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Assessing Farmers' Perceptions of Chololo Pits for Enhancing Cereal Crop Yields in Semi- Arid Tanzania

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Research Article

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Abstract

Rain-fed agriculture in semi-arid central Tanzania faces mounting pressure from erratic rainfall patterns, prolonged dry spells, and progressive soil degradation. This study investigated farmer perceptions of Chololo pit effectiveness, measured cereal crop yield trends using structured recall protocols, and identified contextual factors shaping yield variability across four villages: Buigiri, Handali, Manchali, and Mvumi. Data was collected between January and March 2025 through structured household interviews (n = 337), four focus group discussions, and twelve key informant interviews. Quantitative data were analyzed using IBM SPSS version 25, while qualitative data were subjected to thematic analysis. Findings reveal that 99.3% of surveyed farmers rated cereal yields under Chololo pit cultivation as high or very high, with no respondents reporting low or very low performance. Recall-based yield estimates showed maize averaging 0.7–1.3 tons/ha, sorghum 0.6–1.0 tons/ha, and pearl millet 0.6–0.9 tons/ha across villages. These results indicate that Chololo pits meaningfully support cereal production in semi-arid environments, but yield gains are contingent on access to complementary inputs including improved seed varieties and inorganic fertilizers. The study concludes that scaling up Chololo pit benefits requires integration with targeted input supply programs and location-specific agronomic guidance, particularly for pearl millet farmers facing high production uncertainty.

1. INTRODUCTION

1.1 Background and Problem Statement

Smallholder farmers across semi-arid sub-Saharan Africa confront a persistent convergence of environmental pressures: rainfall that arrives late, ends early, or fails altogether; soils that have lost organic matter through decades of continuous cultivation; and markets that remain distant and poorly connected to rural producers. In central Tanzania, these pressures are particularly acute. Dodoma Region receives between 500 and 700 mm of annual rainfall, most of which falls within a single, unpredictable wet season between December and April (URT, 2022). Interannual variability is high, and episodes of severe drought have become more frequent over the past two decades (Msongaleli et al., 2015). Under these conditions, conventional flat-bed cultivation where seeds are planted directly into unprepared soil leaves crops exposed to rapid moisture loss between rainfall events, with no mechanism to retain runoff or organic material deposited by wind and water.

One locally developed response to this vulnerability is the Chololo pit system. Chololo pits are small, manually excavated planting basins arranged across cropland to intercept surface runoff, trap wind-deposited organic matter, and concentrate moisture around individual crop root zones (Kahimba et al., 2014). Farmers in Chamwino District have practiced pit cultivation for several decades, and the approach has been formally promoted through government agricultural extension programs and NGO-supported projects since the early 2000s (Ismail et al., 2022). Unlike externally introduced technologies that require significant capital investment or specialized knowledge, Chololo pits are constructed using locally

available materials and knowledge systems, which contribute to their appeal among resource-limited households.

Despite the long history and growing adoption of this practice, several important knowledge gaps remain. First, while farmers' adoption rates have been documented (Nindi, 2024), systematic measurement of how farmers subjectively evaluate Chololo pit performance and whether those perceptions differ across village contexts has received limited attention. Second, yield data for maize, sorghum, and pearl millet under Chololo pit cultivation are scattered across grey literature and project reports, with few peer-reviewed studies providing village-level comparisons based on primary data. Third, the role of complementary inputs particularly improved seed varieties and inorganic fertilizers supplied through external projects in shaping yield outcomes under Chololo pit systems has not been adequately disentangled from the direct effects of the water-harvesting technology itself.

2. LITERATURE REVIEW

2.1 Water-Harvesting Technologies in Semi-Arid African Agriculture

Water harvesting defined as the collection, concentration, and storage of rainfall runoff for productive use has been practiced across dryland Africa for centuries (Critchley and Siegert, 1991). Contemporary forms range from large-scale earth dams and underground cisterns to field-level techniques such as zai pits in the Sahel, half-moon bunds in Niger, and tassa holes in northern Nigeria (Fatondji et al., 2006; Zougmoré et al., 2014). What these systems share is a basic hydraulic principle: by slowing or redirecting surface runoff, they increase the proportion of rainfall that infiltrates into the soil profile, thereby extending the period during which crops can draw on stored moisture between rainfall events.

Field-level evidence for the productivity benefits of water-harvesting technologies is substantial. In Burkina Faso, Kaboré and Reij (2004) documented a tripling of sorghum yields in fields treated with half-moon bunds compared to untreated controls over a five-year monitoring period. In Ethiopia, Biazin et al. (2012) reviewed 47 studies and found that in-situ rainwater harvesting increased crop yields by an average of 41% under semi-arid conditions, with greater gains recorded in years of below-average rainfall. In Tanzania, Kahimba et al. (2014) reported maize yield increases of 224 kg/ha and millet yield increases of 670 kg/ha in Chololo pit fields compared to flat-bed cultivation in Dodoma Region. More recently, Nindi (2024) found that Chololo pit adoption was associated with statistically significant improvements in household food security indicators in Chamwino District, though causal attribution was complicated by simultaneous access to external input support.

Despite this evidence, researchers have consistently cautioned against treating any single water-harvesting technology as a universal solution. Biazin et al. (2012) found that yield responses to in-situ harvesting varied substantially depending on soil texture, slope gradient, and crop type. Zougmoré et al. (2014) emphasized that combining water-harvesting with soil fertility management particularly organic

matter additions produces yield outcomes significantly larger than either intervention alone. These findings are directly relevant to the Chololo pit context, where pit construction creates favorable conditions for organic matter accumulation through trapping of wind-deposited debris, but where additional nutrient inputs may be necessary to realize full yield potential.

2.2 Farmer Perceptions and Technology Adoption

Farmer perceptions of agricultural technology performance are recognized as a primary determinant of sustained adoption beyond initial promotional periods (Rogers, 2003). Farmers evaluate technologies along multiple dimensions simultaneously: perceived productivity gain, labor requirements, cost, compatibility with existing practices, and reversibility if the technology fails to perform as expected (Davis et al., 2012). Technologies that score well on perceived relative advantage and compatibility tend to achieve higher and more durable adoption rates (Uematsu and Mishra, 2010).

In the context of water-harvesting technologies specifically, Myeya and Mulungu (2021) found that farmers in central Tanzania who reported high perceived effectiveness of soil and water conservation practices were significantly more likely to continue and expand their use over time, independent of whether those perceptions aligned with measured yield outcomes. This finding has two important implications for the present study. First, understanding perceptions is valuable independent of yield measurement, as it predicts future adoption behavior. Second, discrepancies between perceived and measured performance if they exist may indicate either measurement error in yield recall data or genuinely optimistic reporting by farmers with positive prior dispositions toward the technology.

2.3 Cereal Crop Performance Under Variable Rainfall

Maize, sorghum, and pearl millet represent the three dominant cereal crops in semi-arid central Tanzania, each with distinct physiological characteristics that shape their response to moisture stress. Maize (Zea mays L.) is the preferred staple food across most of the region, but it is the most sensitive of the three to moisture deficits, particularly during flowering and grain fill stages (Edmeades, 2013). Its priority as a household food security crop means farmers typically allocate their best land, seed, and available inputs to maize cultivation, which tends to produce higher measured yields relative to other crops even under stress conditions.

Sorghum (Sorghum bicolor L.) possesses superior drought tolerance through several mechanisms including deeper root systems, the ability to remain dormant during short dry spells and resume growth when moisture returns, and lower minimum transpiration requirements than maize (Blum, 2011). Under severe rainfall deficits, sorghum typically produces more reliable yields than maize, though absolute yield levels are generally lower under adequate moisture conditions. Pearl millet (Pennisetum glaucum L.) is the most drought-tolerant of the three crops and can produce grain even in environments receiving below 300 mm of annual rainfall (Thakur et al., 2025). However, its yield response is highly sensitive to soil fertility levels, and under low-nutrient conditions, production can be highly variable from season to season (Liaqat et al., 2025).

2.4 Conceptual Framework

This study is guided by a conceptual framework that positions Chololo pits as one component within a multi-input agricultural production system. Drawing on the production function concept from agricultural economics (Debertin, 2012), cereal yields are understood as outputs produced by the interaction of land quality, seed variety, water availability, soil nutrient status, and management skill. Chololo pits directly address the water availability component by increasing infiltration and reducing runoff losses and partially address soil nutrient status by concentrating organic debris within pit basins. However, improvements in water and organic matter availability cannot compensate fully for deficiencies in seed variety quality or inorganic nutrient supply, which is why yield outcomes vary across input environments.

Farmer perceptions are understood through Rogers' (2003) diffusion of innovations framework, which identifies perceived relative advantage the degree to which a technology is seen as better than the practice it replaces as the strongest individual predictor of adoption behavior. Perceptions are expected to be shaped partly by actual production experience and partly by social learning processes through which neighboring farmers' experiences influence individual assessments.

3. METHODOLOGY

3.1 Study Area

The study was conducted in Chamwino District, Dodoma Region, central Tanzania (Fig. 1). Chamwino District covers approximately 11,000 km² and is characterized by semi-arid climatic conditions, with mean annual rainfall of 550–650 mm concentrated in a single wet season from December to April (URT, 2022). Soils are predominantly sandy loams and clay loams with low organic matter content, limited water-holding capacity, and susceptibility to surface crusting following heavy rainfall events. Agriculture is the primary livelihood activity for approximately 85% of the district's population, with maize, sorghum, and pearl millet constituting the dominant food crops.

Four villages were included in the study: Buigiri, Handali, Manchali, and Mvumi (Fig. 1). These villages were selected based on three criteria: (i) documented history of Chololo pit cultivation for at least five years; (ii) variation in access to external project support Manchali and Mvumi receive input support through RECODA and TAHEA projects respectively, while Buigiri and Handali do not allowing comparison of input-supported and non-supported production contexts; and (iii) logistical accessibility for research teams operating from Dodoma town.

3.2 Research Design

The study employed a mixed-methods research design, combining quantitative data from structured household surveys with qualitative evidence from focus group discussions and key informant interviews. This design was selected because farmer perceptions the primary focus of objective one are most

effectively captured through standardized rating instruments administered to large samples, while the contextual explanations for yield variability require the depth of inquiry that qualitative methods provide (Creswell and Plano Clark, 2017). Quantitative and qualitative data streams were collected concurrently and integrated at the interpretation stage.

3.3 Sampling Strategy

3.3.1 Village Selection

Villages were selected purposively based on the three criteria outlined in Section 3.1. Purposive selection was appropriate because the study required villages with established Chololo pit practices and variation in input access, conditions that simple random selection from the full district village list could not guarantee (Tongco, 2007).

3.3.2 Household Sample

The target population comprised all households practicing Chololo pit cultivation in the four study villages. Village registers maintained by local government offices provided sampling frames. Based on these registers, the household populations in each village were: Buigiri (n = 1,247), Handali (n = 893), Manchali (n = 553), and Mvumi (n = 634), giving a combined population of 3,327 Chololo pit-practicing households.

Following the recommendation of Delice (2010) for a minimum sampling intensity of 5% in community-level agricultural studies, a target sample of 167 households was initially calculated. To account for expected non-response and to ensure adequate statistical power for village-level comparisons, this was doubled to 334 households, subsequently rounded to 337 through field adjustments(Table 1).. Households within each village were selected by simple random sampling using a computer-generated random number list applied to the village registers. The resulting village samples were: Buigiri (n = 126), Handali (n = 91), Manchali (n = 56), and Mvumi (n = 64).

Table 1
Sampling Frame and Sample Sizes by Village

Village	Total Chololo Pit HH	Sample (n)	Sampling Fraction (%)
Buigiri	1,247	126	10.1
Handali	893	91	10.2
Manchali	553	56	10.1
Mvumi	634	64	10.1
Total	**3,327**	**337**	**10.1**

3.3.3 Qualitative Participants

One focus group discussion (FGD) was conducted in each study village, involving eight to twelve purposively selected participants per group, chosen to represent variation in gender, age, farming experience, and level of Chololo adoption. Total FGD participants: 42 across four villages.

Twelve key informants were selected purposively on the basis of their professional knowledge of Chololo pit systems or local agriculture: four district and ward agricultural extension officers, two representatives each from RECODA and TAHEA, two village executive officers, and two community elder farmers with more than twenty years of Chololo pit experience.

3.4 Data Collection

3.4.1 Household Survey Instrument

A structured questionnaire was developed in English, translated into Kiswahili by a professional translator, and back translated into English to verify conceptual equivalence. The instrument was pre-tested with fifteen farmers from a neighboring village not included in the main study, and revisions were made based on identified ambiguities before the main data collection period.

The questionnaire covered three domains. The first domain captured household characteristics including farm size, years of Chololo pit experience, crop portfolio, and access to inputs. The second domain assessed farmer perceptions of Chololo pit performance on a five-point ordinal scale: Very High (5), High (4), Moderate (3), Low (2), and Very Low (1). Farmers were asked to rate the performance of Chololo pits for each cereal crop they cultivated separately maize, sorghum, and pearl millet rather than providing a single undifferentiated assessment. The third domain collected recall-based yield estimates for the 2022, 2023, and 2024 cropping seasons. Farmers were asked to estimate production in debe (a locally standardized measure equivalent to approximately 20 kg) and area cultivated in acres, using landmark-based area estimation methods. Field enumerators converted units to kilograms per hectare using standard conversion factors verified against local extension records.

Enumerator training covered questionnaire administration, local unit conversions, strategies for facilitating accurate recall using seasonal event calendars, and data quality checking procedures. Six trained enumerators conducted interviews in pairs, with one asking questions and one recording responses to reduce transcription errors.

3.4.2 Focus Group Discussions

FGDs were conducted using a semi-structured discussion guide covering three thematic areas: farmers' collective understanding of why Chololo pits affect yields; inter-seasonal variation in crop performance and its attributed causes; and perceptions of constraints limiting further productivity gains. Discussions lasted between 90 and 120 minutes, were conducted in Kiswahili, audio-recorded with participant consent, and later transcribed and translated into English by the same professional translator used for questionnaire translation.

3.4.3 Key Informant Interviews

Individual in-depth interviews with key informants followed a guide covering technical assessments of Chololo pit yield potential, observations of differences across villages, and institutional perspectives on input supply and extension support. Interviews lasted 45–75 minutes, were audio-recorded with consent, and transcribed in full.

3.4.4 Field Observation

Structured field observations were conducted in all four villages to record the physical characteristics of Chololo pit installations pit dimensions, spacing, fill status, and associated crops and to verify the presence of the external project activities described by survey respondents.

3.5 Data Analysis

3.5.1 Quantitative Analysis

Household survey data were entered into IBM SPSS version 25 and checked for entry errors through range and logic checks. Descriptive statistics frequencies, percentages, weighted means, and standard deviations were computed for all key variables. Weighted mean perception scores were calculated using village sample sizes as weights to ensure that larger villages contributed proportionally to aggregate figures. Yield data were analyzed using one-way analysis of variance (ANOVA) to test whether mean yields differed significantly across villages for each crop, with post-hoc Tukey HSD tests applied where overall F-tests were significant. Inter-annual yield change was expressed as percentage difference between consecutive seasons. The coefficient of variation (CV) was calculated for each village-crop combination as a measure of yield stability, with CV exceeding 30% classified as indicating high instability following the threshold used by Bänziger et al. (2000).

3.5.2 Qualitative Analysis

Transcribed FGD and key informant data were analyzed using thematic analysis following Braun and Clarke's (2006) six-phase framework: familiarization with data; generation of initial codes; searching for themes; reviewing themes; defining and naming themes; and producing the report. Two researchers coded independently, and discrepancies were resolved through discussion. Member checking was conducted by sharing summary findings with two key informants and two FGD participants to verify interpretive accuracy.

3.6 Limitations

Three methodological limitations merit explicit acknowledgment. First, the recall method for yield estimation is subject to memory error, and the three-year recall window used in this study may introduce systematic underestimation or overestimation relative to recorded production figures. Seasonal event calendars and were used to anchor recall, but this cannot fully compensate for the absence of written farm records. Second, farm area estimation relied on landmark-based farmer recall rather than GPS measurement, which introduces measurement error in the denominator of yield calculations. Third, the

absence of a concurrent comparison group of flat-bed cultivation farmers limits causal attribution of observed yield levels to Chololo pit effects specifically.

3.7 Ethical Considerations

Ethical clearance was obtained from the University of Dodoma Research Ethics Committee (Reference: UDOM/REC/2024/089) prior to data collection. All participants provided informed verbal consent before interviews and discussions, having been informed of the study's purpose, their right to withdraw without consequence, and the conditions under which their responses would be used. Individual responses were anonymized in all records, and no personally identifying information is reported. Key informants and FGD participants who chose to remain anonymous are identified only by professional role in this paper.

4. RESULTS

4.1 Household Characteristics

The 337 surveyed households had practiced Chololo pit farming for an average of 8.3 years (SD = 4.1, range = 2–24 years). Mean farm size was 2.6 acres (SD = 1.2), with Chololo pit fields comprising an average of 1.8 acres. All surveyed households cultivated maize; 71.2% cultivated sorghum; and 58.4% cultivated pearl millet. Households in Buigiri and Handali relied primarily on manure and saved seed from previous seasons, while the majority of households in Manchali and Mvumi had received improved seed varieties and fertilizer through RECODA and TAHEA project interventions respectively within the two years preceding the survey.

4.2 Farmer Perceptions of Cereal Yields Under Chololo Pits

4.2.1 Overall Perception Ratings

Table 1 presents the distribution of farmer perception ratings for cereal crop yield performance under Chololo pit cultivation, disaggregated by village. Ratings were collected separately for each crop cultivated by the respondent; the figures in Table 1 represent aggregate ratings across all crops per village, weighted by crop prevalence.

Table 1
Farmer Perception Ratings of Cereal Crop Yield Performance Under Chololo Pits, by Village

Village	n	Very High (%)	High (%)	Moderate (%)	Low (%)	Very Low (%)	Weighted Mean Score
Handali	91	87.5	11.7	0.8	0.0	0.0	4.87
Mvumi	64	90.0	9.6	0.4	0.0	0.0	4.90
Buigiri	126	89.6	9.5	0.9	0.0	0.0	4.89
Manchali	56	86.0	13.4	0.6	0.0	0.0	4.85
Weighted total	**337**	**88.7**	**10.7**	**0.6**	**0.0**	**0.0**	**4.88**

Note: Weighted mean calculated on 1–5 scale (1 = Very Low, 5 = Very High). Village weights are based on sample size.

The weighted aggregate figures show that 99.4% of surveyed farmers rated cereal yields from Chololo pit cultivation as either High or Very High, with 0.6% performance as Moderate. No respondent in any village assigned a Low or Very Low rating. The weighted mean perception score of 4.88 out of 5.0 indicates near-unanimous positive assessment across the sample.

Inter-village variation in perception ratings was minimal. Mvumi recorded the highest proportion of Very High ratings (90.0%), while Manchali recorded the lowest (86.0%), a difference of four percentage points. Weighted mean scores ranged from 4.85 in Manchali to 4.90 in Mvumi, a range of 0.05 scale points, suggesting that the positive evaluation of Chololo pit performance is consistent across villages regardless of differences in input access or project support.

4.2.2 Crop-Specific Perceptions

When perception ratings were disaggregated by crop, maize attracted the highest proportion of Very High ratings in all four villages (averaging 91.2% across villages), followed by sorghum (87.4%) and pearl millet (82.6%). The lower perception ratings for pearl millet reflect farmers' direct experience of inter-annual production variability for this crop, a pattern confirmed in the yield recall data presented in Section 4.3.

4.2.3 Qualitative Evidence Supporting Perception Findings

FGD participants across all four villages described the fundamental mechanism by which Chololo pits improved their perceived crop performance: moisture conservation during dry spells within the growing season. A participant in the Handali FGD explained:

"When rain stops for two weeks, the crops in flat fields begin to die but crops in the pits continue growing. The pit holds water in the soil. After many years of using pits, I have rarely lost an entire harvest, but my

neighbor who uses flat planting loses everything in dry years."

This testimony illustrates the perceived insurance value of Chololo pits during intra-seasonal dry spells a benefit distinct from average yield improvement that is difficult to capture through perception rating scales alone.

An agricultural extension officer with twelve years of experience in Chamwino District elaborated on the physical mechanism:

"A properly constructed Chololo pit works in two ways. First, it slows runoff, so more water enters the soil rather than flowing away. Second, crop residues, dust, and animal droppings carried by wind and water collect in the pit and decompose there. After three or four years, the soil in the pit is noticeably darker and softer than surrounding soil. Farmers on flat fields do not get this benefit."

This observation is consistent with reported evidence that Chololo pits accumulate organic matter over time, gradually improving soil physical and chemical properties (Kahimba et al., 2014; Nindi, 2024).

Participants in Manchali and Mvumi additionally attributed their positive perceptions to the combined effect of pits and improved inputs received through external projects. A participant in the Mvumi FGD stated:

"The pits alone are good, but the pits together with the seeds we got from TAHEA that is when yields really changed. We can see the difference between our fields and the fields of people who have pits but only old seeds."

This testimony reinforces the quantitative finding that input access mediates yield outcomes and suggests that perceptions may partly reflect the joint benefit of pits and complementary inputs rather than the technology effect in isolation.

4.3 Cereal Crop Yields Under Chololo Pit Cultivation

4.3.1 Recall-Based Yield Estimates, 2022–2024

Table 2 presents recall-based cereal crop yield estimates for the 2022, 2023, and 2024 cropping seasons across the four study villages.

Table 2
Recall-Based Cereal Crop Yields Under Chololo Pit Cultivation, 2022–2024 (tons/ha)

Village	Crop	2022	2023	2024	3-Year Mean	SD	CV (%)
Handali	Maize	0.60	1.30	1.10	1.00	0.29	29.0
Mvumi	Maize	0.50	0.70	0.90	0.70	0.16	22.9
Buigiri	Maize	1.00	1.30	1.60	1.30	0.25	19.2
Manchali	Maize	0.40	0.70	1.00	0.70	0.24	34.3
Handali	Sorghum	0.90	0.60	1.20	0.90	0.25	27.8
Mvumi	Sorghum	0.30	0.90	0.60	0.60	0.25	41.7
Buigiri	Sorghum	0.90	1.10	1.00	1.00	0.08	8.0
Manchali	Sorghum	0.80	0.50	0.70	0.70	0.13	18.6
Handali	Pearl Millet	0.70	0.50	0.90	0.70	0.17	24.3
Mvumi	Pearl Millet	1.20	0.60	0.90	0.90	0.25	27.8
Buigiri	Pearl Millet	0.50	0.60	0.70	0.60	0.08	13.3
Manchali	Pearl Millet	0.60	1.20	0.90	0.90	0.25	27.8

SD = Standard deviation; CV = Coefficient of variation. High instability defined as CV > 30% following Bänziger et al. (2000).

4.3.2 Maize Yield Patterns

Maize yields showed a generally positive trend across the recall period in most villages. Buigiri recorded the highest three-year mean (1.30 tons/ha) and the most consistent upward trajectory, moving from 1.00 ton/ha in 2022 to 1.60 tons/ha in 2024 a 60% increase over three years. Handali showed a sharp increase from 0.60 tons/ha in 2022 to 1.30 tons/ha in 2023, followed by a modest decline to 1.10 tons/ha in 2024, likely reflecting the effect of a relatively better rainfall season in 2023 as reported by key informants. Mvumi and Manchali recorded lower three-year means of 0.70 tons/ha each, though both showed positive year-on-year trends, suggesting gradual improvement. Coefficient of variation values for maize ranged from 19.2% in Buigiri to 34.3% in Manchali, indicating that Buigiri and Mvumi had more stable maize production than Handali and Manchali.

One-way ANOVA revealed a statistically significant difference in mean maize yields across villages ($F(3,333) = 8.42$, $p < 0.001$). Post-hoc Tukey HSD tests confirmed that Buigiri's mean maize yield was significantly higher than those of Mvumi ($p = 0.001$) and Manchali ($p = 0.002$) but did not differ significantly from Handali ($p = 0.14$).

4.3.3 Sorghum Yield Patterns

Sorghum yield trends were more mixed across villages. Buigiri recorded both the highest mean (1.00 ton/ha) and the greatest stability (CV = 8.0%), suggesting that sorghum in this village benefits from relatively consistent soil conditions and management practices. In contrast, Mvumi's sorghum showed the highest inter-annual variability (CV = 41.7%), with yields ranging from 0.30 tons/ha in 2022 to 0.90 tons/ha in 2023 before declining to 0.60 tons/ha in 2024. Key informants attributed the 2022 low yield in Mvumi to localized flooding that damaged pits in low-lying areas, illustrating that Chololo pit performance can be adversely affected by extreme rainfall as well as drought.

ANOVA indicated a significant effect of village on mean sorghum yield ($F(3,333) = 5.17$, $p = 0.002$). Buigiri's mean sorghum yield was significantly higher than Mvumi's ($p = 0.004$) but did not differ significantly from Handali or Manchali.

4.3.4 Pearl Millet Yield Patterns

Pearl millet showed more erratic patterns than either maize or sorghum. In Mvumi, yields fell from 1.20 tons/ha in 2022 to 0.60 tons/ha in 2023 before recovering to 0.90 tons/ha in 2024. In Manchali, the opposite pattern was observed: a sharp increase from 0.60 tons/ha in 2022 to 1.20 tons/ha in 2023 followed by a partial decline to 0.90 tons/ha in 2024. FGD participants attributed pearl millet variability primarily to two factors: sensitivity to the timing of first rainfall late planting following delayed rains consistently reduced pearl millet yields more than maize yields and the absence of regular fertilizer application for pearl millet crops compared to maize.

ANOVA did not reveal a statistically significant difference in mean pearl millet yields across villages ($F(3,333) = 1.83$, $p = 0.14$), indicating that the high inter-village variability in year-specific pearl millet yields does not translate into stable inter-village differences in average performance.

4.3.5 Comparison with Expert Yield Estimates

Key informants from TAHEA and RECODA estimated attainable yields under optimal Chololo pit management combining properly constructed pits, improved seed varieties, and recommended fertilizer rates at 2.5 tons/ha for maize, 2.0 tons/ha for sorghum, and 2.0 tons/ha for pearl millet. These figures are approximately double the recall-based averages reported by households surveyed.

This gap between typical farmer yields and expert-estimated attainable yields is significant and deserves careful interpretation. Several explanations are plausible. First, expert estimates may reflect yields achieved on demonstration plots or by the most intensively supported farmers, rather than average performance across all practitioners. Second, the recall method likely underestimates production somewhat because farmers tend to report conservative estimates in the absence of written records (Beegle et al., 2012). Third, and most importantly, most surveyed households particularly in Buigiri and Handali do not have access to improved seed varieties or inorganic fertilizers, meaning they are producing under conditions considerably less favorable than those underpinning expert estimates. The yield gap therefore reflects an input access deficit as much as a technology performance deficit, a distinction with direct implications for program design.

5. DISCUSSION

5.1 The Meaning of Near-Universal Positive Perceptions

The finding that 99.4% of surveyed farmers rated Chololo pit yields as High or Very High is striking in its consistency and warrants both affirmation and critical scrutiny. On the affirmative side, this level of agreement across four villages with different input environments, different project histories, and different agro-ecological micro-conditions suggests that farmers are responding to a genuinely experienced and broadly shared benefit. The recall yield data, although imperfect, support this interpretation: yields under Chololo pit cultivation in all four villages exceed published estimates for flat-bed cultivation in comparable semi-arid environments in Tanzania, which average between 0.4 and 0.6 tons/ha for maize and below 0.5 tons/ha for sorghum under poor rainfall conditions (Msongaleli et al., 2015).

At the same time, several factors may inflate perception ratings beyond what objective yield measurements alone would support. Social desirability biases the tendency of survey respondents to provide answers they believe interviewers expect or approve of is a documented risk in technology perception studies, particularly where the technology has been actively promoted by government or NGO partners (Whitfield et al., 2015). Farmers who have invested significant labor in constructing Chololo pits may also be subject to cognitive dissonance effects, reporting higher satisfaction to justify the investment already made (Festinger, 1957). Additionally, as the Mvumi FGD participant quoted in Section 4.2.3 indicated, farmers in project-supported villages may be rating the combined effect of pits plus improved inputs rather than the pit technology alone. These considerations do not invalidate the perception findings, but they do suggest that perception data should be interpreted alongside rather than as a substitute for measured yield data.

5.2 Input Access as the Primary Driver of Yield Differences

The most substantive finding to emerge from the yield analysis is that inter-village differences in cereal yields are more strongly associated with input access than with any other measured factor. Buigiri consistently achieved the highest maize, and sorghum yields despite receiving no formal project support during the recall period. Key informant and FGD evidence suggest that Buigiri's relatively better performance reflects longer average experience with Chololo pits among surveyed households (mean 11.4 years, compared to the sample average of 8.3 years) and better pit construction quality as assessed during field observation. This finding is consistent with Kahimba et al.'s (2014) observation that pit construction quality particularly pit depth, spacing, and maintenance significantly affects water capture efficiency and therefore yield outcomes.

In project-supported villages, the higher perception ratings in Mvumi relative to Manchali despite similar input support packages may reflect differences in extension officer engagement quality. Key informants from TAHEA noted that Mvumi's extension officer had conducted more frequent farm visits than the RECODA officer serving Manchali, consistent with evidence that the intensity of extension contact mediates the productivity returns to input packages in smallholder settings (Davis et al., 2012).

5.3 Crop-Specific Implications

The differential stability of maize, sorghum, and pearl millet yields under Chololo pit cultivation has practical implications for farming system design in Chamwino District. Maize's consistent positive yield trends across villages confirm its suitability as the primary beneficiary crop of Chololo pit investment, particularly for households with access to complementary inputs. Its status as the preferred household staple creates strong incentives for farmers to allocate management attention to maize, which likely contributes to the more consistent yields observed relative to other crops.

Sorghum's combination of moderate mean yields and low inter-annual variability exemplified by Buigiri's CV of 8.0% makes it a strategically important component of a diversified cropping system. During the 2022 season, which key informants described as drier than average, sorghum yields in Handali and Buigiri held above 0.90 tons/ha while maize yields in the same villages were appreciably lower than in subsequent seasons. This pattern is consistent with sorghum's physiological drought tolerance mechanisms described by Blum (2011) and supports the recommendation that farmers maintain sorghum cultivation as a production hedge against poor rainfall years.

Pearl millet's high yield variability evident in both the year-to-year fluctuations in Table 2 and in farmers' lower perception ratings for this crop points to the need for crop-specific management interventions. FGD evidence identifying planting date timing and fertilizer availability as primary drivers of pearl millet variability suggests that targeted interventions in these two areas could substantially reduce production risk for households dependent on pearl millet. This is particularly relevant for Handali and Buigiri farmers who currently have no access to subsidized fertilizer for pearl millet production.

5.4 The Yield Gap and Its Implications

The approximately 50–100% gap between typical farmer yields and expert-estimated attainable yields under optimal management represents both a measure of unrealized potential and an argument for the type of integrated support that RECODA and TAHEA provide. Closing this gap fully would require extending improved seed access, fertilizer supply, and quality extension services to all Chololo pit farming households a resource challenge that exceeds the current capacity of project programs covering only two of four study villages. A more realistic intermediate target would be reducing the yield gap by 30–40% through expanding access to improved seed varieties alone, given evidence from comparable contexts that variety improvement can increase semi-arid cereal yields by 20–35% without additional fertilizer input (Edmeades, 2013; Kadigi et al., 2025).

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study set out to assess farmer perceptions of Chololo pit yield performance, measure cereal yield trends across four villages in Chamwino District and identify contextual factors shaping yield variability.

On each objective, the findings provide clear and consistent evidence.

Farmer perceptions of Chololo pit performance are overwhelmingly positive, with 99.4% of farmers surveyed ratings as High or Very High. This consensus spans villages with different input environments and project histories, indicating that technology delivers a benefit that farmers across different contexts recognize and value. The qualitative evidence points to moisture retention during intra-seasonal dry spells as the most consistently appreciated mechanism, a finding that has direct relevance for technology promotion messaging.

Recall-based yield data confirm that maize, sorghum, and pearl millet production under Chololo pits exceeds published benchmarks for conventional flat-bed cultivation in similar environments. Maize achieves the most consistent positive trends, sorghum demonstrates stability under variable conditions, and pearl millet shows high inter-annual variability that warrants targeted management attention. Critically, yield differences across villages are most strongly associated with access to improved seeds and fertilizers rather than with pit construction quality or village-level environmental differences per se.

The substantial gap between typical farmer yields and expert estimates of attainable yields under optimal management underscores the fact that Chololo pits function as a necessary but not sufficient condition for high cereal productivity. The technology provides a foundation improved soil moisture and gradually enriching organic matter on which higher-yielding varieties and appropriate nutrient management can build. Without those complementary elements, yield gains remain real but partial.

6.2 Recommendations

Based on the empirical findings of this study, the following specific recommendations are offered:

Recommendation 1: Expand Improved Seed Access to Non-Project Villages

Buigiri and Handali farmers currently depend on saved seed from previous seasons, which progressively loses yield potential through disease accumulation and genetic drift. National and district government programs should prioritize these villages for subsidized improved seed access through agro-dealer voucher schemes, targeting maize and drought-tolerant sorghum varieties in the first instance.

Recommendation 2: Develop Pearl Millet-Specific Management Protocols

The high yield variability observed for pearl millet across villages indicates that existing extension messaging largely focused on maize does not adequately address this crop's specific management requirements. District agricultural extension services should develop and disseminate pearl millet planting calendars based on seasonal rainfall onset data and facilitate access to low-dose starter fertilizer for pearl millet fields.

Recommendation 3: Institutionalize Pit Quality Standards

Field observation revealed considerable variation in Chololo pit construction quality, particularly in depth and spacing consistency. The correlation between longer practice experience and better yield outcomes in Buigiri suggests that construction quality improves with practice but could be accelerated through structured peer learning. Farmer-to-farmer training programs pairing experienced Chololo pit practitioners with newer adopters should be supported through village-level agricultural committees.

Recommendation 4: Investigate and Monitor the Yield Gap

The gap between recall-based yields and expert estimates needs systematic investigation using plot-level measurement rather than recall methods. Establishing permanent trial plots in each study village comparing yields under different input combinations within Chololo pit systems would generate the evidence base needed to design cost-effective packages for scaling up productivity gains.

Recommendation 5: Strengthen Extension Service Intensity

Evidence from Mvumi suggests that more frequent farm visits by extension officers produce better yield outcomes, consistent with the broader literature on extension effectiveness. District agricultural authorities should review officer-to-farmer ratios in Chololo pit communities and allocate additional extension resources to underserved villages.

Disclosure

Statement

The author declares that no potential conflict of interest influenced the conduct of this research or the reporting of its findings.

Declarations

Ethics Approval

Ethical approval for this study was obtained from the University of Dodoma, approval reference number MA.84/261/01/90/141. The study was conducted in accordance with the applicable ethical guidelines and regulations.

Consent to Participate

Informed consent was obtained from all participants before data collection. Participants were informed about the purpose of the study, their voluntary participation, and their right to withdraw at any time without penalty.

Consent to Publish

Not applicable. This manuscript does not contain any individual person's identifiable data or images requiring consent for publication.

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Author Contribution

Wrote the whole manuscript myself

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Footnotes

1. Chololo pits are small planting basins, generally measuring about 20–30 cm in depth and 20–25 cm in width, that are used in semi-arid Tanzania to capture rainwater, retain soil moisture, and enhance crop productivity.

Figures

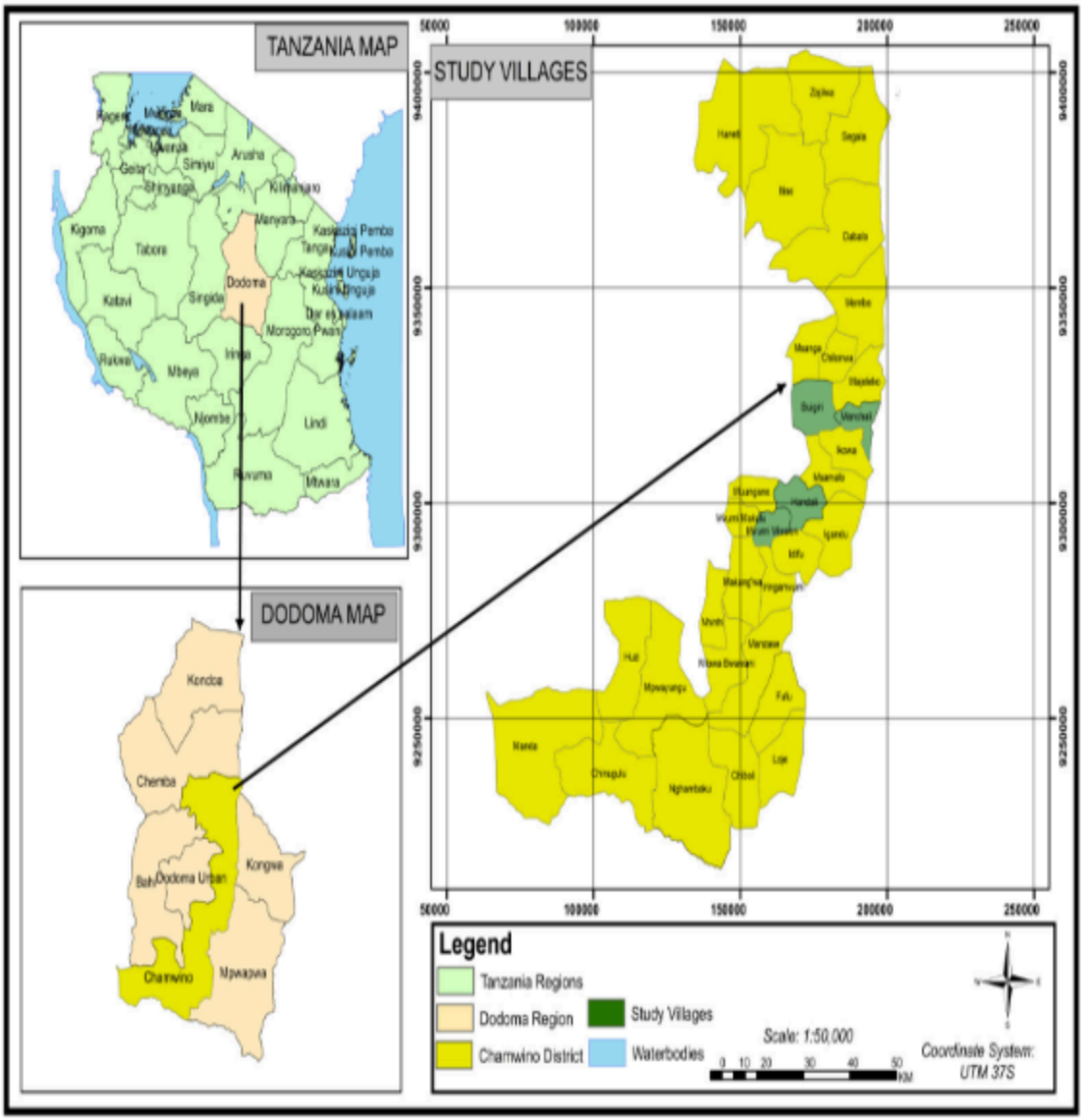

Figure 1

Map of Chamwino District showing the four study villages. Source: Author, adapted from ISRIC (2025).