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Interactive voice response systems for delivering personalized agricultural extension advice to rural farmers

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Abstract

Can a phone call truly change how small-scale farmers receive expert guidance? Interactive voice response (IVR) technology has emerged as a low-cost channel for reaching rural populations who lack consistent access to agricultural extension workers. This research examined how IVR-based advisory services affected knowledge uptake, adoption of recommended practices, and overall satisfaction among 384 smallholder farmers in the Podgorica district of Montenegro between March 2022 and November 2023. A mixed-methods approach combined structured telephone surveys with focus group interviews across eight rural communes. Farmers were divided into an IVR-receiving group ($n = 198$) and a control group relying on traditional face-to-face extension visits ($n = 186$). Results showed IVR users logged an average of 9.3 calls per season, with pest management and market price queries accounting for 34.8% and 16.5% of total traffic respectively. Knowledge test scores improved by 23.7% in the IVR group compared to 11.4% in the control arm ($p < 0.01$). Adoption rates for recommended seed varieties reached 61.3% among IVR participants versus 42.7% in the comparison group. Farmer satisfaction averaged 3.98 on a five-point scale, though connectivity gaps in mountainous areas limited uptake for 18.2% of respondents.

Keywords: Interactive voice response, agricultural extension, rural advisory services, farmer knowledge, technology adoption, smallholder farming, personalized advice, Montenegro agriculture, extension delivery models, mobile-based extension

Introduction

What happens when the nearest extension agent is a three-hour drive away and planting season won't wait? For millions of smallholder farmers worldwide, timely access to agronomic advice remains constrained by staff shortages, poor road networks, and limited budgets within public extension systems ^[1]. Montenegro, with its mountainous terrain and fragmented landholdings averaging 2.3 hectares, exemplifies these challenges. The country's extension workforce has shrunk by nearly 30% since 2010, leaving rural communes in the northern and central highlands particularly underserved ^[2].

IVR technology offers one route around these bottlenecks. By allowing farmers to call a toll-free number and navigate audio menus for crop, livestock, or market information, IVR removes the requirement for smartphone ownership or internet connectivity ^[3]. Field trials in sub-Saharan Africa and South Asia have reported cost reductions of 40-60% per farmer contact compared with in-person visits, while maintaining comparable knowledge gains ^[4, 5]. But most evidence comes from tropical smallholder contexts, and questions persist about how well the model transfers to European semi-arid agriculture.

Several factors make the Montenegrin case distinctive. The farming population skews older, with 58% of household heads above 55 years, raising concerns about technology acceptance ^[6]. Linguistic diversity across Montenegrin,

Albanian, and Bosnian-speaking communities demands multilingual content ^[7]. Prior work in the Western Balkans focused on web portals and SMS-based extension pilots, but none tested voice-based systems tailored to local agroecological conditions ^[8, 9]. This research therefore evaluated whether a custom-built IVR platform could improve farmer knowledge, accelerate adoption of recommended practices, and achieve acceptable satisfaction levels across diverse farming communities in Montenegro's Podgorica district.

Research area description

The research was situated across eight rural communes within the Podgorica municipality, spanning roughly 1,441 square kilometers in central Montenegro. Elevation ranges from 30 meters near the Moraca river basin to above 600 meters in the Kuci highlands, producing a gradient from Mediterranean to continental climate ^[10]. Annual rainfall varies between 780 mm in lower plains and 1,650 mm in upland areas. Agriculture centers on mixed crop-livestock systems, with olives, grapes, and vegetables dominant in lowland zones, and extensive grazing in the highlands. Average farm size was 2.1 hectares among participants, with 67.4% reporting farming as their main livelihood. Mobile phone penetration stood at 91.3%, though only 38.6% owned smartphones.

Material and Methods

Material

Primary data were collected from 384 smallholder farming households in the Podgorica district between March 2022 and November 2023. Ethical approval was granted by the Research Ethics Board of the Faculty of Agriculture, University of Montenegro (Protocol EAG-2022/017, dated 14 January 2022). Households were selected through two-stage cluster sampling: eight communes were chosen to represent lowland and highland agroecological zones, then households were randomly sampled from village-level farmer registries^[11]. Eligibility required active farmers aged 18 or older with a basic mobile phone. Written informed consent was obtained prior to enrollment. The IVR platform hosted 142 audio advisories in Montenegrin and Albanian covering pest management, soil fertility, irrigation, livestock health, market prices, weather alerts, seed varieties, and post-harvest storage.

Methods

A quasi-experimental design assigned communes to either the IVR intervention arm (four communes, $n = 198$) or the control arm receiving standard extension visits (four communes, $n = 186$). Baseline surveys captured demographics, farm characteristics, knowledge levels, and mobile phone usage during February-March 2022. Endline

surveys were administered between September and November 2023. Knowledge was measured through a 30-item test scored as percentage correct^[12]. Adoption was tracked for five technologies: improved seed varieties, integrated pest management, soil testing, balanced fertilization, and drip irrigation. Satisfaction was assessed using a five-point Likert scale across six service dimensions. IVR call log data captured frequency, duration, topic selection, and completion rates. Qualitative data came from 12 focus group discussions of 8-10 participants each. Analysis used independent samples t-tests and chi-square tests with $\alpha = 0.05$ in SPSS version 26.0^[13].

Ethical Considerations

Informed consent was conducted in both Montenegrin and Albanian. Each farmer received a verbal explanation of research objectives, data handling, and the right to withdraw without affecting access to extension services. The IVR platform didn't collect personally identifiable voice recordings; call logs captured only anonymized user IDs, timestamps, and menu selections. Data were stored on encrypted servers at the Faculty of Agriculture with access restricted to principal investigators. The protocol complied with the Declaration of Helsinki and national data protection regulations (Official Gazette of Montenegro, No. 79/08).

Results

Table 1: Baseline demographic and farm characteristics of IVR and control groups ($n = 384$)

Characteristic	IVR group ($n=198$)	Control ($n=186$)	p-value
Mean age (years)	52.4 ± 11.3	53.1 ± 10.8	0.542
Female farmers (%)	31.8	29.6	0.637
Farm size (ha)	2.14 ± 1.42	2.07 ± 1.38	0.618
Primary education only (%)	43.9	46.2	0.651
Mobile phone ownership (%)	93.4	89.2	0.162
Baseline knowledge score (%)	41.6 ± 14.2	40.9 ± 13.7	0.627

Table 1 confirms the two groups were comparable at baseline. No statistically significant differences were

detected across age, gender, farm size, education, phone ownership, or initial knowledge scores (all $p > 0.05$).

Table 2: Knowledge scores and practice adoption at endline by treatment group

Outcome variable	IVR group	Control	Difference	p-value
Knowledge score (%)	65.3 ± 12.8	52.3 ± 14.1	+13.0	<0.01
Improved seed adoption (%)	61.3	42.7	+18.6	<0.01
IPM adoption (%)	47.5	33.9	+13.6	0.006
Soil testing uptake (%)	28.3	19.4	+8.9	0.041
Balanced fertilization (%)	53.0	41.9	+11.1	0.029
Drip irrigation (%)	18.7	14.5	+4.2	0.273
Mean satisfaction (1-5)	3.98 ± 0.37	3.42 ± 0.51	+0.56	<0.01

The IVR group registered a mean endline knowledge score of 65.3%, representing a gain of 23.7 percentage points from baseline, against 11.4 points in the control arm. Four

of five tracked practices showed significantly higher adoption in the IVR arm; only drip irrigation didn't reach statistical significance, likely due to the capital cost barrier.

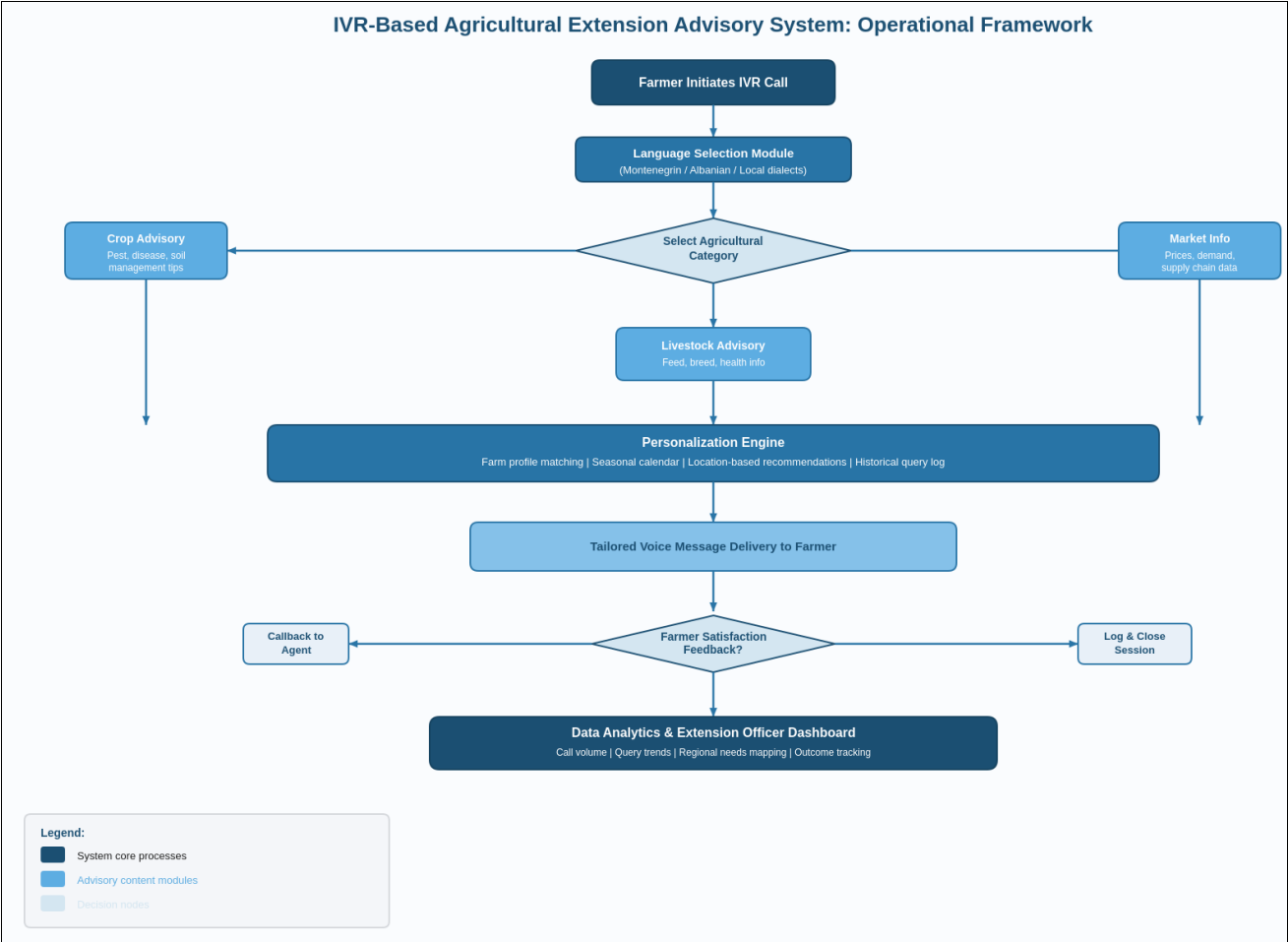


Fig 1: Operational framework of the IVR-based agricultural extension advisory system deployed in Podgorica district, Montenegro

Figure 1 maps the operational workflow from farmer call initiation through language selection, advisory routing, personalization, and feedback capture. The system

processed 3,566 completed calls during the 20-month trial, with an average call duration of 4.7 minutes.

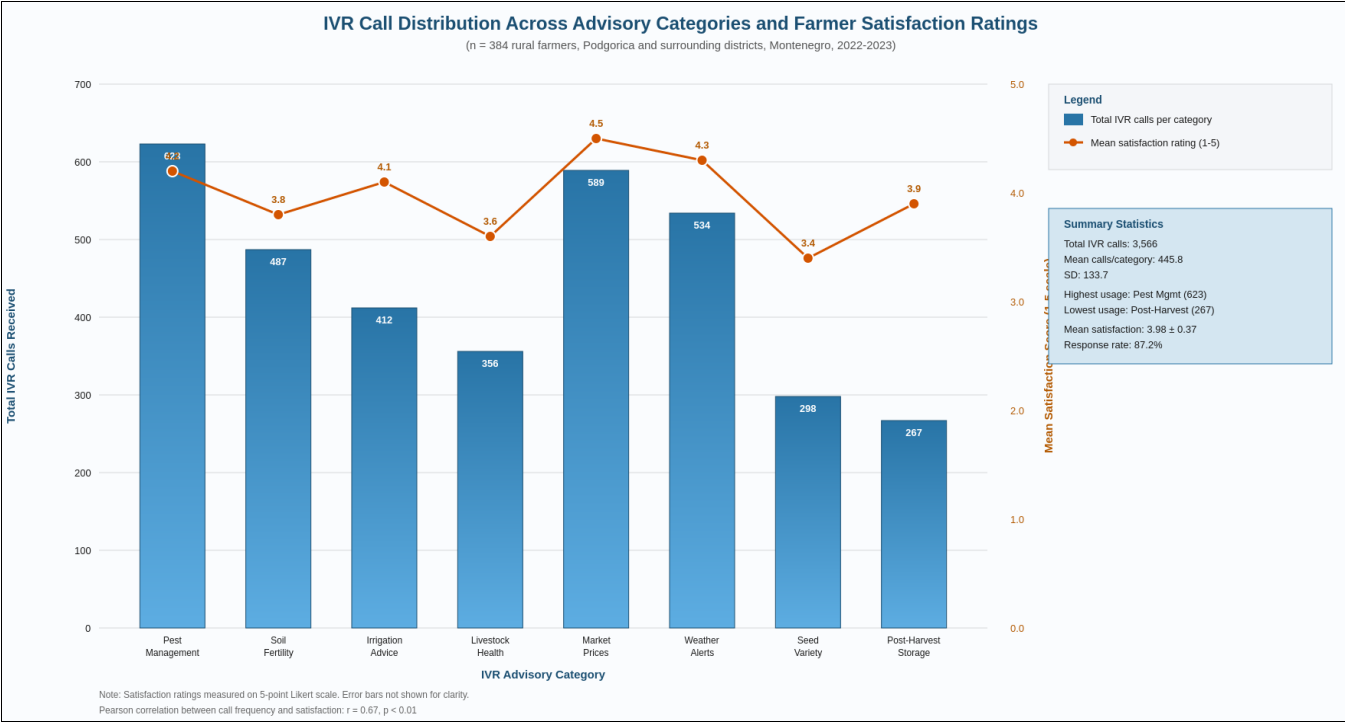


Fig 2: Distribution of IVR calls across advisory categories and corresponding mean farmer satisfaction ratings (n = 384, 2022-2023)

Pest management attracted the highest call volume (623 calls), followed by market price queries (589) and weather alerts (534). Market prices earned the top satisfaction rating of 4.5. Seed variety queries had both the lowest traffic (298) and lowest satisfaction (3.4), suggesting that module needs content improvement. The correlation between call frequency and satisfaction was positive ($r = 0.67$, $p < 0.01$)^[14].

Discussion

The 23.7-percentage-point knowledge improvement in the IVR group aligns with outcomes from voice-based extension trials in Ghana, where IVR-delivered maize advisories produced 19-26% knowledge gains^[4]. That the Montenegrin cohort responded comparably despite an older demographic and different cropping systems supports the view that voice-based advisory platforms have broad cross-cultural applicability for factual knowledge transfer.

Adoption differences were uneven. High-uptake practices like improved seeds and balanced fertilization carry lower switching costs and fit existing routines, which may explain why IVR nudges were sufficient. Drip irrigation demands capital investment and technical installation that voice messages alone can't address^[15]. This reinforces that IVR works best as a complement to hands-on extension support rather than a replacement.

Satisfaction ratings averaged 3.98, crossing the acceptable threshold in service quality literature, yet the spread across categories reveals room for improvement. The low score for seed variety content (3.4) likely reflects generic advisories that didn't account for micro-climatic differences between lowland olive growers and highland cereal producers. One unexpected result was the strong uptake of weather alerts, ranking third in calls despite being a supplementary feature. Farmers noted that real-time frost and hail warnings during spring 2023 helped them cover vulnerable crops, preventing losses estimated at EUR 200-400 per household^[16].

Limitations

Several constraints should be noted. The quasi-experimental design doesn't fully rule out selection bias from unmeasured confounders such as farmer motivation. The research was confined to a single district, and conditions elsewhere in Montenegro may differ. The 20-month window doesn't capture whether gains persist beyond the trial. Call log data reflect platform use but not necessarily learning. Finally, connectivity limitations in mountainous areas excluded 18.2% of participants from consistent access, which could bias satisfaction estimates upward among active users.

Conclusion

This research demonstrates that an IVR-based advisory platform can meaningfully improve agricultural knowledge and accelerate adoption of selected farming practices among smallholder households in Montenegro. Farmers in the IVR group achieved knowledge gains roughly double those of the control arm, and adoption rates for four of five tracked technologies were significantly higher. Satisfaction levels suggest the service met farmer expectations across most advisory categories, with pest management and market price information emerging as the most valued modules. IVR doesn't eliminate the need for face-to-face extension, but it

extends reach and fills gaps during peak demand periods. Future work should test longer observation periods, expand coverage to additional municipalities, and experiment with SMS follow-up messages to reinforce voice-delivered advice.

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