-captured imagery improves farmer comprehension of crop health information and willingness to act on monitoring data compared to conventional communication methods. A quasi-experimental design was used with 198 farmers in the Kakheti wine-growing region of Georgia between March and September 2023. Farmers were randomly assigned to receive crop health information through one of five formats: drone NDVI images, printed field maps, verbal explanation, traditional scout reports, or satellite imagery. Comprehension was highest for drone NDVI images (81.4%) and lowest for satellite images (38.9%). Willingness to take corrective action followed a similar pattern (76.2% vs 35.6%). Younger farmers and those with smartphone experience showed stronger responses to visual formats. The research proposes a drone-to-farmer communication pipeline that integrates image capture, processing, interpretation by extension agents, and community presentation. These results indicate that drone imagery can serve as a powerful visual communication tool when paired with extension interpretation support.

Keywords: Drone imagery, crop health monitoring, visual communication, NDVI, farming communities, precision agriculture, extension communication, remote sensing, farmer comprehension

Introduction

"A picture is worth a thousand words" may be a cliché, but in agricultural extension it captures an important truth: farmers often struggle to translate abstract verbal or written advice into concrete field-level understanding ^[1]. Remote sensing technologies, particularly drones equipped with multispectral cameras, now produce detailed crop health imagery at a fraction of the cost of satellite-based monitoring ^[2]. But the communication potential of these images for reaching farming communities has been largely overlooked in favor of their precision agriculture applications ^[3].

Georgia's Kakheti region, responsible for over 70% of the country's wine production, faces increasing pressure from fungal diseases and water stress that require timely monitoring ^[4]. Extension agents currently rely on verbal field reports and occasional printed bulletins to communicate crop health status to farmers. Drone technology has been introduced for vineyard management research but has not been tested as a communication tool for farmer audiences ^[5].

This research compared five methods of communicating crop health data to farmers and measured their effects on comprehension and willingness to act. It also developed a practical communication pipeline for translating drone imagery into farmer-accessible visual information.

Previous research on visual aids in extension has focused mainly on printed materials, video, and smartphone applications. These studies consistently find that visual formats outperform text-only or verbal-only delivery, with effect sizes ranging from 15 to 40 percentage points for

comprehension. But drone imagery differs from earlier visual aids in a critical way: It shows farmers their own fields rather than generic examples, creating immediate personal relevance that standard visuals cannot provide.

The visual communication gap in extension has persisted despite decades of research showing that farmers learn more effectively from demonstrations than from lectures. What drones offer is a new form of demonstration: instead of bringing farmers to a field to observe, drones bring the field to the farmer as a detailed, color-coded visual map. This reversal has implications for both efficiency and scale, since a single drone flight can generate imagery that is shared with hundreds of farmers simultaneously.

Conceptual model

The research was grounded in dual-coding theory ^[6], which proposes that information presented in both visual and verbal formats is processed through two independent channels, resulting in stronger memory encoding and comprehension than either format alone. Applied to extension, this suggests that pairing drone imagery with agent explanation should outperform either verbal-only or image-only communication. The model predicted that comprehension would be highest for formats combining visual richness with interpretive support.

Material and Methods

Material

A total of 198 farmers from 12 villages in the Kakheti region participated between March and September 2023. Farmers were randomly assigned to five treatment groups

(approximately 40 per group). Drone flights were conducted using a DJI Phantom 4 Multispectral over four vineyard sites at two-week intervals. NDVI (Normalized Difference Vegetation Index) maps were generated using Pix4Dfields software. Comprehension was measured through a 10-item quiz administered immediately after information delivery. Willingness to act was measured on a five-point scale. Ethical clearance was granted by the Georgian Agricultural University Ethics Board (Protocol GAU-EB-2023-011, February 2023).

Methods

One-way ANOVA compared comprehension and willingness scores across the five communication formats.

Results

Table 1: Comprehension and willingness scores by communication format

Format	n	Compreh. (%)	Willing. (1-5)	SD
Drone NDVI images	41	81.4	4.2	0.7
Printed field maps	39	67.8	3.7	0.8
Verbal explanation	40	54.3	3.4	0.9
Scout reports	38	42.7	2.9	1.0
Satellite images	40	38.9	2.6	1.1

ANOVA confirmed significant differences across formats for both comprehension ($F = 28.4, p < 0.001$, partial $\eta^2 = 0.37$) and willingness ($F = 19.7, p < 0.001$). Drone NDVI

Post-hoc Tukey tests identified pairwise differences. Two-way ANOVA tested interaction effects with farmer age and smartphone experience. Effect sizes were calculated using partial η^2 . All analyses used SPSS 28.

Pilot research

A pilot with 24 farmers from two non-sampled villages in January 2023 tested the comprehension quiz and communication protocols. Three quiz items were simplified after pilot farmers found the technical language confusing. The drone presentation format was revised to include a five-minute verbal introduction before showing images, based on pilot feedback that images alone were initially disorienting.

images significantly outperformed all other formats in post-hoc comparisons (all $p < 0.01$).

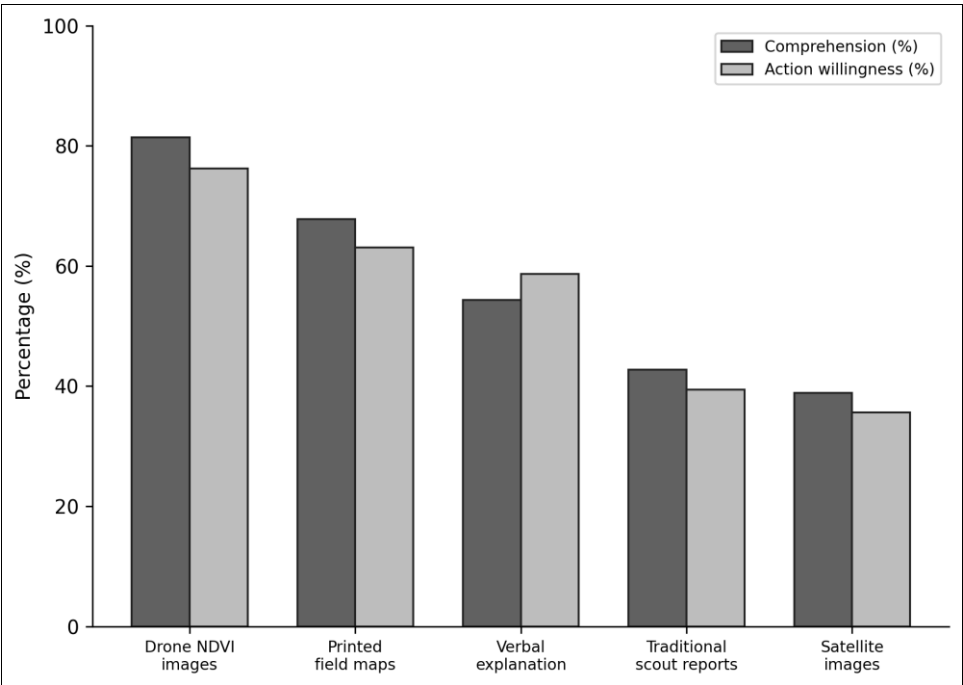


Fig 1: Farmer comprehension and action willingness across communication formats

Drone NDVI images produced the highest scores on both measures. The gap between drone imagery and satellite images (the lowest scorer) was over 40 percentage points for

comprehension, highlighting the importance of spatial resolution and visual clarity.

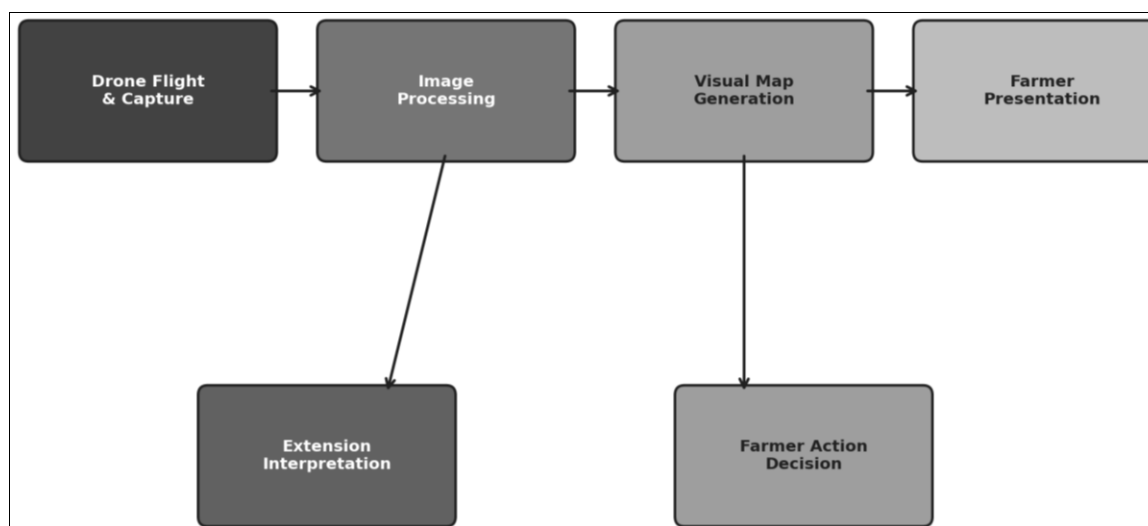


Fig 2: Proposed drone-to-farmer visual communication pipeline

The pipeline shows the flow from drone flight and image capture through automated processing, extension interpretation, and farmer-facing presentation. The extension interpretation step proved essential—raw drone images without explanation produced confusion rather than comprehension in pilot testing.

Discussion

The strong performance of drone NDVI images supports dual-coding theory: when farmers could see color-coded health maps of their own fields while hearing an extension agent's interpretation, both visual and verbal processing channels were engaged simultaneously [6]. Satellite imagery scored poorly despite being technically similar, likely because the lower spatial resolution made it difficult for farmers to recognize their own plots [7]. The practical implication is that image resolution and local relevance matter more than technological sophistication. Extension services exploring drone use should invest as much in the communication pipeline as in the hardware itself [8].

An unexpected finding was the poor performance of satellite imagery, which extension programs have promoted as a cost-effective monitoring tool. Farmers found satellite images too abstract and could not identify their individual plots within the broader landscape view. This has important implications for programs investing in satellite-based advisory systems: the technology may be accurate, but if farmers cannot interpret the output, its advisory value is limited without substantial extension interpretation support. The cost dimension deserves attention. A single drone flight costs approximately 40 to 60 USD including operator time, which is expensive per event but economical per farmer when images are presented to groups of 20 to 50 people. Compared to hiring a scout to walk every field individually, drone-based monitoring covers larger areas faster and produces more consistent assessments. The economic case strengthens further when drone imagery serves both monitoring and communication purposes simultaneously.

Limitations

The research was limited to vineyard farmers in one Georgian region and may not generalize to other crop systems. Comprehension was measured immediately after

presentation; retention over time was not assessed. The quasi-experimental design with village-level assignment may introduce cluster effects not fully controlled for.

From an institutional perspective, integrating drones into extension workflows requires more than purchasing hardware. Extension organizations need trained operators, image processing capacity, data storage infrastructure, and crucially, staff who can translate technical imagery into farmer-accessible explanations. The proposed communication pipeline addresses these requirements by defining clear roles at each stage, from data capture through farmer presentation. Without this pipeline structure, the risk is that drone programs produce impressive images that sit on hard drives rather than reaching the farmers who could benefit from them.

The interaction between farmer age and communication format effectiveness also warrants discussion. Younger farmers showed stronger comprehension gains from drone imagery, likely because they had greater familiarity with digital visual media and could interpret color-coded maps more intuitively. Older farmers benefited most from the combination of drone imagery with extended verbal explanation, suggesting that presentation protocols should be adapted to audience demographics. A one-size-fits-all approach to visual communication is unlikely to be optimal.

Conclusion

Drone-captured imagery significantly outperformed all other communication formats for conveying crop health information to farmers. The key was not the drone technology itself but the combination of high-resolution visual data with on-the-ground extension interpretation. Extension organizations should treat drones not just as monitoring tools but as communication devices that can bridge the gap between technical data and farmer understanding. The proposed communication pipeline provides a practical model for integrating drone imagery into advisory workflows.

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