

**Reversing *in situ* crop genetic diversity loss through incentive-based conservation**

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## Abstract

Crop genetic diversity underpins the adaptive capacity of food systems but is declining. Maintaining diversity is challenging because most crop varieties underperform the best-suited ones under current conditions, therefore the private value of currently low-yielding varieties to farmers is limited. However they may carry traits that become critical as conditions change, so their public value as a genetic resource is large and long-term. Payments for Agrobiodiversity Conservation Services (PACS) – adapted from Payments for Ecosystem Services – aims to address this disparity by compensating farmers' opportunity cost of conserving declining landraces. Here we provide the first counterfactual evaluation of a PACS scheme, using competitive bidding to allocate community conservation contracts among 461 farmers. We focus on enset (*Ensete ventricosum*), a staple food for over 20 million Ethiopians, which is almost entirely absent from *ex situ* collections. Of 141 enset landraces, 70% were threatened and 26% locally extinct. Using two complementary difference-in-differences designs we show that, relative to controls, PACS increased richness by 4.9 landraces per household, doubling typical farm diversity, and increased the number of households cultivating contracted landraces tenfold. Rather than crowding out non-contracted landraces, PACS improved their conservation status, with larger gains in communities with a greater share of contracted landraces. This indicates motivational crowding in, with PACS delivering conservation gains beyond those paid for. Scaling average compensation (US\$8.46 per household) suggests that securing threatened enset diversity nationally would require US\$141,000-640,000, <0.1% of Ethiopia's agriculture and food security budget. PACS offers a cost-effective, scalable strategy for *in situ* agrobiodiversity conservation.

## Significance statement

Modern food systems depend on a narrowing set of crops and varieties, increasing vulnerability to shocks. Maintaining *in situ* crop diversity can strengthen the resilience of global food systems, but these wider public benefits are rarely reflected in market prices. Payments that directly reward farmers for conserving rare varieties, may correct this market failure. Yet their effectiveness has not been causally assessed. We implemented and evaluated a community-based incentive scheme for enset, an Ethiopian staple crop. Targeted incentives increased on-farm diversity, improved conservation outcomes for rare varieties, and generated positive spillovers improving outcomes for varieties that received no payment. Well-designed incentives can reverse local genetic erosion at modest cost while supporting farmer livelihoods and safeguarding future crop options.

## 1. Introduction

The Green Revolution achieved dramatic advances in food production (1), but increased global dependence on a narrow set of staple crops (2–4). Of approximately 30,000 edible plants, just three species - wheat, rice and maize - now provide approximately 60% of global calorific consumption (5). Within these staples, genetic homogenisation has led to a handful of 'megavarieties' dominating production landscapes (6): just four rice varieties and six maize varieties account for 60-70% of global production (7). This simplification undermines resilience by reducing the ability of food systems to buffer against climate shocks, pests, diseases and market volatility (8, 9).

Efforts to conserve declining crop diversity have primarily focused on *ex situ* collections and major crops (10, 11). While *ex situ* collections are useful for facilitating research and breeding (12), they are heavily skewed toward staple cereals which make up 42 percent of global accessions (13). By contrast, crops disproportionately important in tropical smallholder systems, such as roots and tubers, are both harder to conserve *ex situ* due to clonal propagation methods (14) and represent only two percent of total holdings (11, 13). *In situ* agrobiodiversity conservation offers unique benefits, complementing *ex situ* conservation, by maintaining crop genetic resources within the ecological, cultural, and management contexts in which locally adapted varieties continue to evolve to emerging stressors (4, 15–19). For smallholder and subsistence farmers, this diversity can also provide direct livelihood benefits. For example, growing varieties that respond differently to drought, pests and disease stabilises production and buffers households against crop failure (20, 21).

Farmers who maintain diversity within crops generate a range of public benefits, including genetic resources for future adaptation and crop breeding (3, 22–24), and preservation of cultural heritage and traditional knowledge (25, 26). These public goods are rarely reflected in market prices (27, 28) meaning private incentives are typically insufficient to sustain on-farm crop genetic diversity at levels that reflect its full value to society (29, 30). This mismatch is particularly acute for landraces (crop varieties) that are less desirable to farmers today, due to lower production or susceptibility to environmental stress, yet may be among the best performers under future conditions (31). Subsistence farmers operating with little margin for risk, therefore often prioritise short-term private returns over these undervalued public goods, even when the latter could offer greater private resilience over the medium- to long-term (27, 32).

Payments for Agrobiodiversity Conservation Services (PACS) have been proposed as a mechanism to correct this market failure by directly compensating farmers now for conserving

100 rare or underutilised crop varieties whose public good value may increase in the future (30,  
101 33, 34). PACS builds on the logic and success of Payments for Ecosystem Services (PES)  
102 schemes (35), and adapts these to incentivise conservation of crop genetic diversity (Fig. 1).  
103 While the effectiveness of PES programmes has been extensively evaluated (36) including for  
104 unintended spillovers (37) such as geographic leakage (38) and motivational crowding in or  
105 out whereby external rewards strengthen or weaken a person's intrinsic motivation (39–41),  
106 the effectiveness of PACS remains largely untested. It is unclear whether comparable effects  
107 would arise in PACS (for example, via payments displacing cultural motivations for growing  
108 landraces), especially given the substantial competing incentives for commercial varieties  
109 already shaping farmer behaviour (42). Early pilot PACS schemes in Latin America and South  
110 Asia have demonstrated conceptual feasibility (30, 34, 43), and have examined heterogeneity  
111 in conservation costs (43–45), participation patterns, and short-term changes in targeted  
112 landraces (30, 34). None of these studies employed counterfactual methods to evaluate  
113 agrobiodiversity conservation outcomes relative to what would have occurred in absence of  
114 the intervention or tested for spillovers regularly documented in PES.

116 Centres of crop origin and diversification, such as Ethiopia, represent key priorities for  
117 implementing PACS as these areas have high diversity of traditional varieties (46–48). We  
118 focus on the Ethiopian indigenous staple enset (*Ensete ventricosum*), a drought-resistant crop  
119 that provides a reliable, year-round source of carbohydrates for more than 20 million people  
120 (49). Enset comprises hundreds of locally recognised landraces with wide-ranging functional  
121 traits, including variation in maturation time, drought tolerance, and nutritional content (49–  
122 51). Yet, as with many other traditional crops (2, 52, 53), enset's genetic diversity is  
123 increasingly threatened by varietal replacement, land use change and erosion of traditional  
124 knowledge (54). *In situ* conservation is essential for safeguarding enset diversity, as the  
125 challenges of clonal propagation and limited international conservation investment mean  
126 enset remains almost entirely absent from *ex situ* collections (49).

127 Here we provide the first counterfactual assessment of whether PACS can halt and reverse  
128 crop diversity loss. We implement and evaluate a community-based incentive scheme  
129 involving participatory identification of threatened landraces and community-level  
130 conservation contracts, in which communities bid for in-kind payments to cultivate and  
131 maintain selected threatened landraces. Using repeated surveys of landrace rarity, we  
132 estimate impacts through two complementary difference-in-differences approaches,  
133 comparing changes over time in (i) community-level diversity between treated communities  
134 and control pseudo-communities, and (ii) landrace-level conservation outcomes between

contracted landraces and non-contracted landraces within participating communities. We then test for potential spillover effects on non-contracted landraces, examine drivers of cost heterogeneity revealed through competitive bids for PACS contracts, and estimate the cost of scaling PACS to conserve threatened enset landraces nationally. Together, these analyses provide a rigorous test of whether PACS offers an effective replicable strategy for incentivising *in situ* conservation of crop genetic resources.

## 2. Results

We implemented the PACS scheme in Keffa and Bench Maji zones of the South West Ethiopia Peoples' Region (Supplementary Figure 1), working with 461 farmers in 22 communities spread across five woredas (districts). The scheme aimed to support the *in situ* conservation of the indigenous crop enset and incentivise community-level maintenance and expansion of threatened crop genetic diversity through structured conservation contracts.

To conduct an initial conservation threat assessment, we performed participatory surveys with farming communities. Through these surveys we documented 141 farmer-recognised enset landraces (previous genetic analyses indicate that most farmer-recognised enset landraces are distinct clonal lineages (55), supporting their use as meaningful units of conservation). Among these landraces, 70% were considered threatened (grown by few farmers, in small quantities) and 26% were known but had become locally extinct (Fig. 2C). These empirical data are consistent with farmer perceptions, with interviewees frequently describing the loss of landraces from their communities (Supplementary Tables 1 & 2).

Landraces cultivated in low numbers, by few households in a small number of communities are vulnerable to stochastic extinction (2, 56). Yet, these threatened and lost landraces had diverse functional traits valued by farmers: 76% were considered high value for kocho (primary food product – fermented flatbread made from the pulverised corm of enset), 54% for bulla (secondary food product – dried starch extract commonly consumed as porridge), 55% for fodder use, 24% for fibre (rope) use, 18% for drought tolerance, and 5% for medicinal use. The PACS intervention targeted the conservation of threatened landraces, inviting communities to bid for conservation contracts to cultivate and maintain them.

### **PACS increased community-level landrace richness relative to counterfactual expectations**

Treated communities exposed to the PACS intervention showed substantial gains in landrace diversity (Fig. 3A). The average number of landraces cultivated per household increased across all communities (mean change = 4.46, SE = 0.37), and the total number of unique landraces per community also increased (mean change = 4.27, SE = 0.56). In the absence of

non-treated comparison communities, we estimated expected background trends using size-matched control pseudo-communities, constructed by bootstrap resampling from a pool of geographically comparable non-treated independent households (Supplementary Figure 1). Across bootstrap resamples, the average number of landraces per household in control pseudo-communities decreased, with an average change of -0.45 landraces per household (95% bootstrap interval: -0.67 to -0.24). Similarly, the total number of unique landraces present across each pseudo-community declined by an average of -1.85 landraces (95% bootstrap interval: -2.87 to -0.86), indicative of ongoing crop genetic erosion.

Comparing the observed changes in PACS treatment communities to this counterfactual, the mean treatment effect across all communities was 4.92 additional landraces per household (95% bootstrap interval: 4.70 to 5.13;  $p < 0.001$ ) and 6.11 additional unique landraces per community (95% bootstrap interval: 5.13 to 7.13;  $p < 0.001$ ). At the individual community level, treatment effects – defined as the difference between observed treated change and mean pseudo-control change – were all positive (Fig. 3B). These results were robust to using all control households in the bootstrap pool rather than only those considered geographically comparable (Supplementary Results 1).

### **PACS contracts improved conservation outcomes for threatened landraces**

Within treated communities, we estimate the causal impact of receiving a PACS contract for a particular landrace using a community-landrace panel difference-in-differences design with community and landrace fixed effects (Supplementary Figure 2). The treatment effect therefore represents the additional change in contracted landraces relative to non-contracted threatened landraces within a community.

At baseline contracted landraces had an average rarity score of 5.6 meaning that most were either absent from a community entirely or being grown by a single household with few plants (Fig. 2A). After the scheme the average rarity score of contracted landraces improved to 2.75 meaning a typical landrace was now being grown by five to nine households with 25 to 47 plants per household (Fig. 2A). This was a significant improvement compared to counterfactual non-contracted landraces ( $\beta = -2.54$ ,  $SE = 0.19$ ,  $p < 0.001$ ; Fig. 4A). These improvements were driven primarily by expansion across households. Contracted landraces were cultivated by approximately 19 additional households per community relative to non-contracted landraces following implementation ( $\beta = 19.02$  households,  $SE = 0.78$ ,  $p < 0.001$ ; Fig. 4B). In addition, contracted landraces increased in abundance within cultivating households relative to controls ( $\beta = 11.52$ ,  $SE = 5.27$ ,  $p = 0.046$ ; Fig. 4B). Set against the background decline observed in control pseudo-communities, these findings provide strong

evidence that PACS contracts causally improved *in situ* conservation outcomes for threatened  
enset landraces.

### **Programme effects extended beyond contracted landraces through crowding in**

A potential risk is that by incentivising certain landraces, we crowd out intrinsic conservation  
services that would have been provided anyway – a problem that is common in PES schemes  
(40). We test this by measuring the impact of PACS on landraces that did not receive contracts  
(Supplementary Figure 3). Greater programme coverage (measured as the proportion of  
landraces under contract in a community) was associated with reductions in within-community  
rarity scores among non-contracted landraces ( $\beta = -2.58$ ,  $SE = 0.42$ ,  $p < 0.001$ ), equivalent  
to an approximately one-unit improvement in rarity score (Fig 2A) across all landraces for  
every 39-percentage-point increase in programme coverage. Similarly, greater programme  
coverage was associated with an increase in the number of households cultivating non-  
contracted landraces. For a 10-percentage-point increase in programme coverage, nearly one  
(0.98) extra household cultivated a non-contracted landrace ( $\beta = 9.83$ ,  $SE = 1.83$ ,  $p < 0.001$ ).  
There was no statistically significant relationship between programme coverage and the  
number of plants per household for non-contracted landraces ( $\beta = -34.56$ ,  $SE = 25.33$ ,  $p =$   
0.19) and losses landraces were rare (of all landraces present at baseline, only one had  
disappeared from all communities by endline). This demonstrates no evidence of crowding-  
out and instead is consistent with positive spillover effects (crowding-in), whereby programme  
exposure improves conservation outcomes beyond targeted landraces.

Programme coverage was not randomly assigned due to community bid offers varying with  
their willingness to participate and the offer selection process prioritising cost-effectiveness.  
Therefore, to assess whether spillover estimates may be driven by pre-existing differences  
across communities, we examined whether programme coverage was systematically related  
to baseline conservation conditions including the total number of landraces grown in a  
community and the average rarity status and abundance of those landraces prior to the  
intervention. Spearman rank correlations between the proportion of landraces contracted and  
baseline conservation conditions are small and statistically insignificant (all  $p > 0.05$ ;  
Supplementary Table 3). Spillover patterns were also robust to alternative measures of  
programme intensity. Replacing the proportion of landraces contracted with the absolute  
number of contracts or the total compensation received per farmer yielded consistent results,  
although the magnitude of effects was smaller (Supplementary Table 4).

### **Bid heterogeneity explains farmer opportunity costs**

There was substantial willingness to participate in the PACS incentive scheme. We received  
212 bid offers, each reporting the level of compensation requested for conserving target

landraces. Competitive bidding revealed substantial heterogeneity in private net conservation costs across community-landrace contracts with bid offers ranging from US\$0.44-28.89 (mean = US\$4.63) per plant (Supplementary Fig. 4), with significant variation across both communities ( $F_{(20,191)} = 36.07, p < 0.001$ ) and landraces ( $F_{(48,163)} = 3.05, p < 0.001$ ). Variance partitioning showed that most variation occurred at the community level (80%), with smaller contributions from landrace identity (8%) and residual variation (12%).

We examined how community and landrace characteristics explain variation in the private opportunity costs of farmers. Using a weighted linear mixed-effects model with community included as a random intercept ( $R_m^2 = 0.52, R_c^2 = 0.93$ ; Supplementary Figure 5), we find that requested compensation per plant was lower for drought-tolerant landraces ( $\beta = -0.043, p = 0.021$ ), and landraces with greater fodder quality ( $\beta = -0.077, p = 0.001$ ) but higher among communities with a larger proportion of female farmers ( $\beta = 0.19, p = 0.03$ ). Pseudostem growth (the part of the plant used for food production) interacted negatively with kocho (primary food product) quality ( $\beta = -0.10, p < 0.001$ ), such that greater pseudostem growth increased compensation required for landraces with low or moderate kocho quality but had little effect when kocho quality was high. Offer size also influenced bids, with bids involving larger numbers of plants associated with lower per plant compensation requests ( $\beta = -0.29, p < 0.001$ ), consistent with economies of scale. Full model output, including non-significant predictors, is reported in Supplementary Table 5.

## **Estimating the cost of conserving range-wide domesticated enset genetic resources**

Qualitative feedback suggests demand for project expansion: participants repeatedly expressed willingness to grow additional landraces, share planting material with other communities, and receive further training and monitoring (e.g., “*We are willing to propagate and distribute to other communities if we want to do the project with other communities in the future*” and Supplementary Table 2).

Given the demand for expansion, we estimated the scale of resources that would be required to support nationwide incentives for *in situ* conservation of enset diversity. We combined observed compensation levels from our intervention data with national estimates of enset landrace richness in Ethiopia ( $n = 475$  to  $1270$ ; (49)). Prior to programme implementation, ~4% of assessed landraces were classified as safe, falling in the “secure” or “common” rarity categories (Figure 2C). We therefore assume 96% of enset landraces nationally (~455 to 1216) would require further conservation effort. Median compensation per additional household cultivating a landrace was US\$8.46, with an interquartile range of US\$6.20-10.53. As these estimates are based on total observed changes in cultivation, they incorporate both direct effects of PACS contracts and positive spillover increases in cultivation among non-

contracted landraces. There are no reliable estimates of how many communities would be needed to maintain a landrace to ensure persistence, and landrace clonality means that effective population size is challenging to determine. However a reasonable target of each landrace being present in 50 households (34, 57, 58), would require compensation of US\$141,000-640,000. This is a one-off payment made on verification of planting, and we would expect the resulting conservation benefit to persist at minimum until plants reach maturity and are harvested for consumption, typically 4-7 years for enset ((49); Supplementary Results 2); beyond this point, continued conservation depends on farmers choosing to propagate the landrace again from surviving corms rather than replacing it with another crop, which post-intervention interviews suggest is the intention of many participating farmers (Supplementary Table 2). These estimates assume similar tender bid levels and compensation structures across Ethiopia, and reflect compensation only, excluding broader implementation costs such as logistics, planting material, staffing, coordination, and monitoring.

### **3 Discussion**

We provide the first causal evidence that Payments for Agrobiodiversity Conservation Services (PACS) schemes can reverse crop genetic erosion and improve the conservation status of threatened landraces. Our baseline rarity assessments indicated our target crop enset was highly vulnerable, with many landraces only maintained by very few farmers in small quantities (Fig. 2). Following implementation of the PACS scheme, participating communities gained on average five additional landraces per household over a two-year period, while the control household pool declined by an average of 0.5 landraces (Fig. 3). The magnitude of this change is impressive given the average enset farm across our control data had 4.9 landraces and national estimates are  $7 \pm 3$  landraces per farm (59). This positive impact was also seen at the individual landrace level with contracted landraces improving their conservation status significantly compared to counterfactual non-contracted landraces (Fig. 4A). This improvement was primarily driven by expansion across households rather than more intensive cultivation within them, with around a tenfold increase in the number of cultivating households (Fig. 4B). This matters because landraces maintained by only a few households are more vulnerable to stochastic loss as well as being driven by changes in preferences, practices, and pressures (15). Reversing ongoing declines delivers substantial public good, because the threatened and lost landraces encompass a wide variety of traits and functions valued by farmers rather than being simply unused or low-value varieties (e.g., 76% were considered to be high value for kocho). PACS should therefore be interpreted not only as a compensation mechanism, but as an investment in maintaining adaptive options, farmer

knowledge and functional diversity within crop systems that underpin food security and livelihoods.

A key concern for PACS is that by incentivising the cultivation of specific landraces, the intervention may lead to crowding out where farmers redirect effort towards contracted landraces at the expense of uncontracted ones. A global meta-analysis of PES found that 42% showed evidence of this (40). Here, PACS appears to have reinforced farmers' commitment to conserving landrace diversity. Communities with greater PACS programme coverage were associated with significantly greater improvements in rarity status and significantly larger increases in cultivating households across non-contracted landraces. Qualitative data from participant interviews also support this: participants described increased awareness of landrace diversity, renewed motivation to recover lost varieties, willingness to continue cultivation, and intentions to multiply and share planting material with others (Supplementary Table 2). Together, these results suggest that PACS may have shifted local norms and knowledge around agrobiodiversity conservation, consistent with motivational crowding-in, whereby conservation incentives reinforce rather than weaken intrinsic motivations for stewardship (40).

Scaling agrobiodiversity conservation incentive schemes, such as PACS, will require mechanisms that can efficiently incorporate locally specific costs (30, 34, 43, 45, 60). Our tender revealed substantial heterogeneity in compensation demands, a more than sixtyfold difference between the lowest (US\$0.44) and highest (US\$28.89) per plant bid offer, highlighting difficulties in applying a fixed rate to allocate compensation. Most variation occurred between communities rather than between landraces, suggesting that local context strongly shapes compensation demands. This may reflect variation in perceived opportunity costs arising from unmeasured factors such as land and labour availability, market access, and alternative livelihood options (61–63). After accounting for community-level differences, we found that farmers requested lower compensation for drought-tolerant landraces and more fodder-suitable landraces, consistent with those traits providing private value. For example, drought-resistant landraces may support household resilience, and this benefit may offset the cost of lower yields (64). This suggests that trait-based cost modelling could help to inform relative pricing within communities. We also found higher compensation demands for communities with greater female participation which may suggest gendered differences in opportunity costs, preferences or bargaining dynamics (65–67), and aligns with broader evidence that incorporating equity consideration into agrobiodiversity conservation payment designs has real cost implications (44). Overall, conservation costs are strongly context-dependent and difficult to infer from observable characteristics alone, highlighting the value of tender mechanisms. Despite this heterogeneity, our scaling analysis suggests that securing

threatened enset landraces nationally would only require relatively modest compensation costs of US\$141,000-640,000 with conservation benefits expected to last at least 4-7 years (Supplementary Results 2). Even the upper estimate represents < 0.1% of Ethiopia's national agriculture and food-security budget (68), and less than half the annual operating costs of the *Musa* International Transit Centre's *ex situ* collection of banana, a comparable clonal crop (69).

As with many real-world conservation interventions, our design involves some trade-offs between experimental control and implementation under policy-relevant conditions (70, 71). The community-level counterfactual relies on bootstrapped pseudo-communities from geographically comparable non-treated households rather than randomized assignment of communities to treatment (see Supplementary methods 7 for the social and ethical reasons for this design). However, this approach benchmarks observed gains against background trends in similar farming systems, and our within-community landrace analysis provides consistent and stronger causal evidence by comparing contracted and non-contracted threatened landraces within the same participating communities. Future PACS evaluations could build on this design through randomized or phased implementation at larger spatial scales. Programme intensity for spillover assessments was not randomly assigned, and unmeasured community attributes such as leadership, cohesion, or prior interest in enset conservation could influence both likelihood of receiving contracts and subsequent outcomes (45). Nevertheless, baseline balance and robustness checks reduce this concern. Repeated participatory assessments may also have increased the awareness of landrace conservation or improved recall and reporting of rare landraces; however, such awareness effects are themselves a plausible mechanism through which PACS schemes can strengthen community-based conservation (34), and the large increases observed for contracted landraces relative to comparable non-contracted landraces are unlikely to be explained by reporting changes alone.

Meeting international commitments to conserve the crop diversity that underpins future food security (72–74) cannot rely on gene banks alone. Only a fraction of the world's crop diversity is conserved *ex situ*, and clonal crops are especially poorly represented. Of the 203 major food crops, 115 are clonally propagated (75). Keeping landraces within active farming systems allows them to continue adapting to changing conditions through exchange of planting material, gene flow with crop wild relatives, and farmer-mediated selection (3). As climate change intensifies and global food systems become increasingly homogenised (2), this adaptive potential is likely to become increasingly important (2, 6, 76, 77). Yet the farmers who maintain this diversity bear the costs, while its benefits are shared far more widely (27, 29, 30). Scaling incentive schemes such as PACS across crops and regions could help

maintain both the genetic diversity and the evolutionary processes on which future food system resilience depends.

## Methods

### 4.1 Design and implementation of the Payments for Agrobiodiversity Conservation Services scheme

Implementing PACS involved three stages: identifying conservation targets, allocating conservation contracts through a competitive tender, and verifying planting. First, we identified target landraces with a low chance of persistence through participatory rarity assessments. Using a community focus group discussion approach (34, 78, 79), landraces were categorised according to the proportion of households cultivating them and their abundance within households (Fig. 2A). Community-level rarity scores were subsequently aggregated across the study landscape to generate an overall conservation status for each landrace ranging from *Secure* (widely grown across many communities with high abundance) to *Critical* (grown in one or two communities with very low abundance) and *Lost* (no longer grown in any community in the study landscape) (Fig. 2B). Landraces classified as *Restricted*, *Endangered*, or *Critical* at the landscape level were considered threatened and therefore eligible for intervention; *Lost* landraces were excluded from the intervention as planting material could not be sourced. We also assessed whether threatened and lost landraces retained locally valued functions by linking baseline conservation status to farmer-reported trait data (Supplementary Methods 1).

Second, to quantify the level of compensation needed to conserve threatened landraces *in situ*, we implemented a community-level competitive tender (45). Initial workshops with elected male and female community leaders introduced the bidding process through role-play exercises designed to ensure that farmers fairly and comprehensively understood how the tender process would work (Supplementary Methods 2). Each community was then provided with the same list of 55 of the eligible landraces (Supplementary Methods 3) from which they could choose to submit bid offers. Communities were invited to submit bids specifying (i) which landraces they were willing to conserve, (ii) the number of plants to be cultivated per landrace, and (iii) the total payment requested, which would be paid through group-level in-kind compensation (Supplementary Methods 4). Each submission corresponded to a specific community-landrace pair. We also collected information on the total number of farmers and number that were female in each community. Winning bids were selected from these community-landrace pairs, treating each pair within the community independently and using a mixed-integer optimisation model (Supplementary Methods 5) implemented in R using the package *ompr* (80). Optimisation selected the combination of community-landrace planting

offers that maximised the number of landraces conserved within the available budget, paying each successful bid the amount it requested (a so-called “pay-as-bid” pricing rule). Among these, preference was given to the lowest-cost option that resulted in the largest total number of plants being established, while ensuring that at least 35% of farmers across participating communities were female. Where multiple solutions still performed equally well on all criteria, preference was given to portfolios that included rarer landraces. Communities with any successful bids were informed of which bids were successful and confirmed their commitments prior to implementation.

Finally, enset corms (the underground stem base which can be clonally propagated to produce up to 100 plants) of the selected landraces were distributed to participating communities. Farmers were given one year (timed to align with the planting cycle) to multiply the planting material and establish the agreed number of plants of each selected landrace. Compliance was verified through follow-up monitoring visits conducted by the project team. In-kind compensation was delivered upon verification of planting. The participatory rarity assessment was then repeated to enable comparison before (2022) and after (2024) the intervention. Structured interviews (Supplementary Methods 6 and Supplementary Table 1) were also conducted with community leaders, and community members were invited to provide open comments regarding programme implementation to capture qualitative feedback.

## 4.2 Impact evaluation

### *Community level effectiveness relative to background trends*

To characterise background dynamics, we used surveys of 52 control households (Supplementary Methods 7, Supplementary Figure 1) outside the intervention communities, carried out prior to the intervention. We resurveyed the same households in 2024 to obtain the number of landraces cultivated at baseline (T1), the number cultivated at endline (T2), and the identity of landraces cultivated at each timepoint. We then calculated: (i) change in the average number of landraces per household, and (ii) change in the total number of unique landraces present. To construct credible counterfactual communities through bootstrapping, we restricted the pool to 29 control households (initially surveyed between 2020 and 2023) which form a geographically contiguous cluster and share similar agroecological conditions to treated communities (Supplementary Methods 8, Supplementary Figure 1). For each treated community (12–28 households), we generated size-matched pseudo-communities by resampling  $N$  households with replacement and calculating changes over time for both outcomes. This was repeated 5,000 times per treatment community to generate expected background change in the absence of the intervention. We then estimated overall treatment effects by comparing observed treated changes to these resampled control changes. In each

bootstrap replicate, the difference between treated and resampled control change was calculated for every treated community, and these differences were averaged across communities to obtain a pooled mean treatment effect. This produced bootstrap distributions of mean treatment effects for both outcomes. Statistical significance was assessed using one-sided empirical bootstrap p-values, calculated as the proportion of bootstrap replicates in which the pooled mean treatment effect was less than or equal to zero. To test the sensitivity of our results to the restriction of the control pool, we repeated the analysis using all control households.

#### *Landrace-level effects of PACS contracts*

To estimate the impacts of a landrace having a PACS contract within treated communities, we used a two-period community-landrace panel (2022-2024) constructed from participatory rarity assessments (Supplementary Methods 9). For each landrace within each participating community, we recorded community-level rarity score on a six-point scale (section 4.1), number of cultivating households, and average plants per household at baseline and endline.

Treatment status was defined at the community-landrace level, where a landrace was classified as treated if the community received a PACS contract to conserve that landrace. Non-contracted landraces served as controls. To ensure comparability, analyses were restricted to landraces classified as *Restricted*, *Endangered* or *Critical* at baseline, such that the treated and control landraces were drawn from the same conservation-risk pool. This dataset comprised 618 observations across 89 eligible landraces observed within 15 participating communities.

Effects were estimated using a difference-in-differences framework (Supplementary Figure 2) comparing changes in conservation outcomes between contracted and non-contracted landraces over time. Models were estimated using linear fixed effects regression with the R package *fixest* (Supplementary Methods 10). All models included community fixed effects to control for time-invariant differences between communities (e.g., agroecological conditions, market access, and local preferences), and landrace fixed effects to control for time-invariant differences between landraces (e.g., intrinsic traits and cultural value). Standard errors were clustered at the community level to account for correlation among landraces within communities.

This difference-in-differences design estimates the additional change over time for contracted landraces relative to non-contracted threatened landraces within the same programme context. As contracting one landrace may influence cultivation of others, the no-interference (or Stable Unit Treatment Value) assumption may not hold. We therefore interpret the difference-in-differences estimates as effects relative to changes within participating

communities and because such interference is a plausible and policy-relevant mechanism, we explicitly estimate spillovers effects.

#### *Analysis of spillovers*

To assess whether PACS programme coverage generated indirect effects on non-contracted landraces, we conducted a spillover analysis using observations for landraces that did not receive contracts within each community. Programme coverage was measured primarily as the share of all landraces within each community that were under PACS contract. This metric captures the relative scale of programme coverage within the local farming system.

We estimated whether conservation outcomes for non-contracted landraces changed through time differently in communities with greater programme coverage using linear fixed-effects models (Supplementary Methods 11). Specifically, we examined whether post-implementation changes in rarity status, number of cultivating households, and plant abundance, for non-contracted landraces were impacted by the community-level share of landraces under contract. We included community and landrace fixed effects to control for time-invariant differences across communities and landraces, and standard errors were clustered at the community level. Positive effects indicate crowding-in, where greater programme exposure improves conservation outcomes for non-targeted landraces. Negative effects indicate crowding-out, where contracts for target landraces displace cultivation of non-target landraces. We also quantified how many non-contracted landraces present at baseline within each community had been lost by endline.

To confirm our findings were not driven by our choice of measure of programme coverage, we re-estimated spillover models using the absolute number of contracted landraces in each community and the average PACS payment per farmer within each community as measures of programme intensity. We also conducted additional checks by assessing whether our primary measure of programme coverage was systematically related to baseline community characteristics. Using Spearman's rank correlation coefficients, we estimated pairwise associations between the share of landraces contracted within each community and baseline conservation conditions, including mean rarity score, the mean number of households cultivating each landrace, mean plant abundance, and baseline landrace diversity.

#### *4.3 Drivers of compensation demands for landrace conservation*

To understand what drives variation in compensation demands within the competitive tender, and therefore what costs the scheme is paying for, we analysed heterogeneity in bid offers across all submitted community-landrace bids, regardless of whether they were selected. Variation in bids may arise from differences in the characteristics of the landraces being

proposed, reflecting agronomic, economic, and cultural trade-offs, or from broader differences in social and economic conditions across communities. Understanding the sources of variation is important for interpreting whether the tender mechanism is capturing meaningful cost differences associated with conservation. To test for systematic differences in bid values across communities and landraces, we fitted separate one-way analyses of variance (ANOVA) with log-transformed compensation per plant as the response and either community or landrace identity as the predictor. To further partition variance, we fitted an intercept-only linear mixed-effects model including random intercepts for both community and landrace and calculated the proportion of total variance attributable to each level based on estimated variance components.

We examined how bid offers varied with landrace and community characteristics using a linear mixed-effects model. Each observation corresponded to an individual bid offer ( $n = 212$ ) such that a single landrace ( $n = 50$ ) could be represented by multiple bids across communities. Models were fitted using the *nlme* package in R, with log-transformed compensation per plant in USD as the response, community included as a random intercept, and a power variance structure to account for residual heteroscedasticity. Predictor variables included: key landrace use traits including kocho (primary food product), bulla (minor food product), amicho (minor food product), fodder, fibre (rope), and medicinal value; plant characteristics including drought tolerance, disease tolerance, pseudostem volume growth and maturity age; community characteristics including average number of enset plants on farms at baseline, number of participating farmers, and the proportion of female participants; and the log-transformed number of individual plants offered per landrace. The number of plants was included to account for potential economies of scale, whereby the per-plant compensation required may decrease as the number of plants offered increases. We also included an interaction between kocho suitability and pseudostem volume growth, reflecting the role of the pseudostem in kocho production. Continuous predictors were standardised (mean = 0, SD = 1). Landrace use values and growth traits were derived from follow-up farmer surveys and field measurements (Supplementary Methods 12). Using the R package *MuMIn*, we compared a set of candidate models containing different combinations of predictors and selected the final model based on the lowest AICc value, indicating the best balance between model fit and complexity. The best-fitting model retained seven of these fourteen predictors (Supplementary Table 5), all with variance inflation factors of less than five. Model fit was assessed using marginal and conditional  $R^2$ , and assumptions were evaluated through inspection of residual and random effect distributions (Supplementary Figure 5). Spearman rank correlations between landrace traits were also examined to aid interpretation of model results (Supplementary Figure 6).

#### 4.4 Scaling up conservation costs

To estimate the scale of household-level compensation required to support nationwide *in situ* conservation of enset diversity, we combined observed intervention data with national landrace richness estimates. We estimated compensation costs per additional cultivating household using observed changes in household cultivation between baseline and follow-up relative to total compensation paid, calculated separately for each community. To capture heterogeneity in conservation costs, we used the interquartile range (25th, 50th, and 75th percentiles) of these community-level estimates in subsequent scaling scenarios. Additionally, as national estimates of enset diversity remain uncertain, we considered both a conservative estimate of 475 phonetic landrace groups and an upper-bound estimate of 1270 unique vernacular names reported by Borrell et al. (2019).

For each scenario, we used the distribution of rarity categories in our baseline dataset to infer the proportion of landraces requiring additional conservation effort and applied this proportion to national diversity estimates to derive the number of landraces at risk. These landraces were assumed to require expansion to a target of 50 cultivating households, a precautionary benchmark informed by conservation genetic theory (34, 57, 58). Total household compensation requirements were then estimated by multiplying the number of additional households required by the corresponding community-level compensation estimate. All estimates should be interpreted as indicative projections, assuming approximately constant marginal conservation costs and similar compensation structures across Ethiopia.

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## Figure legends

**Fig. 1 Payments for Agrobiodiversity Conservation Services (PACS) as an adaptation of Payments for Ecosystem Services (PES).** Both PES and PACS pay local stewards for conservation benefits that are under-rewarded by markets. Conventional PES compensates

landholders for maintaining ecosystem services, such as cleaner water, carbon storage, and habitat, often through actions including habitat restoration or reduced resource extraction. PACS adapts this logic to crop genetic diversity, compensating farmer-custodians for conserving landraces and associated knowledge. As PACS conservation occurs through cultivation, it also generates immediate on-farm benefits such as food, planting material, and more stable production. These immediate benefits occur alongside longer-term public benefits: genetic resources for future crop adaptation and breeding and greater food system resilience. While PES has expanded to over 550 programmes worldwide (35) and been evaluated for feasibility, cost, participation, causal impact, and spillovers, PACS remains limited to roughly a dozen pilot schemes (33, 34) that have not yet been assessed for causal impact or spillover effects.

**Fig. 2 Assessment of baseline landrace rarity.** (A) Community-level rarity scoring framework where landraces within each community were given a score based on the number of households cultivating them and the number of plants maintained. (B) Combined landscape rarity framework illustrating how community-level scores for each landrace were averaged across communities and grouped into landscape-level rarity categories, to do this any absences were populated across all communities to incorporate across community abundance into the rarity classification. (C) Composition of landraces in each landscape-level rarity category showing the spread of (i) the number of landraces, and (ii) the mean plants per household combined with number of communities cultivating

**Fig. 3 Treated communities experienced gains in crop diversity exceeding background dynamics in controls.** (A) Changes in distribution of landraces across rarity scores from baseline (T1-2022) to endline (T2-2024) are shown for each of the 15 treated communities. Landraces not cultivated by any household (score 6 'Lost') are not shown, so bar height reflects the number of landraces in cultivation at each time point (B) Community-level treatment effects, calculated as the difference between the change in treated communities (T1 to T2) and the corresponding change in size-matched control communities constructed by bootstrap resampling of control households. Points show treatment effects for individual communities, and horizontal error bars represent 95% bootstrap intervals. The vertical dashed line indicates no difference between treated and control change. Control communities were generated by resampling households with replacement while preserving community size and applying the same sampled households to both time periods. Across all communities, treatment effects are positive, indicating increases in landrace diversity relative to background trends observed in control communities.

**Fig. 4 PACS contracts reduced local extinction risk of threatened enset landraces by expanding household cultivation and abundance.** Model-estimated outcome trajectories from community–landrace panel difference-in-differences models with community and landrace fixed effects. The models compare changes between baseline (T1) and endline (T2) for contracted landraces relative to changes in non-contracted threatened landraces within the same participating communities. (A) shows changes in within community rarity scores alongside a conceptual illustration of the effect on rarity score, and (B) shows changes in number of households cultivating each landrace and number of plants per household, which are used to determine rarity score (Fig. 2A). Points show predicted values and error bars indicate 95% confidence intervals with standard errors clustered at the community level. Statistical significance is based on the interaction between time and contract status in the fixed-effects regression framework.

**Fig. 5 Drivers of compensation demands in competitive tenders for enset landrace conservation.** Predicted compensation required for adoption of enset landraces for significant predictors from the final weighted linear mixed-effects model. Panels show back-transformed model predictions with 95% confidence intervals from a model fit to log-transformed compensation per plant, including community as a random intercept. Regression coefficients and p-values shown within panels are estimates from the model on the log-response scale. Compensation decreased for landraces with greater drought tolerance and fodder suitability, and with increasing numbers of individuals offered, but increased with proportion of female farmers. The interaction panel shows that the relationship between pseudostem volume growth and compensation depended on kocho suitability, indicating that the effect of growth traits on compensation demands varies with perceived kocho value.

Fig. 1

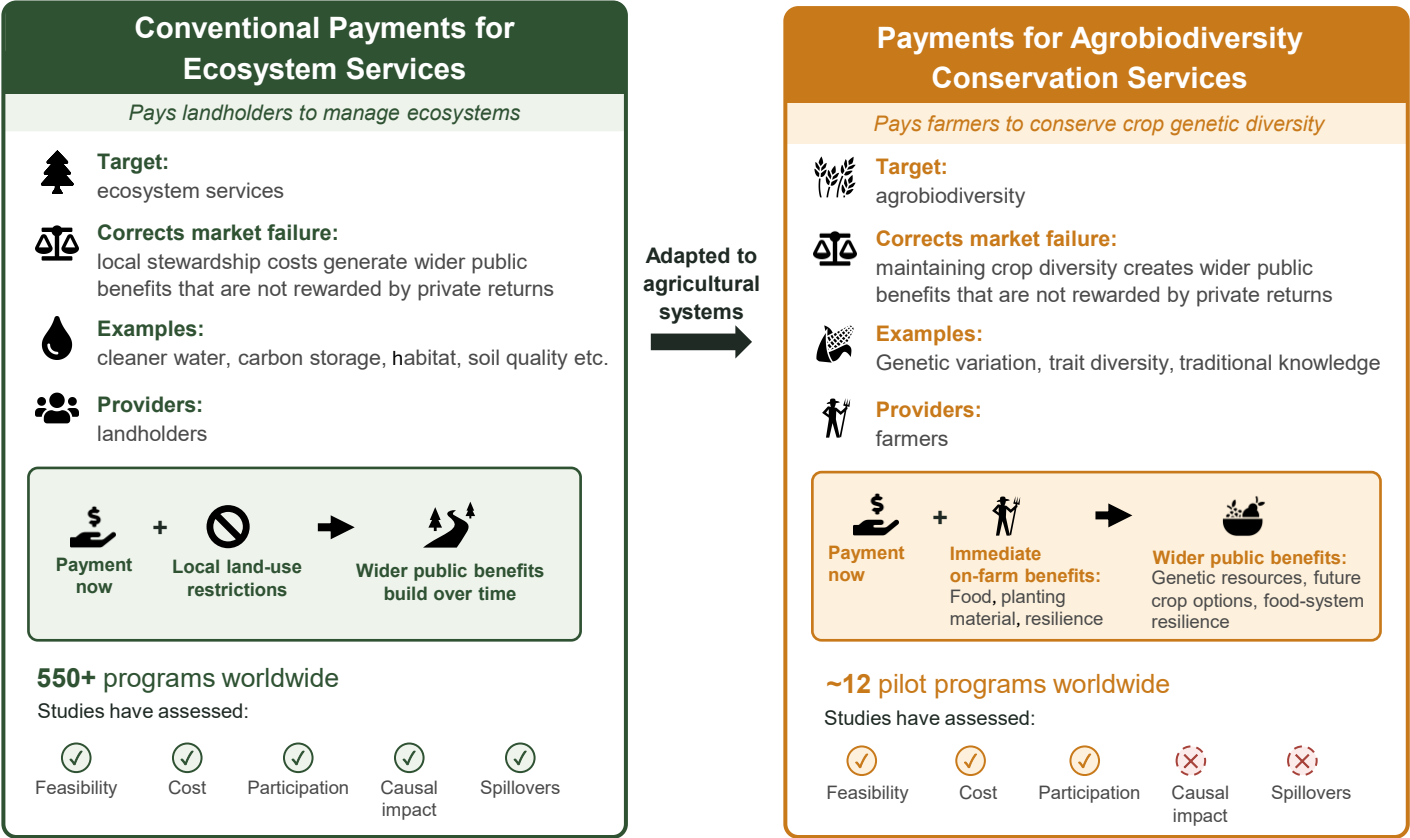


Fig. 2

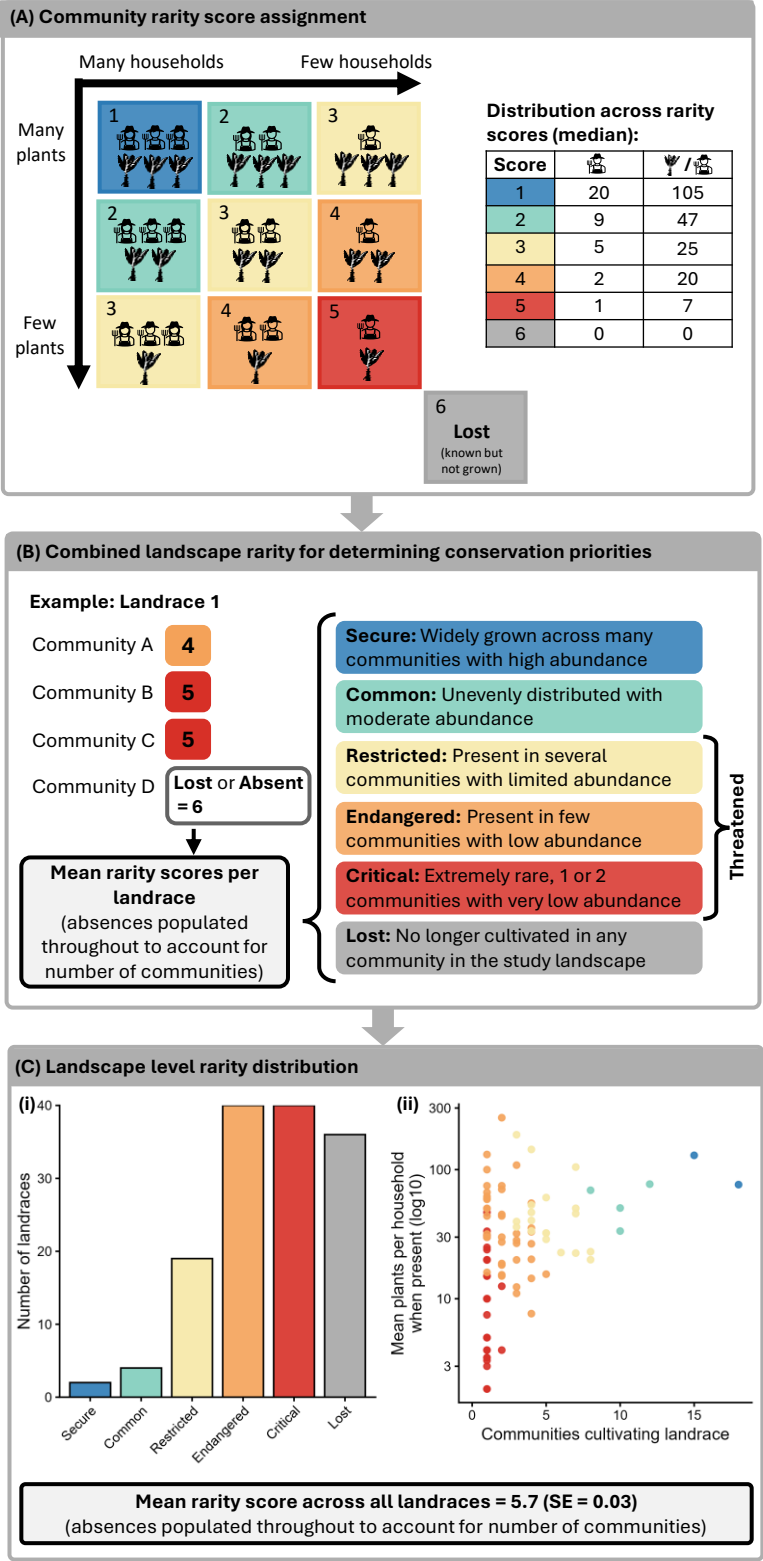


Fig. 3

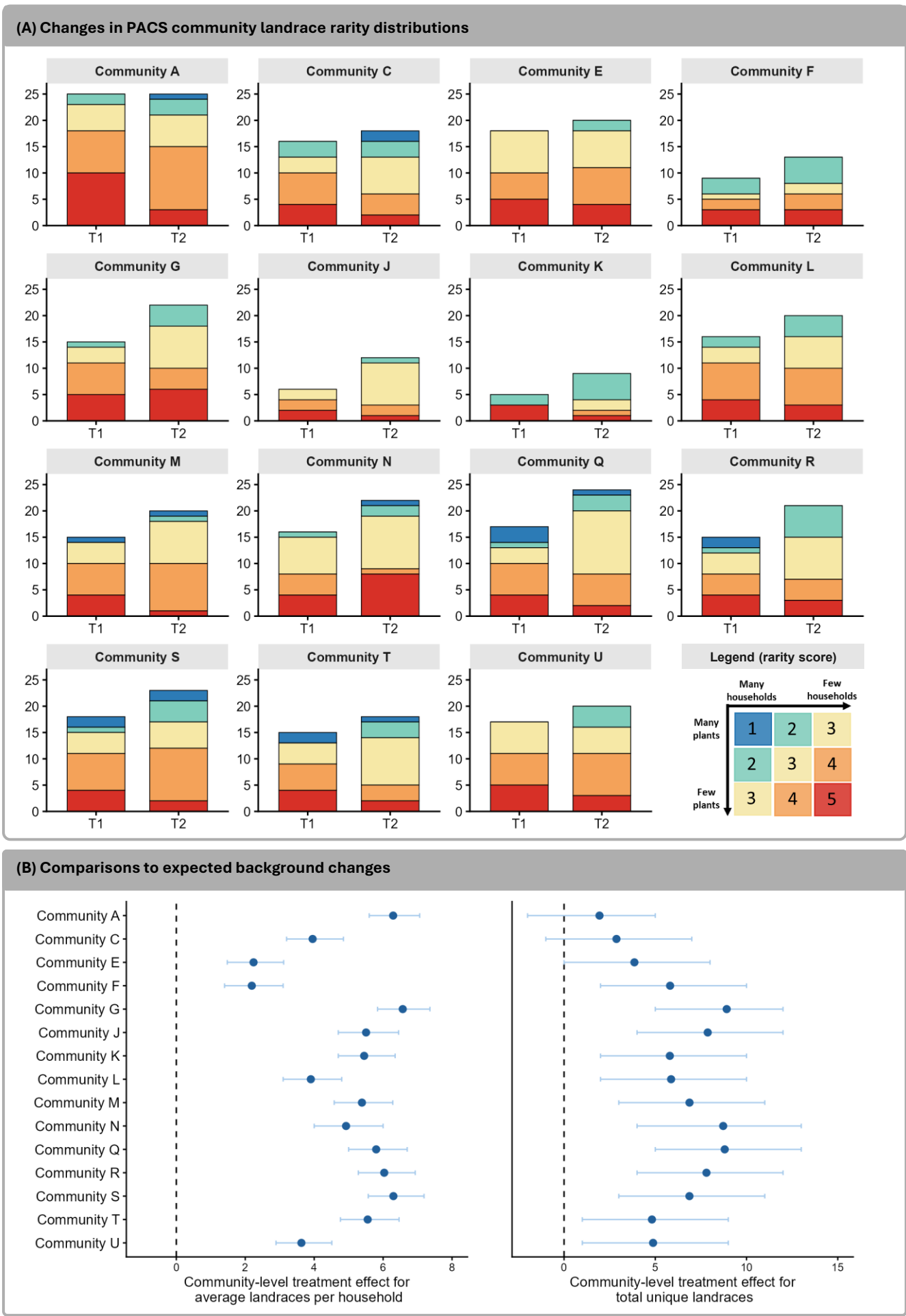


Fig. 4

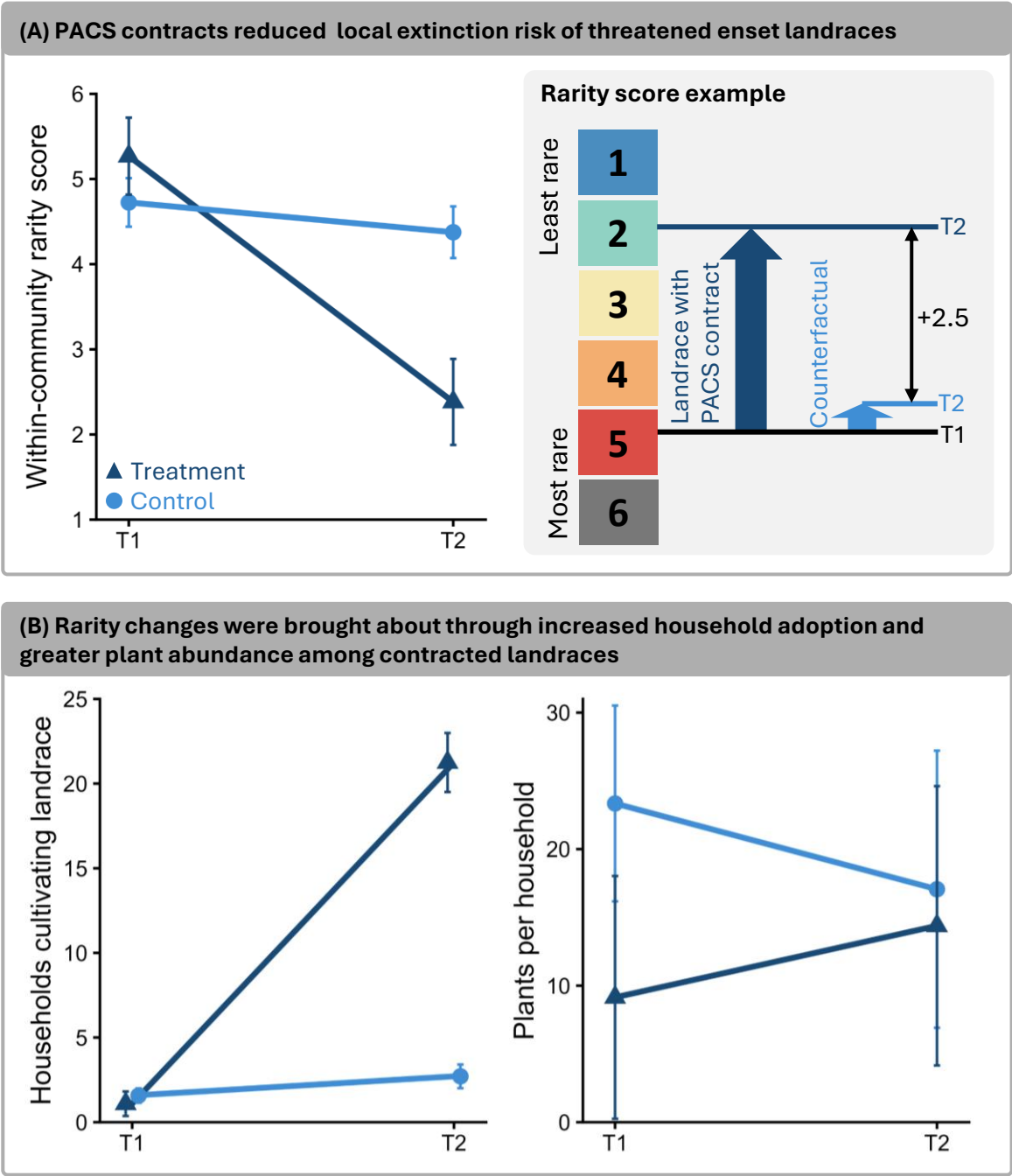
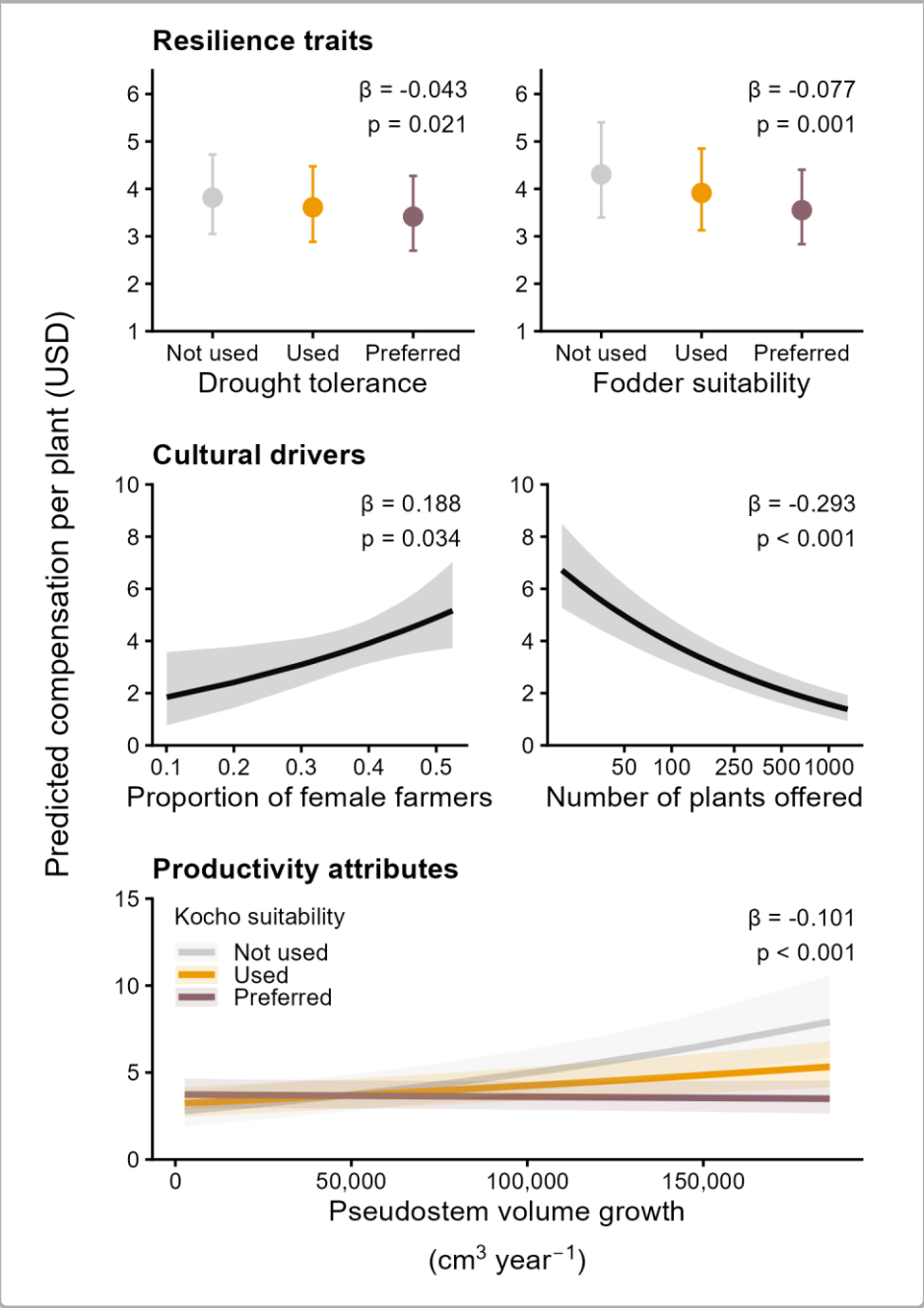


Fig. 5

Drivers of variation in compensation demands for landrace conservation



## SUPPLEMENTAL INFORMATION

### **Reversing *in situ* crop genetic diversity loss through incentive-based conservation**

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## Supplementary Methods

### **Supplementary methods 1. Functional value of threatened and lost landraces.**

To assess whether threatened and lost landraces retained locally valued functions, we linked baseline landscape conservation status with farmer-reported landrace trait data. Landraces classified as Restricted, Endangered, Critical, or Lost were included. Farmer-reported use and resilience scores were coded as 0 where a landrace was not reported for a function, 1 where it was reported as used, and 2 where it was identified as preferred. For each functional trait – kocho production, bulla production, fodder use, fibre use, drought tolerance, and medicinal use – we classified landraces with a score of 2 as high value. We then calculated the proportion of threatened and lost landraces that were high value for each functional trait.

### **Supplementary Methods 2. Role-play exercise for community tender training**

Before communities submitted conservation bids, we used a role-play exercise to explain the competitive tender process to elected community leaders. The exercise was designed to make the bidding, ranking, budget constraint, and selection rules understandable before bids for onset landrace conservation were submitted.

Each participant was given either a cap or a t-shirt and was asked to write down the minimum amount of compensation they would be willing to accept to sell the item back to the project team. Participants were told that they did not have to submit an offer if they did not want to sell their item. They were also told that they could submit a high offer if they would only be willing to sell it for a high price, or a lower offer if they did not particularly want to keep the item and wanted to increase the chance that their offer would be selected. They were asked to think about their own need for the item when deciding their offer. This was used to explain that, in the actual conservation tender, communities should only bid for landraces they were willing and able to conserve and should request compensation that reflected the effort and opportunity costs involved.

The submitted offers were then ordered from lowest to highest price. We announced a hypothetical project budget and selected the lowest cost offers that could be purchased within that budget. This first round demonstrated the basic principle of a pay-as-bid tender, in which lower-cost offers are more likely to be selected, and successful participants receive the amount they requested.

We then repeated the exercise with additional selection constraints. In the second round, participants were told that the project required at least 50% of selected items to be t-shirts. The selection was then repeated, showing that some low-cost cap offers could be excluded to meet the t-shirt target. This illustrated how conservation targets, such as priority for rarer landraces, could be incorporated into bid selection alongside cost, such that some low-cost bids might not be selected if they did not contribute to the required portfolio of conservation outcomes. In the third round, participants were told that the project required at least 50% of selected participants to be women. The selection was then repeated again, showing that some low-cost offers from men could be excluded to meet the gender participation target. This demonstrated how social criteria could be incorporated into the optimisation process alongside cost and conservation objectives.

After the role-play exercise, participants were asked questions about how the tender would work in practice, with different community leaders invited to answer each question. These

questions focused on the actual onset conservation tender and were used to confirm shared understanding of how communities should decide whether to submit a bid, how compensation requests should reflect willingness and ability to conserve a landrace, why some low-cost bids might not be selected, and how conservation and gender participation targets could influence final contract selection. This discussion was used to clarify misunderstandings before communities prepared their actual bids for onset landrace conservation.

### **Supplementary methods 3. Rationale for landraces selected for inclusion in the bidding process.**

Of the 100 landraces classified as threatened at the landscape level (40 *critical*, 40 *endangered* and 19 *restricted*), a subset of 53 was selected for inclusion in the bidding process. This was done to simplify decision-making for participating communities and to concentrate bidding effort across a smaller number of landraces, thereby generating more price information per landrace. Selection retained representation across all threat categories while prioritising more threatened landraces. This resulted in a final list of 28 *critical*, 18 *endangered* and 7 *restricted* landraces. We additionally included one *common* and one *lost* landrace. The remaining threatened landraces were not included in the bidding list, allowing us to ensure there were non-treated threatened landraces to compare our treated outcomes with.

### **Supplementary methods 4. In-kind compensation approach**

Following advice from in-country partners, in-kind rather than monetary compensation was adopted for the tender scheme. This approach reduces the risk of cash payments being diverted toward uses unrelated to, or harmful to, household or community wellbeing, and reduces the risk of compensation being monopolised by a single individual within the participating group. As part of the bid offer submission participants were asked to outline the in-kind items they would like and were informed that the monetary value of any offers they were selected for would be split between the items requested. Item requests were similar across communities consisting primarily of agricultural tools (crocodile steel hoes, iron fork hoes, pick mattocks, gejeras (machetes), spades, watering cans, hammers); household items (blankets, solar lamps, t-shirts, caps); and school equipment (student bags, exercise books, pens).

### **Supplementary methods 5. Optimisation model for selecting winning bids**

Winning bids were selected using a mixed-integer linear optimisation model implemented in R using the package *ompr*. Each bid  $i \in I$  corresponded to one community–landrace pair. For each bid, we recorded the requested payment  $p_i$ , the number of plants offered  $n_i$ , the submitting community  $c(i)$ , and the landrace  $l(i)$ . Let  $B$  denote the total budget,  $C$  the set of communities, and  $L$  the set of landraces. For each community  $c$ ,  $F_c$  denotes the total number of farmers and  $W_c$  the number of female farmers. For each landrace  $l$ ,  $r_l$  denotes its rarity score.

The decision variable  $x_i$  indicated whether bid  $i$  was selected. We also use variables  $y_c$  as the count of the number of successful bids in community  $c$ ,  $u_c$  as an indicator whether a community had at least one successful bid, and  $z_l$  the number of times landrace  $l$  was selected. All decision variables were binary.

The model was:

$$\max_{\text{lex}} \left( \sum_{l \in L} z_l, - \sum_{i \in I} p_i x_i, \sum_{i \in I} n_i x_i, \sum_{i \in I} r_{l(i)} x_i \right)$$

Subject to:

1. Budget constraint - if  $B$  is the total budget, the model can only select bids whose combined requested payments are less than or equal to  $B$ .

$$\sum_{i \in I} p_i x_i \leq B$$

2. Landrace selection constraint – for  $l \in L$ , each landrace can be selected from at most one community.

$$z_l \in \{0,1\}$$

3. Community selection constraint – for  $c \in C$ , a community can have at most four selected bid

$$y_c \in \{0,1,2,3,4\}$$

4. Female farmer constraint – across all selected communities at least 35% of total farmers must be female

$$\sum_{c \in C} W_c u_c \geq 0.35 \sum_{c \in C} F_c u_c$$

The lexicographic objective means that the model first maximised the number of distinct landraces selected. Among all solutions achieving this maximum, it then minimised total payment. Among solutions with the same number of landraces and the same minimum payment, it maximised the total number of plants established. If multiple solutions remained tied, it selected the portfolio with the highest total rarity score.

One community's bid offers were removed from the optimisation process due to bid offers being more than an order of magnitude higher than other communities. Additionally, most of their landrace bid offers only included one farmer rather than the full community. This suggests miscommunication in our programme development process.

### Supplementary methods 6. Post-intervention interviews

Structured interviews were conducted with community representatives and participating farmers across all participating communities following implementation of the PACS scheme. Interviews included both closed and open-ended questions exploring perceptions of landrace

diversity, behavioural responses to the intervention, motivations for participation, and suggestions for improvement (Supplementary Table 1). Additional open comments were collected in group settings.

Interviews were conducted in Amharic by a member of the project team. Responses were subsequently translated into English by the same project team member for analysis, helping to preserve contextual meaning and minimise misinterpretation.

Open-ended responses were analysed using a thematic coding approach. Responses were reviewed and grouped into recurring themes. Themes were identified inductively based on repeated patterns across communities. Given the structured nature of interviews and the study's primary quantitative focus, the analysis is intended to contextualise and interpret observed quantitative outcomes rather than provide independent causal inference.

### **Supplementary methods 7. Control group design and rationale**

The seven of 22 surveyed communities that took part in the tender process but did not receive a successful bid represented an alternative potential control group for the community-level counterfactual. We decided against revisiting these communities for resurveying. Doing so would have required a second full round of lengthy, community-level participatory assessment from communities that had already committed substantial time to the programme without receiving any conservation contract, and with no prospect of any further benefit from participating again. We considered repeating this process to be an inequitable demand on their time, and likely to introduce respondent fatigue, given the length and group-based nature of the participatory rarity assessment, potentially reducing the reliability of the resulting data relative to a fresh survey. These seven communities are therefore not included in either the community-level or landrace-level impact analyses.

For the same reasons, we did not randomly assign whole communities to treatment and control arms: doing so would have required introducing control communities to the PACS scheme through the same participatory workshops and bid-preparation process used for treated communities, raising comparable expectations of potential compensation that would then go unmet.

We instead surveyed individual control households drawn from comparable non-intervention communities, which was both quicker to administer and a more ethically appropriate use of respondents' time given the absence of any programme benefit to them. The crop composition of single households can be established in less than 20 minutes by trained enumerators. Control households were not randomly sampled; rather, they are observational units drawn from non-intervention communities defined independently of this study. As such, they can be considered independent to the intervention. For spatial distribution see Supplementary Figure 1.

### **Supplementary methods 8. Bootstrap comparison with control households.**

Each bootstrap distribution was generated from 5,000 resamples. Given the very large number of possible resampled communities when sampling with replacement from 29 households, this number of iterations represents a small subset of all possible combinations but is sufficient to obtain stable estimates of the expected background distribution.

For each treated community  $c$ , let  $N_c$  denote the number of households. We calculated two observed changes in treated communities: change in the average number of landraces per

household, and change in the total number of unique landraces present in the community. For outcome  $k$ , the observed change in treated community  $c$  was denoted:

$$\Delta_{ck}^T.$$

For each bootstrap replicate  $b = 1, \dots, 5000$ , we generated a pseudo-control community for each treated community  $c$  by sampling  $N_c$  control households with replacement. We then calculated the equivalent change in the pseudo-control community:

$$\Delta_{ck}^{C,b}.$$

The bootstrap treatment effect for community  $c$ , outcome  $k$ , and replicate  $b$  was:

$$\tau_{ck}^b = \Delta_{ck}^T - \Delta_{ck}^{C,b}.$$

We then averaged these community-level effects across the treated communities to obtain the pooled treatment effect for each bootstrap replicate:

$$\bar{\tau}_k^b = \frac{1}{|C_T|} \sum_{c \in C_T} \tau_{ck}^b,$$

where  $C_T$  is the set of treated communities.

This produced a bootstrap distribution of pooled treatment effects,  $\bar{\tau}_k^1, \dots, \bar{\tau}_k^{5000}$ , for each outcome. We summarised this distribution using its mean, median, and 2.5th and 97.5th percentiles. Statistical significance was assessed using a one-sided empirical bootstrap p-value:

$$p_k = \frac{1 + \sum_{b=1}^B 1(\bar{\tau}_k^b \leq 0)}{B + 1},$$

where  $B = 5000$ . This p-value is the proportion of bootstrap replicates in which the estimated pooled treatment effect was less than or equal to zero, with a standard finite-sample correction.

### Supplementary methods 9. Attrition across survey timepoints

Among the 15 communities who had their bid offers selected to participate in the PACS project, a total of 312 farmers contributed to baseline participatory rarity assessments. 95.2% were successfully re-surveyed at endline, corresponding to overall household attrition of 4.8%. Since attrition would reduce the pool of surveyed households equally for contracted and non-contracted landraces within each community, it would not create a systematic difference between the two groups.

### Supplementary methods 10. Regression equation for landrace conservation outcomes.

We estimated the effect of payment on landrace conservation outcomes using fixed-effects regression models of the form:

$$Y_{clt} = \alpha + \beta_1 \text{Post}_t + \beta_2 \text{Paid}_{cl} + \beta_3 (\text{Post}_t \times \text{Paid}_{cl}) + \gamma_c + \delta_l + \varepsilon_{clt}.$$

Here,  $Y_{clt}$  denotes the outcome for landrace  $l$  in community  $c$  at timepoint  $t$ . The primary outcome was landrace rarity status. Secondary outcomes were the number of households cultivating the landrace and the average number of plants cultivated.  $\text{Post}_t$  is an indicator for the post-intervention timepoint, and  $\text{Paid}_{cl}$  is an indicator for whether the community–landrace pair received payment. The coefficient of interest is  $\beta_3$ , the interaction between  $\text{Post}_t$  and  $\text{Paid}_{cl}$ , which estimates the differential post-intervention change in paid community–landrace pairs relative to unpaid pairs.

The model included community fixed effects ( $\gamma_c$ ) and landrace fixed effects ( $\delta_l$ ), thereby controlling for time-invariant differences among communities and among landraces. Standard errors were clustered at the community level.

### Supplementary methods 11. Regression equation for spillover analysis

To test whether payments had spillover effects on non-contracted landraces, we restricted the analysis to community–landrace pairs that did not receive payments. We then estimated whether outcomes for these unpaid landraces varied with the intensity of payment activity in the same community.

For unpaid landrace  $l$  in community  $c$  at timepoint  $t$ , we estimated models of the form:

$$Y_{clt} = \alpha + \beta (\text{Post}_t \times \text{SharePaid}_c) + \gamma_c + \delta_l + \varepsilon_{clt}.$$

Here,  $Y_{clt}$  denotes the outcome for unpaid landrace  $l$  in community  $c$  at timepoint  $t$ . Outcomes were landrace presence, rarity status, number of households cultivating the landrace, and average number of plants cultivated.  $\text{Post}_t$  is an indicator for the post-intervention timepoint, and  $\text{SharePaid}_c$  is the share of landraces in community  $c$  that received payment. The coefficient of interest is  $\beta$ , which estimates whether unpaid landraces changed more or less over time in communities where a larger share of landraces were paid.

The model included community fixed effects ( $\gamma_c$ ) and landrace fixed effects ( $\delta_l$ ), and standard errors were clustered at the community level.

We also tested whether unpaid landraces that were present at baseline were more likely to disappear by the endline in communities with higher payment intensity. For this analysis, we restricted the data to unpaid community–landrace pairs with presence recorded at baseline. We then defined:

$$D_{cl} = \begin{cases} 1, & \text{if unpaid landrace } l \text{ was present at baseline but absent at endline in community } c, \\ 0, & \text{if unpaid landrace } l \text{ remained present at endline in community } c. \end{cases}$$

We estimated:

$$D_{cl} = \alpha + \beta \text{SharePaid}_c + \gamma_c + \delta_l + \varepsilon_{cl}.$$

Here,  $\text{SharePaid}_c$  is the share of landraces in community  $c$  that received payment. The coefficient  $\beta$  estimates whether unpaid landraces were more likely to disappear in communities where a larger share of landraces had been contracted. Community and landrace fixed effects were included, and standard errors were clustered at the community level.

## **Supplementary Methods 12. Landrace trait data from farmer surveys and field measurements**

Follow-up surveys to characterise the use values of enset landraces were carried out by visiting farms and farmers known to grow, or to have knowledge of, each landrace. For each landrace, farmers were asked about its value for key locally recognised uses, including kocho production, bulla production, fodder, fibre, medicinal use, drought tolerance and disease tolerance. A single consensus score was recorded for each landrace–use combination. Use values were coded as ordinal scores: 0 = not used for that function, 1 = used, and 2 = preferred or considered especially suitable.

We also collected growth-trait data through targeted farm visits to locations where each landrace was known to be cultivated. Where possible, we measured five individual plants per landrace. For each plant, we recorded plant age, maturity age, pseudostem height, and pseudostem circumference at the base, middle, and top of the pseudostem. Circumferences were converted to radii using  $r = C/2\pi$ . Pseudostem volume was estimated by approximating the pseudostem as two truncated cones of equal height: a lower section from the base to the middle and an upper section from the middle to the top. For each section, volume was calculated as  $V = \frac{1}{3}\pi h(r_1^2 + r_1r_2 + r_2^2)$ , where  $h$  is half the pseudostem height and  $r_1$  and  $r_2$  are the radii at the ends of the section. Lower and upper section volumes were summed to estimate total pseudostem volume per plant. Total volume was divided by plant age to estimate pseudostem volume growth rate ( $\text{cm}^3 \text{ year}^{-1}$ ), and landrace-level values were calculated by averaging across up to five measured plants per landrace. Growth-trait measurements were unavailable for some landraces because several farms could not be reached due to flooding. Among the 49 landraces which received bid offers, ten had missing growth-trait values; these were imputed using the overall mean across landraces included in the analysis.

## Supplementary Results

### **Supplementary Results 1. Sensitivity of the bootstrap analysis to the control household pool**

In the main analysis, control pseudo-communities were drawn only from control households within 35–37°E, the longitudinal range of the treated communities, to make the counterfactual geographically comparable. To test whether the estimated treatment effects depended on this restriction, we repeated the pooled bootstrap using all 52 control households.

The results were consistent, the mean treatment effect using the broader control pool was 4.58 additional landraces per household (95% bootstrap interval: 4.37 to 4.79;  $p < 0.001$ ) and 4.45 additional unique landraces per community (95% bootstrap interval: 2.53 to 6.33;  $p < 0.001$ ). The positive effect of PACS on landrace richness therefore does not depend on how the geographically comparable control pool was defined.

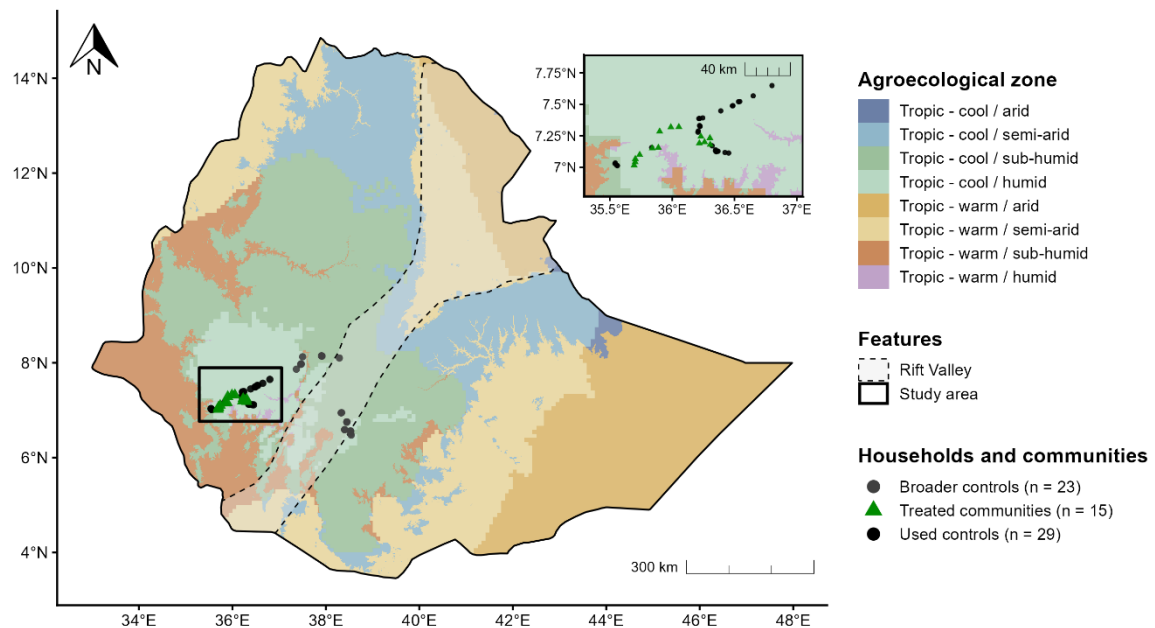
### **Supplementary Results 2. Expected persistence of PACS conservation benefits**

Enset reaches harvestable maturity for kocho and bulla production after approximately 4–7 years, depending on landrace, altitude, and management practices (Borrell et al., 2019). Substantial labour is invested well before this point: suckers are typically transplanted into progressively wider-spaced nurseries up to four times over the growing cycle (Borrell et al., 2020), representing a sustained investment that farmers are unlikely to abandon once underway. At maturity, the corm and pseudostem are processed for food, ending that individual plant's growth cycle; however, because enset multiplies clonally through sucker production, farmers who value a landrace can propagate new plants from the same stock, potentially extending conservation of that landrace well beyond the compensated planting cycle without further payment. Interview data collected after the intervention indicate that many participating farmers intended to continue growing and conserving landraces without further reward (Supplementary Table 2). We did not, however, directly measure farmers' propagation decisions beyond the study period, and the longer-term persistence of contracted landraces remains to be confirmed.

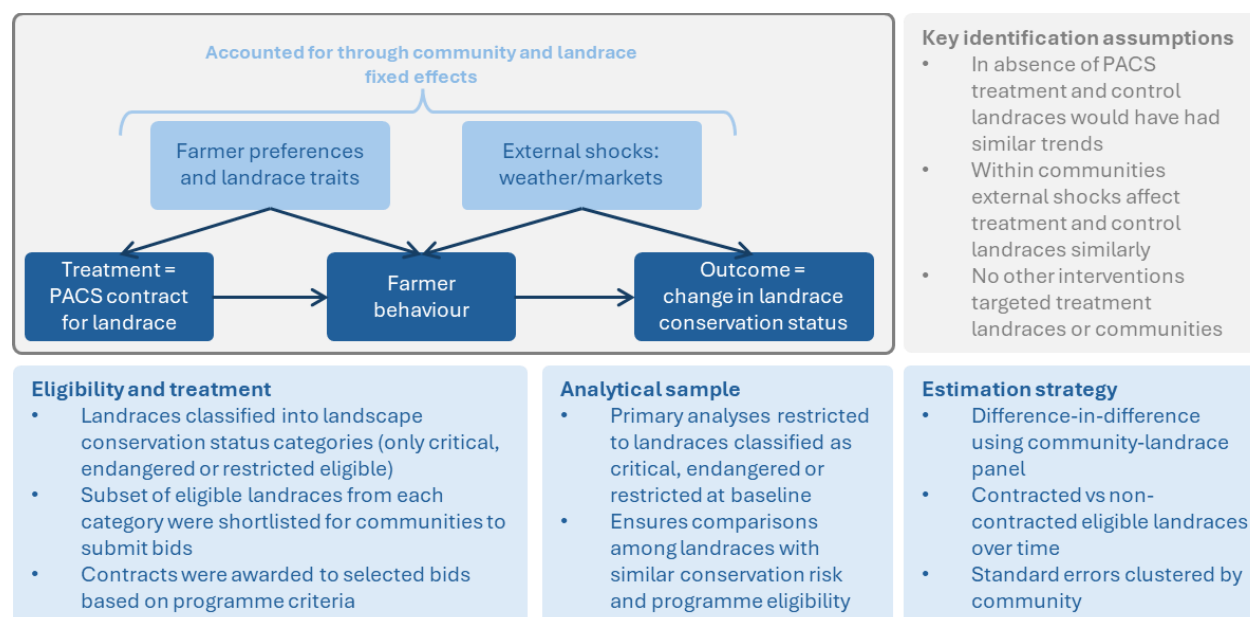
## Supplementary Figures

### Supplementary Figure 1. Spatial distribution of control households and treated communities in southwestern Ethiopia.

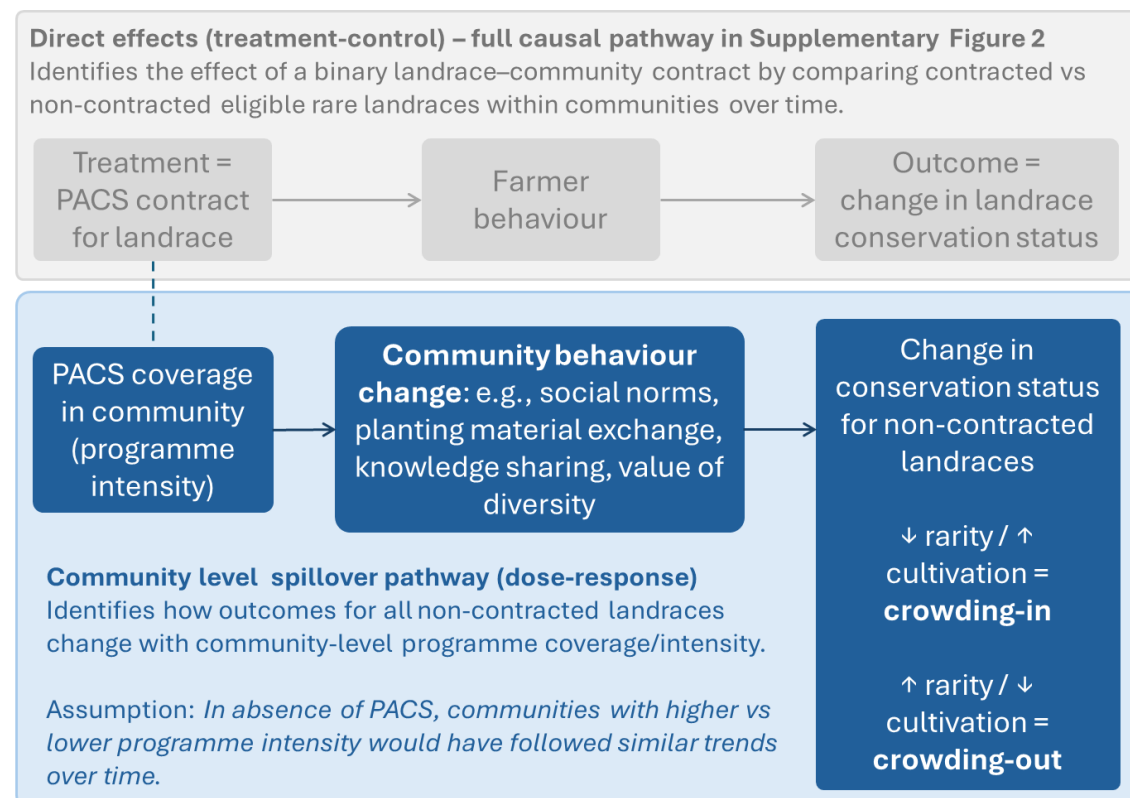
Colours show agroecological zones. Black points indicate control households used in the bootstrap analysis ( $n = 29$ ), grey points indicate broader controls ( $n = 23$ ), and green triangles indicate treated communities ( $n = 15$ ). The dashed line shows the approximate location of the Ethiopian Rift Valley, and the solid black box marks the study area used for constructing pseudo-control communities. The inset provides a zoomed view of this study area. Household locations are jittered for anonymity, and community locations are shown at the centroid of the kebele (smallest administrative unit) in which they are located.



**Supplementary Figure 2. Causal framework for assessing the effect of a PACS contract on the conservation status of a landrace.**

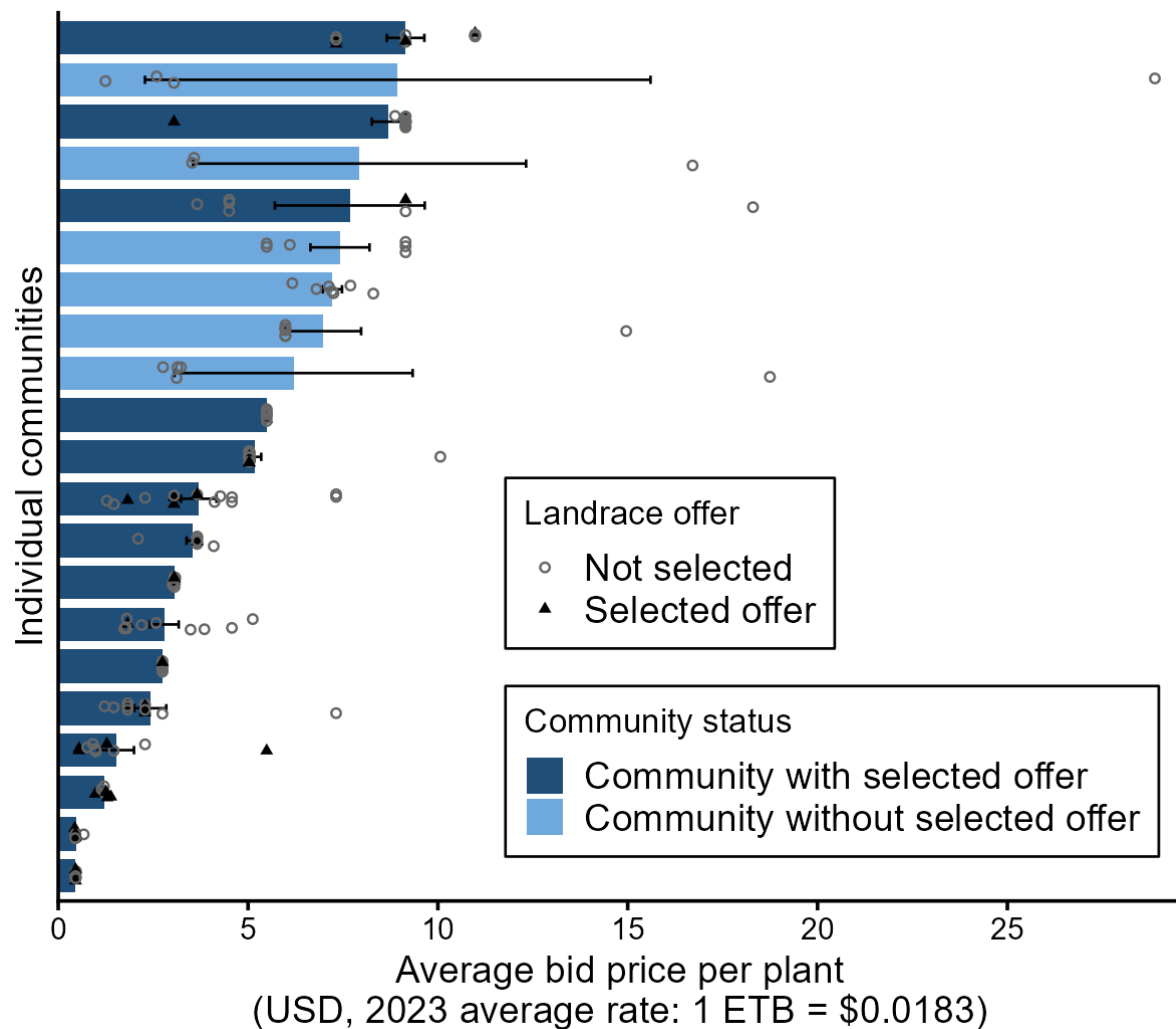


**Supplementary Figure 3. Causal framework for assessing the spillover effect of the PACS intervention among non-contracted landraces.**



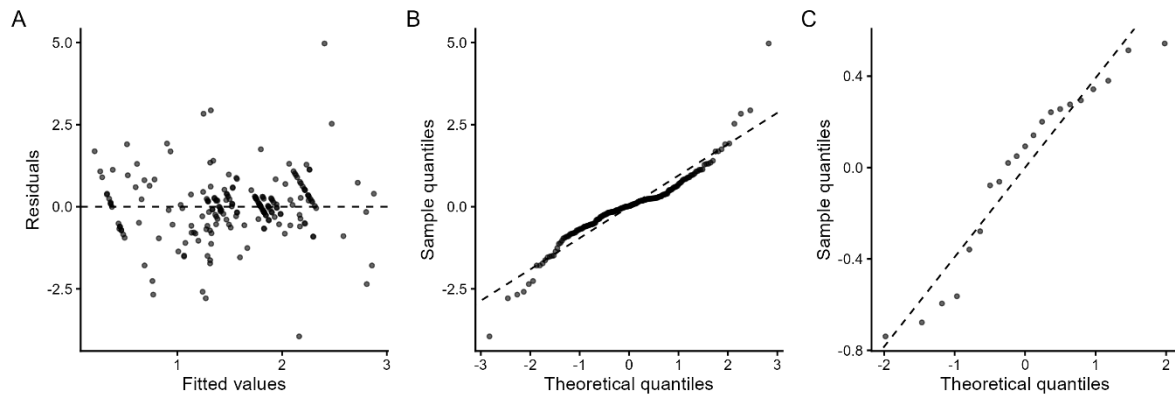
#### Supplementary Figure 4. Distribution of bid offer prices across communities.

Bars show the mean bid price per plant for each community, converted from Ethiopian birr to USD using the 2023 average exchange rate of 1 ETB = 0.0183 USD. Error bars indicate standard error. Communities are coloured according to whether they had at least one selected landrace offer. Points show individual landrace offer prices within each community; triangles indicate selected landrace offers and open circles indicate non-selected offers.



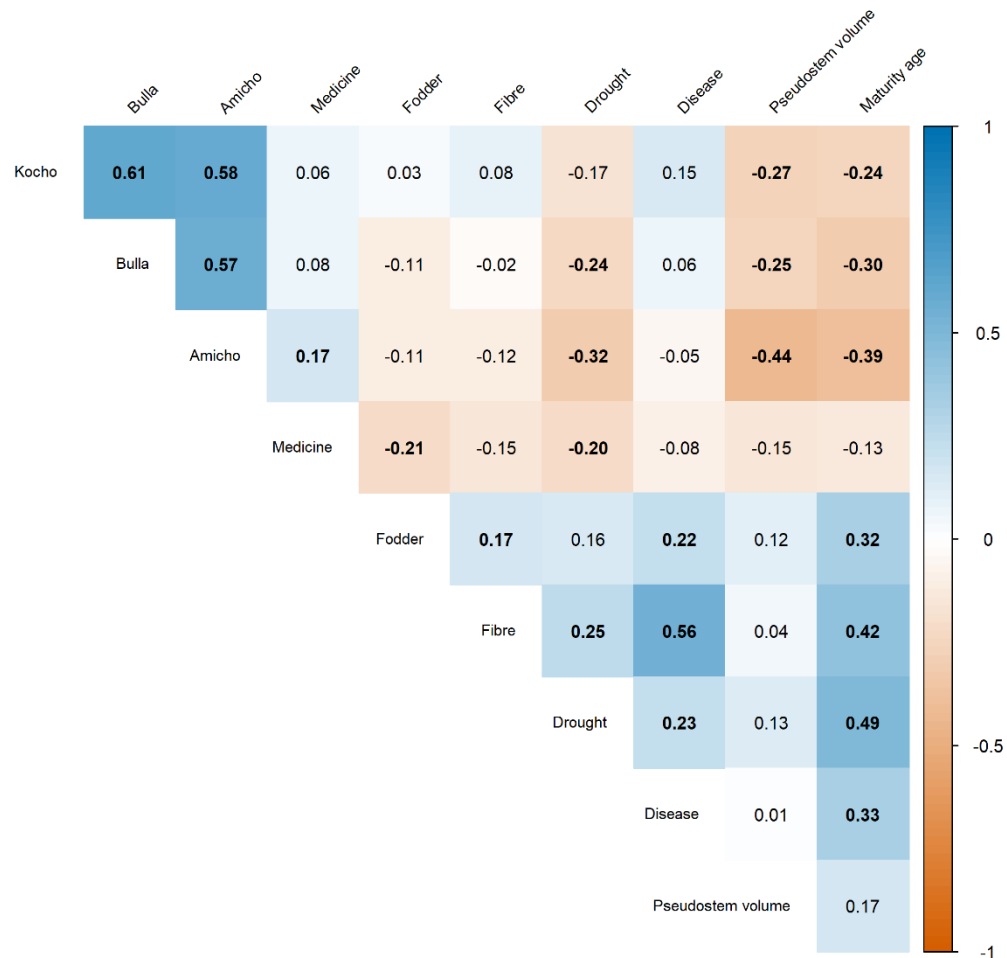
### Supplementary Figure 5. Model diagnostics for compensation demand model

(A) Residuals plotted against fitted values for the final linear mixed-effects model of log-transformed compensation per plant. The dashed line indicates zero residual error. (B) Normal Q-Q plot of model residuals. (C) Normal Q-Q plot of the community-level random intercepts. Together, these diagnostics were used to assess residual structure, heteroscedasticity, and approximate normality.



### Supplementary Figure 6. Correlations among landrace traits

Spearman rank correlations among farmer-reported landrace use values and field-measured growth traits used as candidate predictors in the compensation-demand analysis. Colours indicate the direction and strength of correlations, with orange representing negative correlations and blue representing positive correlations. Values shown are Spearman's  $\rho$ ; bold values indicate correlations significant at  $p < 0.05$ .



## Supplementary Tables

**Supplementary Table 1. Interview questions**

| <b>Question number</b> | <b>Interview question</b>                                                                                               |
|------------------------|-------------------------------------------------------------------------------------------------------------------------|
| 1                      | What do you think about growing different enset landraces?                                                              |
| 2                      | Have your views on enset diversity changed in any way during the project? If so, how?                                   |
| 3                      | If you had access to more planting material, how likely would you be to grow additional landraces without compensation? |
| 4                      | What are your plans for growing enset landraces in the future?                                                          |
| 5                      | What effects, if any, do you think expanding this project could have on your household or community?                    |
| 6                      | What, if anything, have you learned from the project?                                                                   |
| 7                      | What are your overall thoughts on the project? Do you have any suggestions for improvement?                             |

# **Supplementary Table 2. Summary of key themes from interviews**

Full interview response data included in Supplementary Data 1.

| Theme                               | Description                                                                                                                                                                                                                            | Illustrative quote                                                                                                                                                                       |
|-------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cultural and multifunctional value  | Farmers described enset landraces as valuable for food, fodder, fibre/rope, medicine, household uses, cultural practices, and identity.                                                                                                | "Enset is our everything: our food, our wealth, our ornament, and our materials."                                                                                                        |
| Food security                       | Landrace diversity was repeatedly linked to household and community food security, hunger reduction, and reliable food supply.                                                                                                         | "Growing more landraces helps us fight hunger."                                                                                                                                          |
| Livelihood benefits                 | Farmers valued enset and planting material as sources of income through selling suckers, mature plants, kocho, and kacha/rope.                                                                                                         | "People with small landholdings can sustain their livelihoods through enset farming."                                                                                                    |
| Climate resilience                  | Some farmers described enset or particular landraces as useful for coping with drought, climate change, livestock-feed shortages, and harsh future conditions.                                                                         | "Among the different landraces some of them can survive harsh conditions in the future."                                                                                                 |
| Landrace loss                       | Participants reported becoming more aware of landraces that had disappeared or were at risk of being lost and highlighted threats such as crop replacement, cereal expansion, disease, pests, and lack of access to planting material. | "We realised what we have now and what we already lost."<br><br>"Enset is decreasing and being replaced by other crops... many of them have been lost due to diseases and other factors" |
| Recovery of lost landraces          | Farmers described the project as helping them regain, reintroduce, or search for landraces that had previously been lost from farms or communities.                                                                                    | "We have gained a lot of landraces we have lost for a long time...."                                                                                                                     |
| Knowledge and awareness             | Farmers said the project increased their understanding of enset diversity, encouraged them to give enset more attention, and changed how they valued landraces.                                                                        | "Before we saw enset as just a food, but now we know it is more than that and started growing different landraces."                                                                      |
| Public and inter-generational value | Some farmers framed landrace conservation as important beyond the household, including for future generations, other communities, and the country.                                                                                     | "We now understand it is useful at a country level, not just for us if we conserve it very well"                                                                                         |

| Theme                                           | Description                                                                                                                                                           | Illustrative quote                                                                                                                                                                             |
|-------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Increased cultivation and management            | Farmers reported adding landraces, expanding enset farms, multiplying corms, preparing compost, and improving management practices.                                   | "Not only conserving, we are gathering new landraces and started growing them in our farm"                                                                                                     |
| Planting material exchange and social diffusion | Farmers described exchanging corms, bringing landraces from other farmers, sharing with neighbours, teaching others, and distributing landraces to other communities. | "This project taught us to exchange enset with one another."<br><br>"Other farmers who are not participating in this project also understood the benefit and are asking to buy corms from us." |
| Willingness to continue                         | Participants frequently expressed willingness to keep growing and conserving landraces, including without further rewards.                                            | "Happy to grow more landraces, even without the rewards."                                                                                                                                      |
| Inclusion and participation                     | A small number of responses highlighted the importance of women's participation and recognition within the project.                                                   | "Before women were not invited to this kind of project... We thank this project for respecting us and inviting us to participate."                                                             |
| Implementation needs                            | Farmers requested continued monitoring, training, timely provision of corms, more landraces, technical support, and wider community coverage.                         | "More training and regular monitoring is needed."<br><br>"Additional tools and enset landraces corms are needed for us"                                                                        |

**Supplementary Table 3. Spearman rank correlations between the proportion of landraces contracted and baseline community enset diversity characteristics**

| Baseline variable                                   | Spearman's $\rho$ | p-value |
|-----------------------------------------------------|-------------------|---------|
| Total number of landraces grown                     | -0.42             | 0.12    |
| Mean rarity score across landraces grown            | -0.19             | 0.50    |
| Mean number of households cultivating each landrace | 0.19              | 0.50    |
| Mean plants per household across landraces          | -0.20             | 0.48    |

**Supplementary Table 4. Spillover patterns were also robust to alternative measures of programme intensity.**

Outcomes from fixed-effects models of the association between two alternative measures of programme intensity on conservation outcomes for non-contracted landraces: (A) total number of contracts awarded and (B) Mean USD awarded per farmer. Showing the effect, standard error and significance.

(A) Measure of programme intensity: total number of contracts awarded

| Outcome       | $\beta$ | Standard error | P value |
|---------------|---------|----------------|---------|
| Rarity status | -0.11   | 0.02           | < 0.001 |
| Households    | 0.41    | 0.07           | < 0.001 |
| Plants        | -1.49   | 1.01           | 0.16    |

(B) Measure of programme intensity: mean GBP awarded per farmer

| Outcome       | $\beta$ | Standard error | P value |
|---------------|---------|----------------|---------|
| Rarity status | -0.01   | 0.003          | < 0.001 |
| Households    | 0.05    | 0.01           | < 0.001 |
| Plants        | -0.28   | 0.19           | 0.16    |

**Supplementary Table 5. Fixed effects from the linear mixed-effects model of bid offer compensation per plant, as a function of landrace and community characteristics.**

Response variable was log-transformed compensation per plant (USD); community was included as a random intercept with a power variance structure to account for residual heteroscedasticity (n = 212 bid offers across 21 communities). Corresponds to the bid-heterogeneity results reported in the main text (Fig. 5).

| Predictor                             | $\beta$ | Standard error | P value           |
|---------------------------------------|---------|----------------|-------------------|
| Intercept                             | 1.74    | 0.11           | <b>&lt; 0.001</b> |
| Amicho suitability                    | -0.03   | 0.02           | 0.13              |
| Drought tolerance                     | -0.04   | 0.02           | <b>0.02</b>       |
| Fodder suitability                    | -0.08   | 0.02           | <b>0.001</b>      |
| Kocho suitability                     | -0.01   | 0.04           | 0.79              |
| Offer size (log number of plants)     | -0.29   | 0.03           | <b>&lt; 0.001</b> |
| Proportion female participants        | 0.19    | 0.08           | <b>0.03</b>       |
| Pseudostem growth                     | 0.01    | 0.02           | 0.53              |
| Kocho suitability x pseudostem growth | -0.10   | 0.02           | <b>&lt; 0.001</b> |

## Supplementary Data

### Supplementary Data 1. Full responses and open comments from semi-structured interviews conducted after PACS implementation

| Question                                                                                        | Response                                                                                                                                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1. What do you think about growing different enset landraces?</b>                            | We can grow more landraces that are not found in our community. Growing more landraces helps us fight hunger. We can also grow suckers and sell them to other communities and gain money. Growing more enset will also make our village look nice.                                                                                                                                                       |
|                                                                                                 | We are able to get the landraces we have lost before and use them for our cattle and for ourselves as food.                                                                                                                                                                                                                                                                                              |
|                                                                                                 | Different landraces are useful for medicine. Growing more is very important. Growing more landraces helps us secure food security, not only for people but for cattle also. Since enset has many uses, such as making furniture, having more enset plants is very important.                                                                                                                             |
|                                                                                                 | We have gained a lot of landraces we have lost for a long time and now we can protect ourselves from hunger and help the community. The landraces we have received are the ones we have already lost, so now we will take care of them to pass much more diverse enset landraces to the next generation.                                                                                                 |
|                                                                                                 | Most of the communities living around this area are dependent on enset. For food security, and as a way of adding income, it is useful to have more landraces.                                                                                                                                                                                                                                           |
|                                                                                                 | It helps us fulfil our basic food needs, and we get different good nutrients from having more landraces.                                                                                                                                                                                                                                                                                                 |
|                                                                                                 | Enset is the main part of our life. When we are alive it is food for us, for our children. We make kocho, fibre, amicho and other food with it. When we die the leaf is used as a sitting mat. Enset is a culture for Kaffa people. When the climate changes make finding grass for our cattle difficult, we feed them the leaves of enset. So having different landraces will help us fulfil our needs. |
|                                                                                                 | We use it as food for our children, and our neighbours in the community depend on it. It is also used as a source of income by selling one stand for around 4,000 birr and selling kacha (rope) in the market.                                                                                                                                                                                           |
|                                                                                                 | We use it as food, to make kacha, and use the leaves for baking.                                                                                                                                                                                                                                                                                                                                         |
|                                                                                                 | When we have different landraces, they are very beneficial because we get different varieties of kocho and bulla. Among the different landraces, some of them can survive harsh conditions in the future.                                                                                                                                                                                                |
|                                                                                                 | Enset is very important for food security and for mitigating climate change effects. It is drought tolerant because it can hold water, and for other reasons it is important to grow different landraces.                                                                                                                                                                                                |
|                                                                                                 | The use of enset is wide. We need to grow more to preserve it for the next generation.                                                                                                                                                                                                                                                                                                                   |
| <b>2. Have your views on enset diversity changed in any way during the project? If so, how?</b> | This project helped us to understand the benefit of enset very well. It has encouraged us to grow more landraces.                                                                                                                                                                                                                                                                                        |
|                                                                                                 | This project helped us to give enset more attention, and we need to add more landraces to our farms. We have now added more landraces to our farm.                                                                                                                                                                                                                                                       |
|                                                                                                 | The project has changed our thoughts about enset. After the project, the government also came up with a new policy for each farmer to                                                                                                                                                                                                                                                                    |

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|-----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                   | have at least 150 individual enset plants on their farms to fight hunger. Now much attention is being given to enset and growing more landraces.                                                                                                                                                           |
|                                                                                                                                   | This project helped us to differentiate enset landraces we could not differentiate before, despite being plant experts in the community. It helped us realise what we have now and what we already lost. We will look for more lost landraces we do not have now and multiply them.                        |
|                                                                                                                                   | It has taught us to produce enset on a large scale, look for landraces, and add them to our farms. Our understanding has also increased about landraces.                                                                                                                                                   |
|                                                                                                                                   | Our effort to conserve enset and utilise diverse landraces is being supported by this project, and in the future it will help us achieve good results.                                                                                                                                                     |
|                                                                                                                                   | I only had 30 enset on my farm before, but after this project I have 60 because I added more landraces to my farm. I also gave different landraces to my neighbours. Whatever we plant, whether teff or other things, nothing is like kocho for us. Thank you for motivating us to expand our enset farms. |
|                                                                                                                                   | Us women, we know a lot about enset and its different landraces. For the sake of our children, you have taught us to preserve what we have and add more landraces.                                                                                                                                         |
|                                                                                                                                   | We now understand that if we do not take care of the landraces we have, we can lose them in the future, so we have started to take care of what we have. Not only conserving, we are gathering new landraces and have started growing them on our farm.                                                    |
|                                                                                                                                   | Before, we saw enset as just a food, but now we know it is more than that and have started growing different landraces.                                                                                                                                                                                    |
|                                                                                                                                   | Because our parents are farmers, we give attention to enset. But after this project, we gave it even more attention and are trying to cover our farms with it.                                                                                                                                             |
|                                                                                                                                   | We now understand that it is useful at a country level, not just for us, if we conserve it very well.                                                                                                                                                                                                      |
| <b>3. If you had access to more planting material, how likely would you be to grow additional landraces without compensation?</b> | We are willing to add more landraces to our farms.                                                                                                                                                                                                                                                         |
|                                                                                                                                   | We are willing to grow more enset landraces.                                                                                                                                                                                                                                                               |
|                                                                                                                                   | We are always ready to plant more enset. We have huge land for that.                                                                                                                                                                                                                                       |
|                                                                                                                                   | We have prepared common land to plant new corms. We are also preparing compost. Farmers in the community are showing interest in planting more landraces.                                                                                                                                                  |
|                                                                                                                                   | We are willing to grow more landraces.                                                                                                                                                                                                                                                                     |
|                                                                                                                                   | We will grow more landraces.                                                                                                                                                                                                                                                                               |
|                                                                                                                                   | We want to grow more landraces.                                                                                                                                                                                                                                                                            |
|                                                                                                                                   | Yes, we are willing to grow more landraces.                                                                                                                                                                                                                                                                |
|                                                                                                                                   | We are willing to grow more landraces.                                                                                                                                                                                                                                                                     |
|                                                                                                                                   | We plan to grow more landraces. We all want kocho.                                                                                                                                                                                                                                                         |
|                                                                                                                                   | We will grow more landraces. It is a matter of our life.                                                                                                                                                                                                                                                   |
|                                                                                                                                   | We will grow more landraces.                                                                                                                                                                                                                                                                               |
| <b>4. What are your plans for growing enset</b>                                                                                   | We will continue to grow Chegecha and add more landraces in the future.                                                                                                                                                                                                                                    |
|                                                                                                                                   | We will keep growing the landraces we have received, and we are planning more.                                                                                                                                                                                                                             |

|                                                                                                                |                                                                                                                                                                                                                                                                        |
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| <b>landraces in the future?</b>                                                                                | We will continue to grow the new landraces. We will multiply the corms we got and give them to other communities. We also prepare and use compost to grow the enset very well.                                                                                         |
|                                                                                                                | Our plan is to keep enset diversity for the next generation, and we will tell them that this project helped us to do that. We will use the science we learned to multiply more enset.                                                                                  |
|                                                                                                                | Enset is our life. We will do whatever we can to preserve it.                                                                                                                                                                                                          |
|                                                                                                                | We will continue to grow the landraces because enset has a lot of uses. Even if we do not eat it, it will still be used for fodder, the leaves as a sitting mat for funerals, and for kacha. Growing whatever landrace is useful for us.                               |
|                                                                                                                | We will keep growing them very well. We will prepare compost to take care of the landraces.                                                                                                                                                                            |
|                                                                                                                | Yes, we will grow them very well. We will teach others to gather new landraces.                                                                                                                                                                                        |
|                                                                                                                | We will grow them very well. We expect lots of changes in the future.                                                                                                                                                                                                  |
|                                                                                                                | We will multiply what we have and also look for new ones.                                                                                                                                                                                                              |
|                                                                                                                | We will grow them very well.                                                                                                                                                                                                                                           |
|                                                                                                                | Yes, we will continue growing them.                                                                                                                                                                                                                                    |
| <b>5. What effects, if any, do you think expanding this project could have on your household or community?</b> | It helps with food security because we will have more enset to eat and we can also support our livelihoods by selling more suckers.                                                                                                                                    |
|                                                                                                                | These kinds of projects are very important to secure our food security because we will get landraces that are used for food, which we have lost, and we can sell more enset in the market to improve our livelihood.                                                   |
|                                                                                                                | It can help us fight hunger so our food security is secured.                                                                                                                                                                                                           |
|                                                                                                                | In this community, one enset is being sold for 2,000 birr. With the help of this project, we can sell more enset and support our livelihoods. Other farmers who are not participating in this project also understood the benefit and are asking to buy corms from us. |
|                                                                                                                | If we have enset, it is like our food security is guaranteed and our livelihood is improved.                                                                                                                                                                           |
|                                                                                                                | It protects us from the impacts of climate change and from food security problems. We value enset more than our children.                                                                                                                                              |
|                                                                                                                | For food security it is really important. If we get to grow more landraces, we will have enough supply of food. We also sell some of the enset in the market. Before, one enset was sold for 3 birr, but now it is 1,000. We will be able to support our livelihood.   |
|                                                                                                                | If it continues like this, it is good for food security. We consider it really important.                                                                                                                                                                              |
|                                                                                                                | If the project is expanded, we think it is useful for food security.                                                                                                                                                                                                   |
|                                                                                                                | Farmers will give more attention to enset. If we have more enset, we can guarantee food security.                                                                                                                                                                      |
|                                                                                                                | Enset is useful for everything, so it will be very helpful.                                                                                                                                                                                                            |
|                                                                                                                | Enset is helpful for food security.                                                                                                                                                                                                                                    |
| <b>6. What, if anything, have you learned</b>                                                                  | We have learned about new landraces we did not have before. We learned that we should add more to our farms and multiply them.                                                                                                                                         |
|                                                                                                                | We learned that by growing more enset landraces we can secure our food security. We learned that we should keep looking for lost                                                                                                                                       |

|                                                                                                       |                                                                                                                                                                                                                                                 |
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| <b>from the project?</b>                                                                              | landraces to bring to our farm. The rewards we are receiving are going to motivate us to work hard and keep enset diversity.                                                                                                                    |
|                                                                                                       | We learned to be hard workers. We learned we should not sit and wait around for hunger to strike; instead, we should grow more enset.                                                                                                           |
|                                                                                                       | We have learned that there are lots of enset landraces we did not know about. We learned that we should keep looking for the lost landraces and multiply them.                                                                                  |
|                                                                                                       | Adding more landraces to our farms is good.                                                                                                                                                                                                     |
|                                                                                                       | Keep what we have and keep growing more.                                                                                                                                                                                                        |
|                                                                                                       | Having different landraces is really important to secure our future.                                                                                                                                                                            |
|                                                                                                       | Growing different landraces is important.                                                                                                                                                                                                       |
|                                                                                                       | Having different landraces is very important.                                                                                                                                                                                                   |
|                                                                                                       | We can be food secure if we grow more landraces.                                                                                                                                                                                                |
|                                                                                                       | Having different landraces is really important.                                                                                                                                                                                                 |
|                                                                                                       | If we work together, we can bring good changes.                                                                                                                                                                                                 |
| <b>7. What are your overall thoughts on the project? Do you have any suggestions for improvement?</b> | It is good if you monitor frequently to check where we are and what we need for the project to be successful. It is good if you provide more corms and more landraces.                                                                          |
|                                                                                                       | We are really happy with the project. What we suggest for the future is that you should give more training and work with a greater number of communities. If possible, providing more landraces is also going to help secure our food security. |
|                                                                                                       | We are very grateful for the project. In the future, if more training is given to farmers on how to take care of enset, that would be better to get more yield.                                                                                 |
|                                                                                                       | In the future, you should give more training to the representatives so that we can go and teach the farmers well. Regular monitoring is required. Programming our meeting very well is very important.                                          |
|                                                                                                       | Frequent monitoring and checking if the corms are planted and if they are doing well.                                                                                                                                                           |
|                                                                                                       | Regular monitoring, at least twice a year. Providing corms at the right planting season would be more effective.                                                                                                                                |
|                                                                                                       | Regular monitoring and more training on how to take care of our enset.                                                                                                                                                                          |
|                                                                                                       | Regular monitoring and support.                                                                                                                                                                                                                 |
|                                                                                                       | Instead of growing it on individual farms, we think it is better to plant on communal land.                                                                                                                                                     |
|                                                                                                       | It is better to have a trained person to monitor and support the farmers and provide us with more landraces.                                                                                                                                    |
| <b>Open comments</b>                                                                                  | We think it would be very helpful if you gather different landraces from faraway places and distribute them, so we can conserve them.                                                                                                           |
|                                                                                                       | Keep doing what you are doing. We are happy.                                                                                                                                                                                                    |
|                                                                                                       | We are very grateful for the rewards. This will motivate us to do well and show you by growing more landraces of enset and other crops.                                                                                                         |
|                                                                                                       | We are really thankful for the effort you have shown.                                                                                                                                                                                           |
|                                                                                                       | We are very happy to work with you again in the future.                                                                                                                                                                                         |
|                                                                                                       | Happy to grow more landraces, even without the rewards.                                                                                                                                                                                         |
|                                                                                                       | Promise to continue the conservation process in the future.                                                                                                                                                                                     |
|                                                                                                       | Enset is important not just to this community but to the country.                                                                                                                                                                               |

|  |                                                                                                                                                                                                                                                                                                                                                                                                                       |
|--|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | We are willing to propagate and distribute to other communities if we want to do the project with other communities in the future.                                                                                                                                                                                                                                                                                    |
|  | We really appreciate the efforts you are showing to help us secure food security. We will be propagating more enset and will share it with communities that do not have it. This project helped us to get landraces for ourselves and also gave us rewards, which is very motivating. In the future you should do a lot of monitoring and come back to see where the enset is planted and check if we are doing well. |
|  | We are very thankful that you are focusing on enset and helping us to propagate more. This is going to help us increase kocho production.                                                                                                                                                                                                                                                                             |
|  | This is a very nice project. We are doing what we have not done before. Before, women were not invited to this kind of project, let alone given a reward. We thank this project for respecting us and inviting us to participate. Monitoring is very useful to check the status of the enset planted.                                                                                                                 |
|  | We are very thankful for this project. We have lost a number of landraces but now we are able to gain them back. Seeing from the four-cell, we have improved a lot, which makes us so happy. Now we have multiplied the new landraces using compost, and we are very happy.                                                                                                                                           |
|  | Your support has helped us grow more landraces than we had before. Now we are highly motivated, and we will work hard to show you more change when you come next time.                                                                                                                                                                                                                                                |
|  | I want to thank you from my heart. People were losing hope in enset and had started changing their enset farms to eucalyptus. After this project, people are very motivated to grow enset again.                                                                                                                                                                                                                      |
|  | From this project, I learnt the names of different enset landraces from others. Now, I am interested in growing more enset landraces on my farm.                                                                                                                                                                                                                                                                      |
|  | I am motivated to grow more enset, and I now know landraces that I did not know before. After the first phase of our group discussion on enset, farmers started growing new enset landraces by bringing them from other farmers. Really, this project taught us to exchange enset with one another.                                                                                                                   |
|  | Enset farms in this locality had been replaced by other crops. I will expand my enset farm, and I would like to invite you to visit our activities frequently, which can help us to grow more.                                                                                                                                                                                                                        |
|  | This project motivated us to restore lost landraces. The lost landraces listed here should be offered to us so that many landraces can be restored in this area.                                                                                                                                                                                                                                                      |
|  | I appreciate this project because enset is decreasing and being replaced by other crops. When I was a child, I knew different enset landraces, but many of them have been lost. Many farmers are focusing on cereal crops.                                                                                                                                                                                            |
|  | Kafecho people and enset are closely interlinked culturally. People with small landholdings can sustain their livelihoods through enset farming. Having different types of landraces is better than having large farms with fewer landraces because landraces have different uses.                                                                                                                                    |
|  | I learnt more from this project about the lost and existing enset landraces. This kind of monitoring of enset farms is crucial because enset is a multipurpose crop beyond its food value.                                                                                                                                                                                                                            |

|  |                                                                                                                                                                                                                                                                                                                                                                            |
|--|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | I learnt more landrace names from this discussion. Enset is not only used for food but also for numerous other functions.                                                                                                                                                                                                                                                  |
|  | I know all these listed landrace names, but many of them have disappeared from our locality. There is no opportunity to get some of these lost landraces. Others can be obtained from other areas.                                                                                                                                                                         |
|  | The major threat causing the loss of enset landraces is bacterial wilt disease, locally called Nuushoo. For this reason, the Nobo landrace is preferred for its tolerance to disease. Another challenge is mole rats, which feed on enset corms. We would be happy if you came with solutions for these threats. We have been strongly linked to enset since my childhood. |
|  | I appreciate this project for its focus on enset. I learnt and came to know more enset landraces from the discussion. I need more landraces from these lists on my farm.                                                                                                                                                                                                   |
|  | This training is very interesting, and I really need to thank you because enset is a more multifunctional crop than other crops. I will improve my enset farming and add more landraces.                                                                                                                                                                                   |
|  | This project can improve our enset farming and has led me to focus on enset. This project showed the current value of enset when I saw the project teams from our country and foreign scientists.                                                                                                                                                                          |
|  | Enset is all about our life. This project helped us to know the lists of new, existing, and lost enset landraces. I need more landraces on my farm.                                                                                                                                                                                                                        |
|  | I feel happy to have participated in this project. I will conserve these landraces and add more. I will multiply these landraces, and I will even offer them to other farmers.                                                                                                                                                                                             |
|  | From this project, I now know the names of enset landraces that I did not know before. Different enset landraces have different use values. I will propagate them continuously, and I will add more enset landraces to my farm.                                                                                                                                            |
|  | During my childhood, there were many enset landraces, but many have been lost recently. I appreciate your team for focusing on enset to restore these lost landraces. This will help us to exchange enset landraces with one another.                                                                                                                                      |
|  | I appreciate all of you for focusing on our crop. Enset is our everything: our food, our wealth, our ornament, and our materials. When I was a child, I knew different enset landraces, but many of them have been lost due to diseases and other factors.                                                                                                                 |
|  | I found this project helpful for conserving our food crop, enset. Many of the landraces listed here have become lost. Really, I received a lot of information about the lost and existing landraces. I will keep records of these landraces and search for corms.                                                                                                          |
|  | This project teaches us about the value of enset. This can help conserve the variety of enset landraces listed here. Additional tools and enset landrace corms are needed for us.                                                                                                                                                                                          |
|  | Since enset is a multipurpose crop that can be harvested for amicho, kocho, medicine, and other materials, I would be happy if you added these enset landraces from other areas. Enset will be a potential crop to feed many people because other crops are not withstanding the current conditions. Enset is evergreen in different seasons.                              |

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