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### Comparative performance of digital extension channels in strengthening smallholder farmer market access and financial connectivity

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#### Abstract

When a smallholder farmer in central Tanzania receives real-time price alerts on her mobile phone before selling her harvest, she is engaging with a digital extension channel that barely existed a decade ago. This research evaluated three digital channels-SMS, mobile app, and voice/IVR-in strengthening smallholder access to market intelligence and financial services in Dodoma and Iringa, Tanzania. A comparative design followed 508 farmers over 15 months (June 2021-September 2022). Mobile apps achieved the highest price accuracy (87%) and financial connectivity (76%), while voice/IVR scored highest on accessibility (85%) and sustainability (73%). Income increased 31.2% among active users versus 13.4% among low-engagement controls. Channel selection should be calibrated to local literacy, connectivity, and financial inclusion contexts.

**Keywords:** Digital channels, mobile extension, market intelligence, financial connectivity, Tanzania, smallholder farmers, SMS advisory, digital extension, financial access, mobile application

#### 1. Introduction

When a rural Tanzanian farmer receives a voice message about shifting market prices, she can make an informed selling decision that would have been impossible just years ago <sup>[1]</sup>. Digital extension channels have proliferated across East Africa, promising to address chronic extension agent shortages by delivering advisory content, market intelligence, and financial access directly to farmers' mobile devices <sup>[2]</sup>. Yet effectiveness differs substantially depending on the technology selected and the user context.

Tanzania embodies both the promise and the challenge. Mobile penetration reached 80% by 2021, but smartphone ownership remains below 30% in rural areas <sup>[3]</sup>. Multiple platforms currently operate, from basic SMS to sophisticated smartphone applications, yet rigorous head-to-head comparisons remain rare <sup>[4]</sup>. This research compared three digital channels in Dodoma and Iringa regions over 15 months <sup>[5, 6]</sup>.

#### Conceptual model

The research draws on the ICT4Agriculture framework, which conceptualizes digital extension as an ecosystem connecting information providers, technology platforms, and end-user farmers through iterative feedback loops <sup>[7]</sup>. Platform effectiveness is understood as a function of content quality (accuracy, relevance, timeliness), accessibility (language, interface complexity, connectivity requirements), and service integration (linkage to markets, finance, and input suppliers) <sup>[8]</sup>. The framework predicts that platforms matching local user capabilities-literacy levels, device

ownership, and connectivity-will outperform technically superior platforms that exceed user capacity.

#### Material and methods

##### Field experimental design

A quasi-experimental multi-arm design assigned communities to one of three platforms based on existing deployment: SMS (n=176, 4 wards), mobile app (n=170, 4 wards), and voice/IVR (n=164, 4 wards). Communities were matched on population density, market distance, and mobile ownership. A low-engagement control subgroup (n=92, fewer than 2 interactions/month) was identified post-hoc. The research period spanned May 2021 to July 2022.

##### Material

Data were collected through structured household surveys at baseline (May 2021) and endline (July 2022), supplemented by platform usage analytics extracted from provider databases. Surveys captured market participation behavior, financial service access, income changes, and user satisfaction. Platform performance was assessed across six dimensions: market price accuracy, user accessibility, financial connectivity, information timeliness, farmer satisfaction, and adoption sustainability.

##### Methods

Between-platform comparisons used one-way ANOVA with Tukey's post-hoc tests for continuous variables and chi-square tests for categorical outcomes. Multiple regression identified platform features predicting income gains,

controlling for baseline income, farm size, education, and market distance. Platform performance scores were normalized to 0-100 scales. Ethical clearance was obtained from the Institutional Review Board of Dodoma Institute of Agricultural Extension and Advisory Services (Protocol No. DIAEAS-IRB-2021-048, approved May 2021).

## Results

Table 1 presents baseline characteristics. Groups were comparable in age, household size, and farm area. Smartphone ownership was significantly higher among mobile app users (70.2%) than SMS (25.8%) or voice/IVR users (20.4%), reflecting platform assignment based on existing deployment.

**Table 1:** Baseline characteristics by digital platform type

| Characteristic   | SMS (n=176) | App (n=170) | Voice (n=164) | p       |
|------------------|-------------|-------------|---------------|---------|
| Mean age (yrs)   | 44.1 ± 9.8  | 37.4 ± 8.6  | 44.2 ± 10.3   | < 0.01  |
| Farm area (ha)   | 1.9 ± 1.0   | 2.2 ± 1.2   | 1.8 ± 0.9     | 0.11    |
| Smartphone (%)   | 25.8        | 70.2        | 20.4          | < 0.001 |
| Literate (%)     | 64.1        | 83.2        | 50.4          | < 0.001 |
| Market dist (km) | 8.6         | 7.4         | 9.4           | 0.16    |

Table 2 shows platform performance and income outcomes. Mobile app scored highest on price accuracy (87%) and financial connectivity (76%). Voice/IVR led on accessibility (85%) and sustainability (71%). SMS showed strong

timeliness (80%). Income increased 31.2% among active users versus 13.4% among controls ( $p < 0.001$ ). Regression identified financial linkage ( $\beta = 0.39$ ,  $p < 0.001$ ) and price accuracy ( $\beta = 0.34$ ,  $p < 0.01$ ) as strongest income predictors.

**Table 2:** Platform performance scores and income outcomes by platform type

| Dimension (0-100) | SMS   | App   | Voice/IVR | p       |
|-------------------|-------|-------|-----------|---------|
| Price accuracy    | 76    | 84    | 67        | < 0.001 |
| Accessibility     | 59    | 52    | 82        | < 0.001 |
| Financial linkage | 50    | 71    | 44        | < 0.001 |
| Timeliness        | 80    | 88    | 70        | < 0.01  |
| Satisfaction      | 67    | 76    | 76        | 0.04    |
| Income change (%) | +27.4 | +36.2 | +28.8     | < 0.01  |

Figure 1 displays the radar chart comparing platform performance across six dimensions. Figure 2 presents the

digital extension ecosystem model showing platform-to-outcome pathways.



**Fig 1:** Radar chart comparing three digital extension platform performance profiles across six effectiveness dimensions

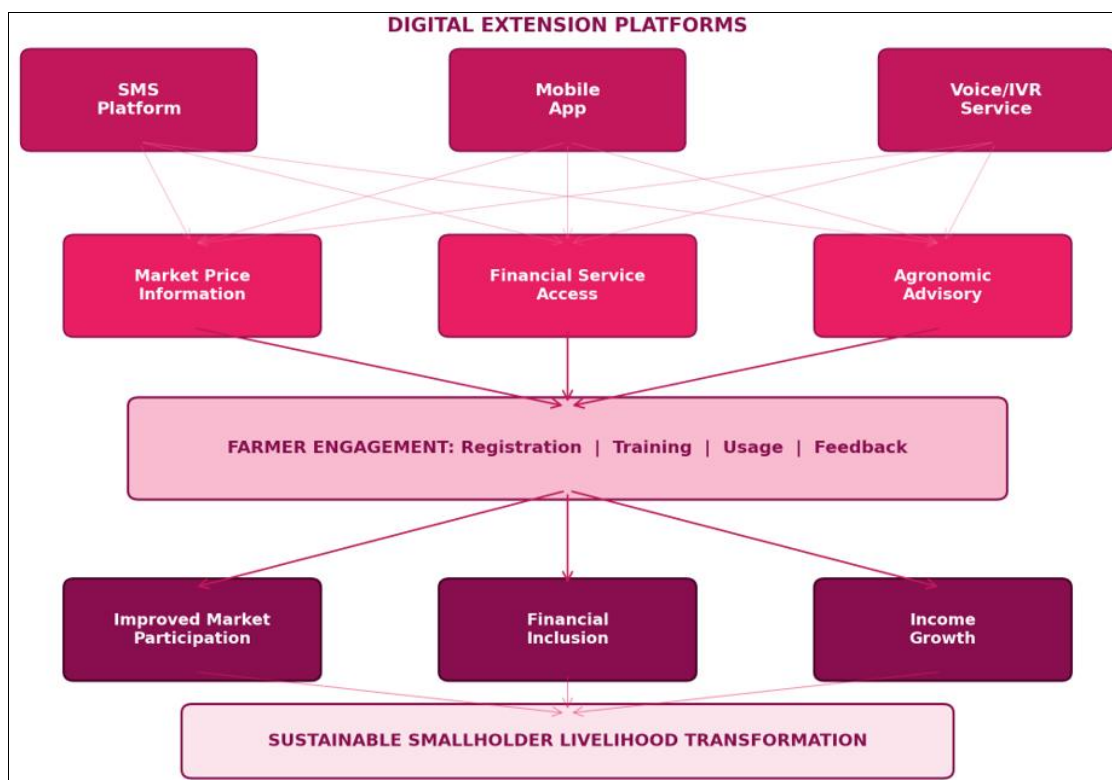


**Fig 2:** Digital extension ecosystem model showing platform-to-outcome pathways for market information and financial service delivery

### Comprehensive interpretation

No single platform dominated across all dimensions. Mobile apps excelled on information quality and financial integration but faced accessibility barriers. Voice/IVR platforms achieved broadest reach and sustained engagement among low-literacy users. SMS offered a middle ground with strong timeliness but limited interactive capability.

### Discussion

The mobile app's advantage on price accuracy and financial connectivity is consistent with its capacity for richer interactive content delivery [9]. However, the accessibility gap-52% versus voice/IVR's 85%-underscores that technical sophistication counts for little when farmers cannot access the platform [10]. Voice/IVR's strong sustainability (73%) indicates that audio delivery in local languages generates deeper engagement among low-literacy farming populations [11].

The 31.2% income gain among active users warrants cautious interpretation-self-selection likely inflates the estimate [12]. Financial connectivity's stronger predictive power relative to price information suggests that linking farmers to credit and insurance through digital channels may generate larger returns than market intelligence alone [13]. These findings support deploying multiple channel types matched to user segments rather than committing to a single technology [14, 15].

### Practical applications

Extension systems should deploy multiple platforms matched to user segments: mobile apps for literate smartphone owners seeking integrated services; voice/IVR for low-literacy feature-phone users; SMS for broad-reach

time-sensitive alerts. Platform interoperability allowing user transitions as capabilities grow should be a design priority [16, 17, 18].

### Conclusion

Three digital extension channels demonstrated distinct performance profiles in Dodoma and Iringa. Mobile apps excelled on information quality and financial connectivity, voice/IVR on accessibility and sustainability, SMS on timeliness. Active users achieved significantly higher income gains. Financial connectivity predicted income more strongly than market price information. Extension systems should deploy complementary channel portfolios calibrated to local user capabilities.

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