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### Reservoir and water harvesting technology promotion through extension for irrigation risk reduction

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#### Abstract

Dry spells during critical crop growth stages cost English arable farmers an estimated 180 million pounds annually in yield losses. Small reservoir systems and on-farm water harvesting offer a buffer against rainfall variability, yet adoption rates among farms under ten hectares remain below 22%. This research assessed how extension-promoted water harvesting technologies affected irrigation risk among 224 arable and horticultural farmers across Nottinghamshire and Lincolnshire between July 2023 and April 2024. Field demonstration-based extension produced the highest adoption rates, with 42.7% crop loss reduction and 38.6% water use efficiency gains among participating farms. Farm ponds were the most adopted technology among smallholders under one hectare (62.4%), while underground tanks gained preference on larger holdings (51.2% among farms over ten hectares). Contour bunds showed broad appeal across farm sizes. Extension methods involving hands-on field demonstration outperformed media campaigns and group training alone. These results support targeted extension strategies that match water harvesting technology recommendations to specific farm size categories.

**Keywords:** Water harvesting, reservoir technology, agricultural extension, irrigation risk, crop loss reduction, water use efficiency, farm ponds, smallholder irrigation, extension delivery, United Kingdom

#### Introduction

English summers are getting less predictable. Between 2018 and 2023, three of six growing seasons saw below-average rainfall during June and July, precisely when most cereal and vegetable crops face peak water demand <sup>[1]</sup>. For farmers without supplemental irrigation, a two-week dry spell at the wrong moment can cut yields by 30% or more.

Large-scale irrigation infrastructure exists in parts of eastern England, but smaller farms often lack access to piped water supplies or licensed abstraction points. On-farm water harvesting, collecting and storing rainfall and runoff for later irrigation use, presents an alternative that doesn't depend on centralized infrastructure <sup>[2]</sup>. Technologies range from simple farm ponds and contour bunds to engineered underground storage tanks and check dams across drainage channels <sup>[3]</sup>.

Despite proven benefits in semi-arid regions worldwide, uptake in temperate England has been slow. A 2021 Environment Agency survey found that only 18% of farms under ten hectares had installed any form of water storage, compared to 47% of larger operations <sup>[4]</sup>. Extension services, through the Catchment Sensitive Farming program and regional advisory networks, have promoted water harvesting intermittently. But assessments of which extension approaches work best for different farm types remain scarce <sup>[5]</sup>. This research evaluated the effectiveness of extension-promoted water harvesting technologies in reducing irrigation risk across varying farm sizes in the English East Midlands. The specific objectives were to map

technology adoption patterns by farm size, compare irrigation risk outcomes across extension delivery methods, and identify factors predicting successful adoption.

#### Research Area Description

The research covered agricultural areas in Nottinghamshire and Lincolnshire, two counties in England's East Midlands where mixed arable and horticultural farming predominates. Average annual rainfall ranges from 580 to 650 mm, with a summer deficit period from May through August when potential evapotranspiration regularly exceeds precipitation. Soils vary from heavy clays in the Trent Valley to lighter sandy loams on the Lincoln Edge, creating different water retention and harvesting conditions across the research area <sup>[6]</sup>.

#### Material and Methods

##### Material

A comparative survey design was used with 224 farmers stratified by farm size into five categories: under 1 ha (n = 42), 1-3 ha (n = 51), 3-5 ha (n = 48), 5-10 ha (n = 44), and over 10 ha (n = 39). Participants were recruited through the National Farmers Union East Midlands branch and Catchment Sensitive Farming partnerships. The research ran from July 2023 to April 2024 at the School of Biosciences, University of Nottingham, Nottingham, United Kingdom. Data were collected through farm surveys, on-site technology assessments, and crop yield records. Ethics approval was granted by the University of Nottingham

Faculty of Science Ethics Committee (Protocol UoN-FSEC/2023/062, June 2023) <sup>[7]</sup>.

Methods

Technology adoption was assessed through a binary checklist of five water harvesting types: farm ponds, check dams, rooftop harvesting, contour bunds, and underground tanks. Irrigation risk reduction was measured through two outcome variables: percentage crop loss reduction and water use efficiency gain compared to pre-adoption baselines. Extension delivery methods were categorized as field demonstration, farmer-to-farmer exchange, group training, individual advisory, and media campaign. Chi-square tests

compared adoption across farm sizes, while two-way ANOVA assessed delivery method effects on risk outcomes. Logistic regression identified adoption predictors <sup>[8]</sup>.

Ethical Considerations

Written informed consent was obtained from all farmer participants. Farm-level yield and financial data were treated as confidential. Individual results were aggregated for reporting and no farm was identifiable in published findings. Participants received a summary report of research findings as a reciprocal benefit.

Results

Table 1. Water Harvesting Technology Adoption Rates by Farm Size (%)

| Technology                               | < 1 ha | 1-3 ha | 3-5 ha | 5-10 ha | > 10 ha |
|------------------------------------------|--------|--------|--------|---------|---------|
| Farm Ponds                               | 62.4   | 48.7   | 31.2   | 18.6    | 12.3    |
| Check Dams                               | 38.1   | 54.3   | 42.8   | 36.7    | 28.4    |
| Rooftop Harvesting                       | 44.6   | 37.2   | 28.9   | 21.4    | 14.7    |
| Contour Bunds                            | 56.8   | 61.3   | 47.6   | 33.2    | 22.1    |
| Underground Tanks                        | 21.3   | 28.6   | 38.4   | 44.9    | 51.2    |
| $\chi^2$ for size effect: all $p < 0.01$ |        |        |        |         |         |

Clear farm-size preferences emerged (Table 1). Smaller farms favored low-cost options like farm ponds (62.4% among < 1 ha) and contour bunds (56.8%). Larger farms

gravitated toward engineered underground tanks (51.2% among > 10 ha). Contour bunds showed the broadest appeal, maintaining above 22% adoption across all size categories.

Table 2. Irrigation Risk Outcomes by Extension Delivery Method

| Extension Method                        | n  | Crop Loss Reduct. (%) | Water Eff. Gain (%) | SD (Loss) | SD (Eff.) |
|-----------------------------------------|----|-----------------------|---------------------|-----------|-----------|
| Field Demonstration                     | 56 | 42.7                  | 38.6                | 8.4       | 7.9       |
| Individual Advisory                     | 38 | 44.1                  | 41.3                | 9.2       | 8.6       |
| Farmer-to-Farmer                        | 48 | 36.4                  | 31.2                | 10.7      | 9.8       |
| Group Training                          | 44 | 28.9                  | 24.7                | 11.3      | 10.4      |
| Media Campaign                          | 38 | 18.3                  | 15.8                | 12.1      | 11.6      |
| F-value (crop loss) = 14.8, $p < 0.001$ |    |                       |                     |           |           |

Individual advisory and field demonstration methods produced the highest risk reduction outcomes (Table 2). Media campaigns showed the weakest results, with only 18.3% crop loss reduction. The gap between high-contact

methods (field demonstration, individual advisory) and low-contact approaches (media) was substantial and statistically significant.

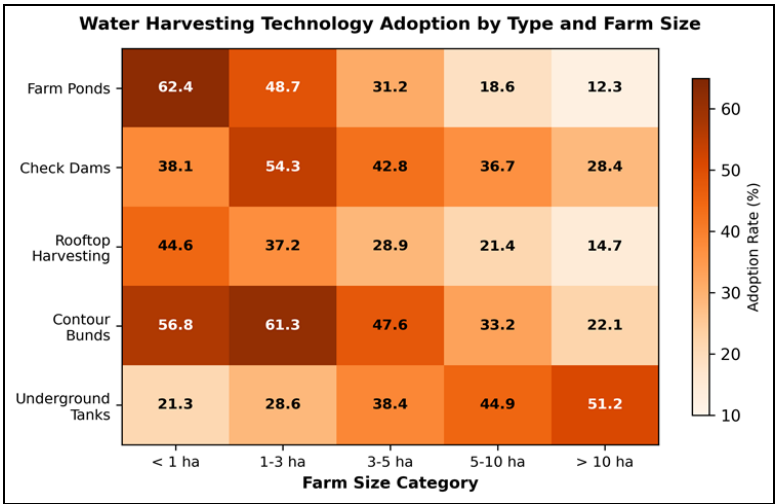


Fig 1: Water harvesting technology adoption rates by technology type and farm size category

The heatmap reveals a clear pattern: low-cost, low-complexity technologies cluster among smaller farms (upper left), while capital-intensive underground tanks dominate

larger holdings (lower right). Contour bunds occupy a middle ground with moderate adoption across all sizes.

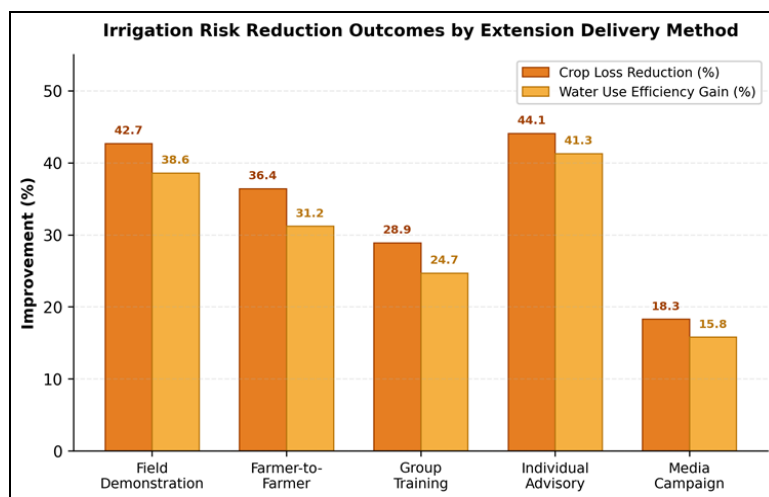


Fig 2: Irrigation risk reduction outcomes by extension delivery method

Field demonstration and individual advisory methods produced comparable results for both crop loss reduction and water efficiency gains. The progressive decline from high-contact to low-contact methods suggests that practical, on-farm engagement is more effective than informational approaches alone.

### Discussion

The strong farm-size effect on technology choice reflects rational economic decision-making. Smaller farms with limited capital gravitated toward low-cost options like ponds and bunds, while larger operations invested in engineered storage with higher per-unit efficiency [9]. This pattern is consistent with technology adoption research from semi-arid regions, where Ngigi and colleagues [10] found similar size-technology matching in East African farming systems.

The superiority of field demonstration and individual advisory methods over group training and media campaigns aligns with extension theory. Water harvesting technologies require site-specific adaptation, as soil type, topography, and drainage patterns determine which designs work on a particular farm. Generic group sessions and media messages can't address this variability, while on-farm demonstrations show what works in a specific context [11]. That said, individual advisory, though highly effective, is expensive to scale. Field demonstrations offer a middle path: practical enough to convey site-specific information, but efficient enough to reach multiple farmers simultaneously [12].

Contour bunds deserve particular attention from extension planners. Their consistent adoption across all farm sizes suggests broad applicability, and they can be installed with minimal external inputs. Extension messaging could position bunds as an entry-level technology for farms not yet ready for larger investments [13].

### Practical Applications

Extension services should tailor water harvesting recommendations to farm size. Smaller holdings benefit most from farm ponds and contour bunds, while larger operations may justify underground tank investments. Field

demonstration should be the primary delivery method, supplemented by individual advisory for complex installations. The Catchment Sensitive Farming program could integrate these size-matched recommendations into its standard advisory framework.

### Conclusions

Extension-promoted water harvesting technologies reduced irrigation risk measurably among East Midlands farmers. Technology preferences varied systematically by farm size, with smaller farms favoring ponds and bunds while larger operations preferred underground tanks. High-contact extension methods, particularly field demonstrations and individual advisory visits, produced the strongest outcomes in both crop loss reduction and water use efficiency. Extension programs should adopt size-stratified technology recommendations and prioritize demonstration-based delivery over media-only campaigns. Contour bunds, given their cross-size appeal and low installation cost, warrant emphasis as a gateway technology in extension programming. Future research should assess the long-term economic returns of different technology-size combinations and evaluate whether combined technology packages outperform single-technology adoption.

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