Received: 25 August 2022 | Revised: 25 April 2023 | Accepted: 5 August 2023

DOI: 10.1002/agr.21841

RESEARCH ARTICLE

Agribusiness An International Journal WILEY

Willingness to pay for agricultural mechanization services by smallholder farmers in Malawi

Adane Tufa[1] | Arega Alene[1] | Hambulo Ngoma[2] | Paswel Marenya[3] | Julius Manda[4] | Md Abdul Matin[2] | Christian Thierfelder[2] | David Chikoye[5]

[1]International Institute of Tropical Agriculture (IITA), Lilongwe, Malawi

[2]International Maize and Wheat Improvement Center (CIMMYT), Southern Africa Regional Office, Mt. Pleasant, Harare, Zimbabwe

[3]International Maize and Wheat Improvement Center (CIMMYT), Nairobi, Kenya

[4]International Institute of Tropical Agriculture (IITA), Arusha, Tanzania

[5]International Institute of Tropical Agriculture (IITA), Southern Africa Research Hub (SARH), Lusaka, Zambia

Correspondence
Adane Tufa, International Institute of Tropical Agriculture (IITA), PO Box 30258, Lilongwe, Malawi.
Email: A.Tufa@cgiar.org

Funding information
Norwegian Agency for International Development (NORAD)

Abstract

One of the main barriers to adopting smallholder agricultural mechanization in developing countries is the mismatch between the economies of scale of machines and farm size. Private sector-led mechanization services hold a promise to address this challenge, but there is a lack of evidence on demand for smallholder mechanization services. This study estimates the farmers' willingness to pay for mechanization services using the double-bounded contingent valuation method and data from 1512 households. Results show that, on average, farmers are willing to pay 11%, 33%, and 5% more than prevailing market rates for land preparation, maize shelling, and transportation services, respectively. The amounts farmers are willing to pay for the mechanization services vary by sex, age group, size of cultivated land, the value of farmer assets, market access, and agroecology. Men are willing to pay 26%, 25%, and 11% more than women for land preparation, maize

Abbreviations: 2WT, two-wheel tractor; 4WT, four-wheel tractor; ACASA, adoption of conservation agriculture in Southern Africa; CA, conservation agriculture; DBDC, double-bound dichotomous choice; EPA, extension planning area; FAO, The Food and Agriculture Organization of the United Nations; FAO-AUC, The Food and Agriculture Organization of the United Nations and the African Union Commission; HIV/AIDS, human immunodeficiency virus/acquired immunodeficiency syndrome; Km, kilometer; LPS, land preparation services; MMP, Malabo Montpellier Panel; MSS, maize shelling services; MWK, Malawi Kwacha; NAIP, National Agricultural Investment Plan; NGO, nongovernmental organizations; SSA, sub-Saharan Africa; STATA, Statistical Software for Data Science; TRS, transportation services; WTP, willingness to pay.

shelling, and transportation services. Moreover, 40% of female and 90% of male farmers are willing to pay more than or equal to the prevailing market rate for land preparation services. The high demand for mechanization services among smallholder farmers points to the need for making the machinery available to rural communities through mechanization service providers or machinery hiring centers run by the private sector. The paper concludes by discussing the contextual factors and policy options for promoting smallholder mechanization in Malawi. [EconLit Citations: O33, Q11, Q13, Q16].

KEYWORDS

hire mechanization service, land preparation, Malawi, two-wheel tractor, willingness to pay

1 | INTRODUCTION

Human labor is the primary source of agricultural power in sub-Saharan Africa (SSA). Bishop-Sambrook (2005) states that humans supply 65% of farm labor. However, farm operations are arduous and tedious. They need long working hours; thus, humans lack the energy to perform them in time, desired quality, and quantity, resulting in low agricultural productivity (Sims & Kenzle, 2006; Vemireddy & Choudhary, 2021). Moreover, there is a reduction in the availability of human labor for arduous farm activities due to improved (1) access to social services (e.g., universal education), (2) illnesses such as HIV/AIDS, malaria, and malnutrition, (3) migration of the rural population to urban areas, (4) aging rural populations, and (5) new economic opportunities in regions from where migrant workers originated (Asenso-Okyere et al., 2011; Bignami-Van Assche et al., 2011; Bishop-Sambrook, 2005; FAO-AUC, 2018). The reduced availability of human labor for agricultural activities causes serious labor shortages during the peak agricultural season. It contributes to the low productivity of agriculture in SSA countries like Malawi, where human labor is the primary source of farm power (Alwang & Siegel, 1999; Baudron et al., 2019; Feder et al., 1985; Leonardo et al., 2015; Mbalule, 2000; Mrema et al., 2008; Wodon & Beegle, 2006). The alternative agricultural power sources are draught animals and tractors. These sources of farm power can improve agriculture productivity, reduce the work burden and time, and reduce agricultural land abandonment (Bandyopadhyay et al., 2016; Belton et al., 2021; Giller et al., 2011; Ma et al., 2021; Olasehinde-Williams et al., 2020; Zhou & Ma, 2022; Zhou et al., 2018). According to Sims and Kenzle (2006), a typical farm family in SSA can cultivate 1.5 ha per year using solely human labor, 4 ha using draught animal power, and over 8 ha using tractor power. Therefore, the operation of primary farm activities using animals such as oxen and donkeys or tractors can increase cultivated land area, increase crop yields through convenient operation, and reduce drudgery levels, thereby helping farmers to redeploy family labor.

More specifically, agricultural mechanization using tractors has significant impacts on labor productivity (Hamilton et al., 2022), farm efficiency (Huan et al., 2022), off-farm income (Nguyen & Warr, 2020), land productivity (Zheng et al., 2021; Zhou et al., 2020), farm income growth (Kotu et al., 2023; Takeshima, 2018), off-farm employment (Ma et al., 2018), and voluntary employment (Zhou & Ma, 2021). Moreover, in a study conducted in Myanmar, for example, agricultural mechanization enabled farmers to have incremental, overlapping, and complementary advantages such as labor savings, reduced drudgery, convenience, increased speed and timeliness of operations, improved ability to manage weather-related risks, and reduced loss of grain during harvesting (Belton et al., 2021). Governments in SSA, such as in Malawi, where hoe culture is prevalent, recognize the need to stop the use of hand hoes which are rudiment, inefficient, and burdensome (FAO-AUC, 2018). Besides, agricultural mechanization can help increase youth engagement in agricultural production, processing, and provision of services to sustainably transform agriculture and reduce youth unemployment (Daum & Birner, 2020).

However, there are several challenges in the use of animals and tractors for agricultural power: (a) the decline in the number of draught animals due to diseases and recurring droughts and the high costs of possession and maintenance of the animals; (b) the high costs of possession and running of tractors; and (c) inadequate supply of implements and spare parts (Sims & Kienzle, 2016). Besides, government-run tractor hire service schemes failed due to poor management, lack of financial support, poor infrastructure, lack of incentives for tractor operators to work extended hours, and inefficient utilization of tractors (Baudron et al., 2015; Daum & Birner, 2020; Diao et al., 2014; Sims & Kenzle, 2006).

A recent development in agricultural mechanization in SSA and Asia suggests the importance of private sector-led hiring services to provide smallholder farmers with access to tractor hire services in their vicinities from medium and large-scale tractor owners (Adu-Baffour et al., 2019; Asfaw et al., 2018; Belton et al., 2021; Diao et al., 2014; FAO-AUC, 2018; Houssou et al., 2017; Van Loon et al., 2020; Zheng et al., 2022). Different institutions and private enterprises have also promoted small-size and low-cost tractors to encourage smallholder farmers to own tractors for use and hire out to others (Baudron et al., 2015; FAO-AUC, 2018). In Myanmar, the availability of outsourcing services has enabled farmers to mechanize their farms irrespective of tractor ownership and independent of farm size (Belton et al., 2021). However, in Malawi, where human power is the primary source of farm labor and the landholdings are small (less than 1 ha on average), there is a need to assess the demand for tractor hire services. Empirical evidence of the willingness to pay (WTP) for mechanization services can guide the government, service providers, and other institutions supporting the promotion of agricultural mechanization. The study estimates the WTP for two-wheel-based mechanization services for land preparation, maize shelling, and transportation of agricultural produce from farm fields to homesteads. These are the three main power-intensive farm operations (Daum & Birner, 2017). Therefore, this study aims to assess labor shortages related to different farm activities, estimate the WTP for mechanization services, and identify policy options for promoting smallholder mechanization services in Malawi. Previous studies in SSA and Asia showed that smallholder farmers are willing to pay for tractor-hire services for agricultural activities such as land preparation, weeding, harvesting, threshing, and transport (Hodjo et al., 2021; Houssou et al., 2016; Nxumalo et al., 2020; Takele & Selassie, 2018; Takeshima, 2018). To the best of our knowledge, however, no study has investigated smallholder farmers' WTP for agricultural mechanization services in Malawi.

This study contributes to the thin literature on mechanization in at least two ways. First, we used nationally representative comprehensive household survey data to assess agricultural labor use patterns and constraints related to major farm operations. This informs policymakers and development actors about the farm operations for which smallholder farmers need mechanization services. Besides, we investigated smallholder farmers' know-how, usage, and ownership of two-wheel tractors (2WT), four-wheel (4WT) tractors, and oxen for agricultural operations. This knowledge helps development actors identify the types of mechanization services to promote and their training needs. Second, we examined the WTP for hiring services of 2WT and their determinants disaggregated by sex, landholding size, agroecology, and market access. Thus, the findings can aid development actors and policymakers in making decisions to enhance mechanization services.

We analyze smallholder farmers' demand for mechanization services using the double-bound dichotomous choice (DBDC) contingent valuation method because the services are not prevalent in Malawi. Our results show that farmers are willing to pay 22,211 MWK/acre for land preparation, 467 MWK per 50 kg shelled maize grain, and 2096 MWK per trip within a range of 6 km. For all the services, farmers are willing to pay amounts within the range of the prevailing market rates. The amounts farmers are willing to pay for the services depend on sex, age, landholding size, market access, agroecology, and asset ownership.

The following is the organization of the rest of the paper. Section 2 briefly describes agricultural mechanization in Malawi, Section 3 outlines the empirical estimation procedures, whereas the fourth section gives an overview of the survey design and data collection. Section 5 provides variable definitions and discusses the sample households' descriptive statistics. Section 6 presents and discusses labor shortages and mechanization and the results of the econometric analysis. The last section draws conclusions and policy implications.

2 | AGRICULTURAL MECHANIZATION IN MALAWI

The use of farm machinery (tractors) in Malawi dates back to the colonial era, around 1945 (Pingali, 2007). However, agriculture mechanization in Malawi is very low (Murray et al., 2016; Takane, 2008). According to the world development report, only about 5% of agriculture in Malawi is mechanized (World Bank, 2012). The number of tractors as of 1968 was 692 (Figure 1), and the number increased only to 707 in 2010/11 (Sheahan & Barrett, 2017), indicating little progress over four decades. However, MMP (2018) estimates a 2.69% average annual agricultural machinery growth rate for Malawi. The estimate was in the number of agricultural machinery units expressed in 40-CV (horse-power) tractor-equivalents based on data from 2005 to 2014. The average number of agricultural machinery units from 2005 to 2015 was 1655 (Kirui & Braun, 2018). Malawi also has a National Agricultural Investment Plan that emphasizes increasing the number of hectares under a tractor-hire scheme (e.g., from 2090 ha in 2009/10 to 10,000 ha in 2013/14) (MMP, 2018). Besides, there is an increase in medium-scale farms (5–50 ha), and the size of landholding by medium-scale farms has doubled since 2005 (Anseeuw et al., 2016), which shows potential for tractor-hire services in the country.

Recently, NGOs have promoted small-scale machines to smallholder farmers through different projects and programs. For example, drip irrigation lines, V-tractors, walk-behind tractors, grain storage facilities, central pivotal irrigation, and groundnut strippers and shellers have been promoted (Kumwenda et al., 2020; Tsusaka et al., 2017). Moreover, 2WT and rippers are being promoted as a complement to conservation agriculture practices to reduce drudgery from the preparation of planting basins, one of the components of conservation agriculture practices (Jaleta et al., 2014; Sims & Heney, 2017).

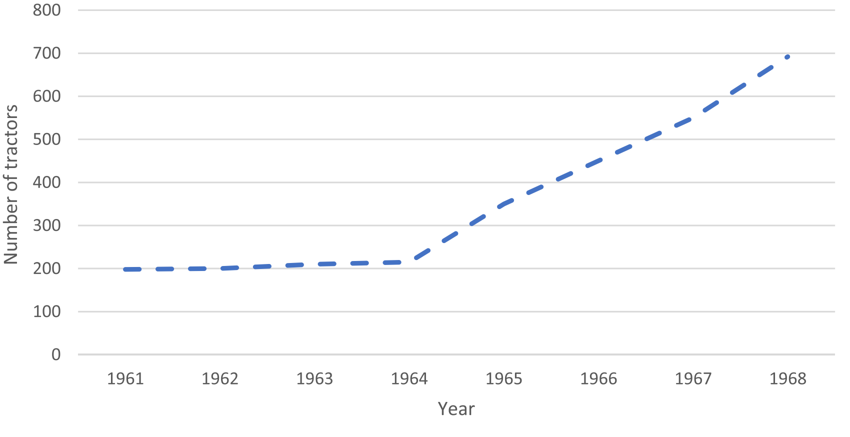

FIGURE 1 Trends in the number of tractors in Malawi (source: FAO, 2023).

3 | ANALYTICAL FRAMEWORK

3.1 | Theoretical framework

To assess smallholder farmers' WTP for mechanization services (land preparation, maize shelling, and transportation), we use the DBDC contingent valuation method (Hanemann et al., 1991; Lopez-Feldman, 2012). The DBDC format was preferred over a single-bound format because of the statistical efficiency of the former over the latter (Hanemann et al., 1991). In the single-bound contingent valuation format, a respondent is asked only one dichotomous question, that is, if the individual is willing to pay a threshold amount for a good or service under consideration. However, the DBDC format involves a follow-up dichotomous question depending on the response to the first question. If the response to the first question is "yes," the individual is asked a follow-up question with a higher bid amount. If the answer to the first question is "no," the individual is asked a follow-up question with a lower bid amount. The DBDC format thus provides individual respondents with more information concerning WTP than the single-bound format and provides an interval within which the actual WTP for an individual lies.

Denoting that b^I is the initial bid amount and b^F is a follow-up bid amount, an individual's WTP can be expressed as (1) $b^I \le WTP < b^F$ if the individual's responses are "yes" for b^I and "no" for b^F; (2) $b^F \le WTP < \infty$ if the individual's responses are "yes" for both bid amounts; (3) $b^F \le WTP < \text{b}^I$ if the individual's responses are "no" for b^I and "yes" for b^F; and (4) $0 \le WTP < \text{b}^F$ if the individual's responses are "no" for both bid amounts. Following Lopez-Feldman (2012), we assume that r_i^1 is a response for b^I and r_i^2 is a response for b^F, the probability that the individual's response is "yes = y" to b^I and "no = n" to b^F can be expressed as $P(r_i^1 = 1, r_i^2 = 0|x_i) = P(y, n)$ where x_i is a vector of explanatory variables. Further assuming that $WTP_i(x_i, u_i) = x_i'\beta + u_i$ where WTP_i is WTP of the i^{th} respondent, β is a vector of parameters, u_i is an error term ($u_i \sim N(0, \sigma^2)$), and $\phi(.)$ is the standard cumulative normal distribution, the probability for each of the four response categories can be given as follows.

a. $r_i^1 = 1 \text{ and } r_i^2 = 0$

$$P(y, n) = P(b^I \le WPT < b^F)$$

$$e = P(b^I \le x_i'\beta + u_i < b^F)$$

$$= P\left(\frac{b^I - x_i'\beta}{\sigma} \le \frac{u_i}{\sigma} < \frac{b^F - x_i'\beta}{\sigma}\right)$$

$$= \phi\left(\frac{b^F - x_i'\beta}{\sigma}\right) - \phi\left(\frac{b^I - x_i'\beta}{\sigma}\right)$$

Using the symmetry of the normal distribution, we can rewrite the last expression as

$$P(y, n) = \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^I}{\sigma}\right) - \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^F}{\sigma}\right) \tag{1}$$

b. $r_i^1 = 1 \text{ and } r_i^2 = 1$

$$P(y, y) = P(WTP > b^I, WPT \ge b^F) = P(x_i'\beta + u_i > b^I, x_i'\beta + u_i \ge b^F)$$

Using Bayes rule $P(y, y) = P(x_i'\beta + u_i > b^I|x_i'\beta + u_i \ge b^F) \times P(x_i'\beta + u_i \ge b^F)$. As $b^F > b^I$ and therefore $P(x_i'\beta + u_i > b^I|x_i'\beta + u_i \ge b^F) = 1$, which also implies $P(y, y) = P(u_i \ge b^F - x_i'\beta) = 1 - \phi\left(\frac{b^F - x_i'\beta}{\sigma}\right)$ which by symmetry is

$$P(y,y) = \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^F}{\sigma}\right) \tag{2}$$

c. $r_i^1 = 0$ *and* $r_i^2 = 1$

$$P(n,y) = P(b^F \le WPT < b^l) = P\left(b^F \le x_i'\beta + u_i < b^l\right) = P\left(\frac{b^l - x_i'\beta}{\sigma} \le \frac{u_i}{\sigma} < \frac{b^F - x_i'\beta}{\sigma}\right)$$
$$= \phi\left(\frac{b^l - x_i'\beta}{\sigma}\right) - \phi\left(\frac{b^F - x_i'\beta}{\sigma}\right)$$

$$P(y,n) = \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^F}{\sigma}\right) - \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^l}{\sigma}\right) \tag{3}$$

d. $r_i^1 = 1$ *and* $r_i^2 = 0$

$$P(n,n) = P(WTP < b^l, WPT < b^F) = P(x_i'\beta + u_i < b^l, x_i'\beta + u_i < b^F) = P(x_i'\beta + u_i < b^F) = \phi\left(\frac{b^F - x_i'\beta}{\sigma}\right)$$

$$P(n,n) = 1 - \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^F}{\sigma}\right) \tag{4}$$

Following Hanemann et al. (1991) and Lopez-Feldman (2012), the likelihood function that comprises Equations 1–4 and that needs to be maximized to find the parameters of the model, β and σ, is:

$$\ln L = \sum_i^N \left[g_i^{yn}\ln\left(\phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^l}{\sigma}\right) - \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^F}{\sigma}\right)\right) + g_i^{yy}\ln\left(\phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^F}{\sigma}\right)\right) + g_i^{ny}\ln\left(\phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^F}{\sigma}\right) - \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^l}{\sigma}\right)\right) + g_i^{nn}\ln\left(1 - \phi\left(x_i'\frac{\beta}{\sigma} - \frac{b^F}{\sigma}\right)\right)\right] \tag{5}$$

where g_i^{yn}, g_i^{yy}, g_i^{ny}, and g_i^{nn} are variables that take on the value of 1 if an individual respondent contributes to the logarithm of the likelihood function and 0 otherwise. Thus a given individual contributes to Equation 5 in only one of its four functions. We can directly obtain estimates of β and σ from the maximum likelihood function (Equation 5) using the "doubleb" command in STATA that estimates double-bounded dichotomous choice model (Lopez-Feldman, 2012).

3.2 | Empirical procedure

We model WTP for agricultural mechanization using a logit model as follows:

$$Y_{ij} = \beta_{0j} + \beta_{ij}x_{ij} + u_{ij} \tag{6}$$

where Y_{ij} is WTP of farmer i for mechanization service j, β_{0j} is the intercept for mechanization j, β_{ij} is the regression coefficient for mechanization service j, and u_{ij} is the error term for mechanization service j, which assumes ($u_{ij} \sim N(0, \sigma^2)$). The logit model is estimated using the "doubleb" command that incorporates the first bid, second bid, first response, and second response, in this order, as dependent variables (Y_{ij}) followed by explanatory variables (Lopez-Feldman, 2012). After running the "doubleb" command, we estimated the predicted WTP values. Several studies applied the "doubleb" method to elicit WTP. For example, "doubleb" has been used to analyze WTP for craft cider in the United States of America (Tozer et al., 2015), access to irrigation water in Ethiopia

(Mekonnen et al., 2020), acacia hybrid nursery stock in Vietnam (Nguyen, Ariyawardana, & Ratnasiri, 2020), land conservation program in Nepal (Pakhtigian & Jeuland, 2019), index-based crop insurance in Nepal (Budhathoki et al., 2019), and enhanced water security in China (Jiang et al., 2019).

4 | STUDY DESIGN AND DATA

This study uses survey data collected from over 1500 households in seven districts of Malawi (Appendix Table A1) under the project "Understanding and Enhancing the Adoption of Conservation Agriculture in Smallholder Farming Systems of Southern Africa." We use a multistage sampling technique to select the households. In the first stage, the seven districts were chosen to represent a high prevalence of CA promotion. The districts also represent two agroecologies, lowland and mid-elevation, and two market-accesses groups, low and high. Balaka, Nsanje, and Nkhotakota districts were selected from the lowland[1] agroecology, whereas Chitipa, Dowa, Rumphi, and Zomba districts were chosen from the mid-elevation[2] agroecology.

Regarding market access, Balaka, Chitipa, Nkhotakota, and Nsanje represent low market access areas, whereas Dowa, Rumphi, and Zomba represent high market access. We used 2 h of cut-off travel time from the district center to the nearest cities or large regional markets (Mzuzu, Lilongwe, Zomba, and Blantyre) to categorize districts into low market access and high market access (Benson et al., 2016). We selected three extension planning areas (EPAs) per district and three sections per EPA, respectively, based on a high prevalence of CA promotion in the second and third stages. Three villages per section and eight households per village were selected randomly in the fourth and fifth stages. The data comprise demographic, socioeconomic, and biophysical agricultural production constraints, institutional, social capital and networks, labor constraints and mechanization, and WTP for mechanization services. The mechanization services include land preparation, maize shelling, and transportation of farm produce from the farm to homesteads.

We use the DBDC contingent valuation data collection format to collect data on WTP for the mechanization services. Initial and follow-up bids were developed using the current market prices for each mechanization service. The initial and follow-up bids for the land preparation services were developed based on the average tractor service hire rate for plowing and ridging. For maize shelling, the bids were developed using the prevailing average cost of shelling 50 kg maize grain as a middle value and subsequently decreasing and increasing by 50 MWK (10% of the median value). The bids for the transportation of produce from the farm to homesteads were estimated based on the average cost of hiring an oxcart per trip as a middle value and decreasing or increasing the subsequent bids by 100 MWK. Based on our assessment, oxen-pulled carts and 2WT[3] carry a similar load.[4] Bid structures for all the mechanization services are in Appendix Tables A2a–A2c. There are 12 initial bid values for all mechanization services and roughly equal questionnaires per bid for all classes. The data were collected using a structured questionnaire programmed in the World Bank's Survey Solutions platform and administered face-to-face by trained enumerators. The face-to-face interview is deemed the best method to collect data on WTP (Guo et al., 2014).

During the elicitation, the enumerators informed the respondents to assume that some individuals will provide land preparation, shelling, and transport services using a tractor. The respondents have to pay a certain amount for the mechanization services. The enumerators also informed the respondents that the amounts they pay for the services are based on their need for the service, affordability, and other necessary expenditures needed to

---

[1]The lowland agroecology includes the lower shire valley (<250 m asl) and the lakeshore, mid and upper shire (200–760 m asl).

[2]The mid-elevation category includes the mid-elevation upland plateau (760–1300 m asl) and the highlands (>1300 m asl).

[3]Two-wheel tractor (2-WT) is a single axle tractor used to perform agricultural activities such as land preparation, transportation, and shelling of maize and other grains, among others.

[4]A full ox-cart of maize in husk yields roughly 400 kg grain when shelled. A full oxcart of groundnut with stalks can yield roughly 100–125 kg of groundnut grain. A full oxcart of groundnut in pods (without stalks—which is 12–15 50 kg bags) yields roughly 350–450 kg of groundnut grain. A full oxcart of soybean with stalks yields roughly 200–250 kg of soybean grain.

TABLE 1 Percent of the responses to the first and follow-up bids (n = 1512).

Responses	Land preparation	Maize shelling	Transport
"No" to the initial and follow-up bids (NN)	47.88	45.44	35.91
"No" to the initial bid and "yes" to the follow-up bid (NY)	6.15	9.19	3.70
"Yes" to the initial and follow-up bids (YY)	31.15	29.03	47.69
"Yes" to the initial bid and "no" to the follow-up bid (YN)	14.82	16.34	12.70
Total	100	100	100

prioritize. The enumerators informed the respondents about the unavailability of credit services; instead, they will pay using their own available money to reduce a hypothetical bias (Loomis, 2014). First, the enumerators asked if the respondents would pay a certain amount of cash (initial bid) to obtain the service. The enumerators then asked follow-up questions to determine if the respondents were willing to pay a lower amount for the "no" response and a higher one for the "yes" response to the initial bids. All initial bids were randomly assigned to respondents (one per respondent per service). Table 1 presents the percentage of responses.

5 | VARIABLE DEFINITION AND DESCRIPTIVE STATISTICS

We selected the variables included in the analysis based on economic theory and past empirical work on WTP for mechanization services in Africa and beyond (Benin, 2015; Paudel et al., 2019). Table 2 presents the definitions of the variables, expected signs in influencing WTP for the different mechanization services, and the descriptive statistics of the variables. We include variables such as the age of the respondent, sex of the respondent, education level of the respondent, household size, the total number of adult males and females working full time on the farm, size of cultivated land, ownership of different types of assets, experience in the use of draft power for agricultural activities, awareness of the use of 2WT of farming activities, and participation in farmers organization. We incorporated information on the distance of the section to the district capital, the section terrains, and whether the section is waterlogged or not at the section level. We have also controlled for interdistrict differences by using district dummies. We expect the following variables to affect the WTP for mechanization services positively. The variables are the household head's education, the number of adult male members working full time on the farm, the total size of cultivated land, awareness of the use of draft power and 2WT for agricultural activities, and ownership of assets.

Household heads with higher education may know the benefits of mechanization services and thus are willing to pay more than their less educated counterparts (Takele & Selassie, 2018). The age of the household head can positively or negatively influence the amount of WTP for all services as younger household heads may have lower income thus their WTP could be less than that of older household heads. Takele and Selassie (2018) found a negative and significant effect of the age of the household head on WTP for tractor hire service in Ethiopia, while Takeshima (2015) in Nepal and Hodjo et al. (2021) in Burkina Faso found positive and significant effects. The sex of the household head had mixed impacts on WTP for hiring agricultural services; for example, being a male household head positively affected WTP for tractor hire service in Ethiopia (Takele & Selassie, 2018), while the same was negative in Nepal (Takeshima, 2015). In Malawi, female household heads usually have less income than their male counterparts (Tufa et al., 2019) and thus may have lower WTP. Therefore, female household heads are expected to have less WTP. Education is expected to increase awareness of farmers about the benefits of new technologies and thus positively affects WTP for agricultural mechanization services. Takele and Selassie (2018) in Ethiopia, Takeshima (2015) in Nepal, and Adu-Baffour et al. (2019) in Zambia found similar results. The number of household

TABLE 2 Description of the variables used in the analysis.

Variable	Description	Expected signs of influence of the variable on WTP for: Tilling/ripping	Shelling	Transport	Mean	Standard deviation
	Dependent variables					
Bid1	First bid value					
Bid2	Second bid value					
Resp1	Response to the first bid					
Resp2	Response to the second bid					
	Explanatory variables					
Age	Age of the household head (years)	−/+	−/+	−/+	43.95	16.22
Sex	Sex of the household head (1 = female)	−	−	−	0.50	0.50
Education	Education level of the household head (years of schooling)	+	+	+	5.93	3.69
Size	Number of members of the household	−	−	−	5.27	2.11
Male	Total number of adult male members working full time on the farm	+	+	+	0.90	0.70
Female	Total number of adult female members working full time on the farm	−	−	−	1.14	0.58
Land	The total size of cultivated land (acre)	+	+	+	2.30	1.86
Ox	Household owned ox (1 = yes)	−	−/+	−	0.03	0.17
Draft	Household have ever used draft power for agricultural activity (1 = yes)	+	+	+	0.14	0.35
Tractor	Heard or know about the use of 2TW tractor for agricultural activity (1 = yes)	+	+	+	0.38	0.49
Player	The household owns radio and/or CD player (1 = yes)	+	+	+	0.36	0.48
Phone	The household owns phone (1 = yes)	+	+	+	0.63	0.48
Oxcart	The household owns oxcart (1 = yes)	−	−	−	0.03	0.17

(Continues)

TABLE 2 (Continued)

Variable	Description	Expected signs of influence of the variable on WTP for: Tilling/ripping	Shelling	Transport	Mean	Standard deviation
Motorbike	The household owns motorbike (1 = yes)	+	+	+	0.04	0.20
Bicycle	The household owns bicycle (1 = yes)	+	+	+	0.39	0.49
Organization	Household head or spouse member of farmers' organization (1 = yes)	+	+	+	0.36	0.48
Distance	Distance of the section to the district main market (km)	−	−	−	48.05	24.24
Flat	The terrain of the section is flat (1 = yes)	+	+	+	0.43	0.50
Medium	The terrain of the section is medium (1 = yes)	−/+	−/+	−/+	0.37	0.48
Steep	The terrain of the section is steep (1 = yes)	−	−	−	0.21	0.40
Waterlogged	The section is waterlogged (1 = yes)	−	−	−	0.17	0.38
Nsanje	The household is located in Nsanje				14.29	
Nkhotakota	The household is located in Nkhotakota				14.29	
Balaka	The household is located in Balaka				14.29	
Dowa	The household is located in Dowa				14.29	
Rhumpi	The household is located in Rhumpi				14.29	
Chitipa	The household is located in Chitipa				14.29	
Zomba	The household is located in Zomba				14.29	
Farm distance	Distance from crop field to homestead (in min of walking)	+		+	32.90	35.97
Maize	Wish to obtain transport service to transport maize from farm to homestead (1 = yes)			+	0.96	0.19
Groundnut	Wish to obtain transport service to transport groundnut from farm to homestead (1 = yes)			+	0.14	0.35

TABLE 2 (Continued)

Variable	Description	Expected signs of influence of the variable on WTP for			Mean	Standard deviation
		Tilling/ripping	Shelling	Transport		
Soybean	Wish to obtain transport service to transport soybean from farm to homestead (1 = yes)			+	0.04	0.20
Beans	Wish to obtain transport service to transport beans from farm to homestead (1 = yes)			+	0.01	0.09
Tobacco	Wish to obtain transport service to transport tobacco from farm to homestead (1 = yes)			+	0.05	0.21

Abbreviation: WTP, willingness to pay.

members indicates labor availability for farming activities and thus we expect that WTP declines with the size of the household. Takele and Selassie (2018) and Takeshima (2015) also found that the larger the number of male household members, the lower the WTP, and vice versa for female household members. As expected, the larger the cultivated land, the higher the labor required for the farm operation, entailing the need for mechanization services because of labor shortage (Hodjo et al., 2021; Takele & Selassie, 2018; Takeshima, 2015, 2017). WTP for households owning oxen could be lower than those without oxen for all services except maize shelling; however, mere awareness of using oxen for agriculture could be related to a higher WTP.

The results of the descriptive analysis show that the household heads are 44 years old and attended formal school for more than 6 years, and 36% of them or their spouses were members of farmers' organizations. The surveyed households had more than five persons and had more than two adult males and females working full-time on the farm. They also resided in section trains with flat and medium terrain, 48 km from the district capital, and cultivated 2.3 acres. On average, 96% of the respondents wish to obtain transportation services to transport maize from the farm to the homestead.

6 | RESULTS AND DISCUSSION

6.1 | Labor shortage and mechanization

Agricultural production in the study areas relies mainly on family labor. Howver, 41% of the households reported using hired labor (Figure 2). Previous studies conducted in six villages (two villages per region—Central, Southern, and Northern Malawi) from medium attitude (760–1300 m above sea level) also shows similar results (Takane, 2008). According to Takane (2008), family labor accounted for 74% of total labor used in tobacco production and 88% in maize production (Takane, 2008). These results are consistent with the situation in many countries in SSA, where manual labor is the primary source of agricultural power (Bishop-Sambrook, 2005).

Limit access to labor and other sources of farm power such as draft animal power or tractors, limit land productivity in agriculture. According to Baudron et al. (2020), land-to-labor ratios are low in most African farming systems and are projected to decrease. However, as shown in Figure 3, farmers reported labor constraints for farm operations associated with major crops in Malawi. These results are consistent with the previous findings (Wodon & Beegle, 2006). The results show that smallholder farmers face severe labor shortages primarily for weeding, followed by land preparation and transportation of produce from the farm to homestead, implying the need for

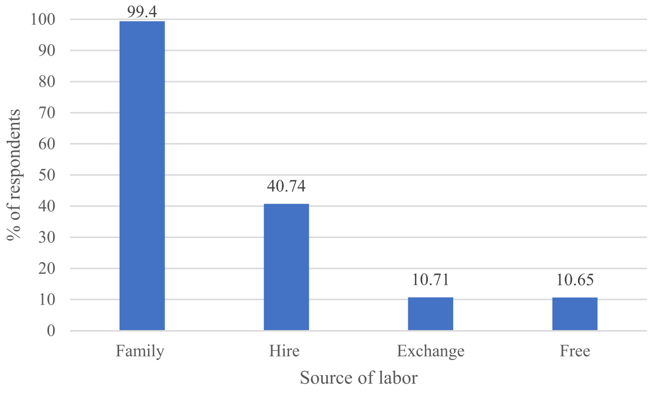

FIGURE 2 Sources of labor for agricultural activities.

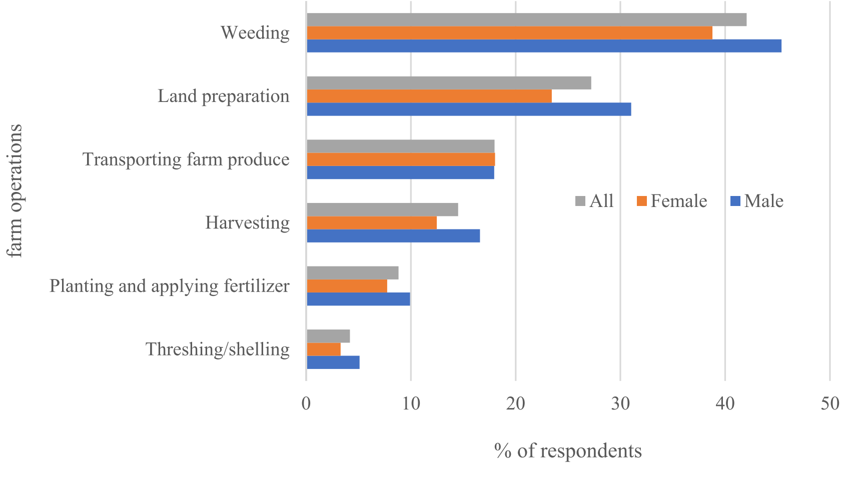

FIGURE 3 Serious labor constraints for major farm operations.

mechanization of farm operations. The labor shortage in weeding and land preparation differs between female and male farmers. A higher proportion of male farmers than female farmers reported facing serious labor shortages during weeding and land preparation.

Figure 4 shows smallholder farmers' knowledge, usage, and ownership of mechanization options. The results show that draft animal power is the most known agricultural mechanization option, as 86% of the respondents reported being aware of the use of draft animal power in farming activities. However, the usage and ownership of draft animal power are very low. Less than 15% of the sample households reported using draft animal power, and less than 3% reported owning draft animal power. These results are consistent with those of a previous study conducted among women smallholder farmers in Kabudula Traditional Authority in Lilongwe district and Nkhamenya Traditional Authority in Kasungu district (Murray et al., 2016). Most (79% of the respondents) know a 4WT, but only very few farmers reported using it for any agricultural activity, and no farmer in the sample owns it. No farmer also said possessing and using 2WT, but about 38% reported being aware of its use. The findings concur with a study that ranked draft animal power as the second most reliable farm power source in SSA after human power and its contribution to 25% of the farm labor (Bishop-Sambrook, 2005). Bishop-Sambrook (2005) reported

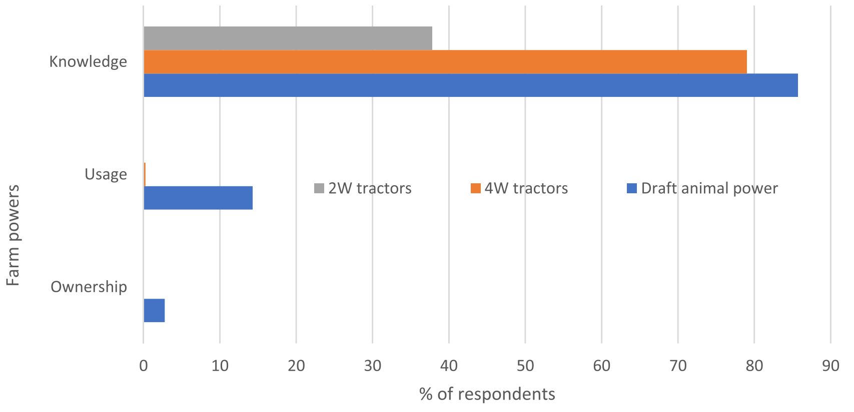

FIGURE 4 Knowledge, usage, and ownership of draft animal power and tractors.

that motorized farm machinery is not economically feasible for most smallholder farmers in SSA and thus is not widely used.

6.2 | Empirical results

6.2.1 | Determinants of WTP

Table 3 presents the results of the maximum likelihood estimation (Equation 5) of the factors affecting WTP for 2WT-powered mechanization services. The results show that WTP for mechanized land preparation service is significantly and positively affected by age, sex, and education level of the household head; the size of cultivated land; radio, phone, and bicycle ownership; and prevalence of waterlogging. The positive and significant effects of age on WTP indicate that older farmers are more labor-constrained than younger farmers. Older farmers have more income to pay for the mechanized land preparation service than younger farmers. However, the significant and negative coefficient of the squared term shows that, after a certain age, the WTP for land preparation service declines. The results are consistent with results of WTP studies on tractore hire services in Nepal (Takeshima, 2015) and Burkina Faso (Hodjo et al., 2021). The positive and significant effect of the size of cultivated land on WTP for mechanized land preparation service is as expected and in line with the result of another study on WTP for tractor hire services in Nepal (Takeshima, 2015, 2017), Ethiopia (Takele & Selassie, 2018), and Burkina Faso (Hodjo et al., 2021). Ownership of radio, mobile phones, and bicycles help farmers to obtain updated information on technologies and related benefits (Aker & Ksoll, 2016; Fu & Akter, 2016; Henriksson et al., 2021). Thus well-informed farmers are willing to pay more than the less informed farmers.

The results show that female farmers have a lower WTP for land preparation services than male farmers, which was also the case with tractor hire services in Ethiopia (Takele & Selassie, 2018). Our study shows that, on average, the value of farm assets for male farmers was double that of female farmers. Farmers in the districts such as Dowa, Rumphi, and Chitipa, where landholding is relatively large, have a higher WTP for land preparation services.

The factors that affect the WTP for maize shelling include the sex and education level of the farmers, bicycle ownership, and distance to the primary market. As expected, being a female farmer lowers the amount the farmer is willing to pay for the shelling services. This lower WTP could be due to the difference in the income level between men and women (Tufa et al., 2019). More educated farmers are more likely to pay more for shelling services than their less-educated counterparts.

TABLE 3 Determinants of WTP for land preparation, maize shelling, and transportation (results of logit model).

Variable	Land preparation	Maize shelling	Transporting farm produce
Age	186.760**	0.434	14.514
	(89.61)	(3.32)	(10.05)
Age-squared	−1.591*	−0.009	−0.137
	(0.90)	(0.03)	(0.10)
Sex	−2849.546***	−73.521***	−86.977
	(519.45)	(19.43)	(59.45)
Education	230.691***	8.469***	30.847***
	(79.51)	(2.96)	(9.15)
Size	31.060	−3.897	−12.534
	(137.54)	(5.10)	(15.54)
Male	542.963	14.466	29.859
	(374.21)	(13.88)	(42.27)
Female	−208.081	5.672	−16.898
	(445.86)	(16.60)	(50.63)
Land	798.675***	4.101	20.607
	(178.16)	(5.50)	(19.07)
Ox	−2933.390	34.645	−349.433*
	(1811.64)	(65.03)	(194.60)
Draft	552.330	9.799	−27.427
	(717.04)	(26.70)	(82.70)
Tractor	−174.679	−40.778**	−91.253
	(490.43)	(18.30)	(55.94)
Player	1192.290**	26.235	206.288***
	(544.58)	(20.51)	(63.79)
Phone	1451.554***	10.996	102.880*
	(549.96)	(20.32)	(61.69)
Oxcart	2915.989	−90.152	−253.442
	(1885.56)	(62.71)	(197.48)
Motorbike	994.415	−39.023	46.692
	(1225.37)	(46.39)	(142.76)
Bicycle	1250.436**	54.585***	132.575**
	(546.19)	(20.44)	(62.28)
Organization	279.692	−1.737	−29.959
	(500.78)	(18.66)	(57.59)

TABLE 3 (Continued)

Variable	Land preparation	Maize shelling	Transporting farm produce
Distance	2.546	0.942**	2.898**
	(11.74)	(0.41)	(1.25)
Flat	−544.226		
	(772.13)		
Medium	−1094.671		
	(718.62)		
Waterlogged	2196.655**		
	(911.56)		
Nsanje	1635.681	2.621	−295.984***
	(1027.54)	(33.81)	(105.00)
Nkhotakota	318.564	−75.814**	14.634
	(956.21)	(34.84)	(105.30)
Balaka	1108.785	−48.451	−58.393
	(935.24)	(33.70)	(101.09)
Dowa	3763.269***	−80.379**	193.456*
	(1062.29)	(36.91)	(115.69)
Rhumpi	4129.747***	−17.032	100.579
	(1028.87)	(35.40)	(111.14)
Chitipa	1793.782*	−73.930**	−222.757**
	(1055.50)	(36.77)	(111.26)
Farm distance			5.511***
			(0.86)
Maize			729.550***
			(153.82)
Groundnut			−120.904
			(81.07)
Soybean			−82.207
			(140.00)
Beans			322.974
			(343.05)
Tobacco			93.334
			(144.08)
Constant	11,629.078***	422.740***	537.089*
	(2292.64)	(79.75)	(288.73)

(Continues)

TABLE 3 (Continued)

Variable	Land preparation	Maize shelling	Transporting farm produce
Sigma			
Constant	7240.322***	278.811***	824.320***
	(299.45)	(10.12)	(40.22)
N	1504	1504	1504

Note: Standard errors are in parentheses.
Abbreviation: WTP, willingness to pay.
**p* < 0.10; ***p* < 0.05; ****p* < 0.01.

WTP for transportation of farm produce from farm fields to homestead is positively and significantly affected by the respondent's education level, radio, phone, and bicycle ownership, walking distance in minutes from the farm to homestead, and whether the farmer wishes to obtain transportation service for maize. As expected, well-informed farmers and farmers who have farms farther away from homestead are more likely to pay more for the transportation service than their counterparts. Oxen ownership negatively affects farmers' WTP for transportation services, as oxen owners usually use carts for transportation.

6.2.2 | Demand for mechanization services

Agriculture is the mainstay of the economy in Malawi. It contributes to more than 64% of the total employment, 80% of total export, and 30% gross domestic product and will continue to contribute similarly (Malawi Government, 2016). However, agricultural production has to increase to benefit the people relying on it. One of the ways to increase agricultural production is to narrow the gap in agricultural productivity between men and women farmers through increased use of mechanization. In Malawi, women farmers are less productive than men farmers and exhibit lower technology adoption (Kilic et al., 2015; Tufa et al., 2022). Agriculture also needs transformation. Engagement of rural youth in agriculture and agricultural mechanization are among the agricultural transformation agenda of many African countries (MMP, 2018). WTP can also vary due to wealth, market access, and agroecology differences. Therefore, to formulate recommendations for sex, different age structures, and other important variables, we disaggregated WTP for the mechanization services by sex, age structure, wealth, market access, and agroecology. For instance, in a WTP study conducted for direct seeded rice with a drum seeder in Maharashtra, India, women had a higher WTP for the labor-saving attribute while men had a higher WTP for the increase in yield and reduction in seed rate of the drum seeder (Joshi et al., 2019).

Table 4 presents the average WTP for land preparation services estimated using the predicted values. The overall average WTP for land preparation services is 22,211 MWK per acre, which is 11% higher than the prevailing market rate (20,000 MWK per acre) for land preparation services using a tractor hire where a tractor is available (Table 4, second row). This result is in line with the result of the study conducted on demand for tractor-hire services among farm households in Burkina Faso (Hodjo et al., 2021), and Zambia and Zimbabwe (Ngoma et al., 2023). The authors found that the WTP for custom-hire tractor plowing was higher by 36% than the rental cost. Men are willing to pay 26% more for land preparation services than women. This result is similar to the results of several studies. For instance, in a WTP study conducted for direct-seeded rice with a drum seeder in Maharashtra, India, men had a higher WTP for the increase in yield and reduction in seed rate of the drum seeder (Joshi et al., 2019). The WTP for land preparation services increases with age, cultivated land size, farm asset value, and market access. High-market access areas exhibit a 9% higher WTP than low-market access areas.

TABLE 4 Predicted mean willingness to pay (MWK[a]/acre) for land preparation services (LPS) by sex of respondent, size of cultivated land, market access, and agroecology.

Items	Number of observations	Mean	Standard deviation
Overall	1504	22,211.06	4324.17
Sex			
Female	753	19,689.08	3342.02
Male	751	24,739.76	3672.08
Youth			
Young youth (<25 years)	151	19,834.86	3692.59
Old youth (25–34 years)	346	21,364.31	3781.12
Non-youth (>34 years)	1007	22,858.31	4414.37
Land size			
Total cultivated land <2 acres	687	19,689.72	3178.55
Total cultivated land ≥2 acres	817	24,331.21	4011.81
Farm asset (in MWK)			
1st quartile: ≤500	16	17,220.09	2703.62
2nd quartile: (500–22,500]	737	19,863.39	3184.68
3rd quartile: (22,500–56,200]	377	23,128.35	3204.39
4th quartile: >56,200	374	26,126.22	4063.19
Market access			
Low market access (≥2 h travel time)	861	21,391.63	3900.23
High market access (<2 h travel time)	643	23,308.31	4614.31
Agroecology			
Lowland (lower shire and lakeshore, mid and upper shire)	646	20,755.82	3793.02
Mid-elevation (includes highland)	858	23,306.73	4378.01

[a]1 USD during the survey period was MWK 790.

The demand curve in Figures 5–7 is constructed using the predicted values of the WTP for the mechanization services. The demand curves for mechanized land preparation service presented in Figure 5 decline with the service price for all categories—sex, cultivated land, market access, and agroecology—the demand curve is generally inelastic. The results show that 40% of female and 90% of male farmers are willing to pay the prevailing market rate (20,000 MWK per acre) for a 2WT-based land preparation service. This result shows a 50% gap between female and male farmers' demand for mechanized land preparation services between female and male farmers. The demand for land preparation services using a 2WT is higher in the high market access and mid-elevation agroecology. The results imply that institutions or private enterprises that promote mechanization services have to consider several factors that enhance the uptake of mechanization for land preparation services. For instance, subsidies can help narrow the gap between males and females in demand for mechanization services for land preparation.

Table 5 presents the average WTPs for 2WT-based maize shelling services estimated using the predicted values from the interval regression model. The overall average WTP for maize shelling service is 467 MWK per

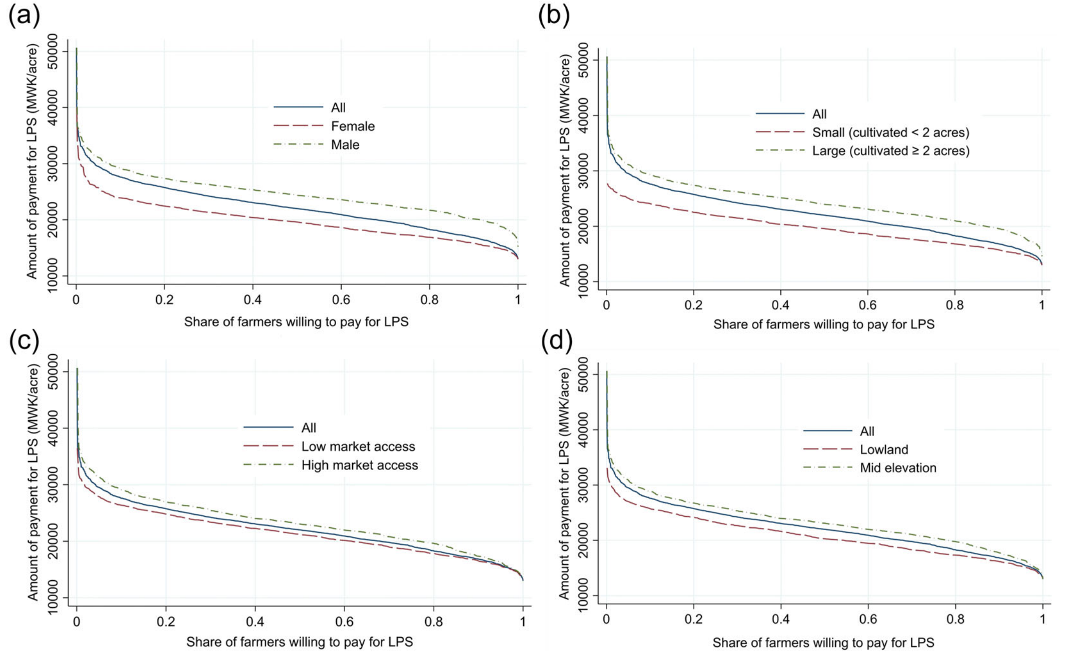

FIGURE 5 Demand curves for mechanized land preparation service (LPS) by gender (a), area of cultivated land (b), market access (c), and agroecology (d).

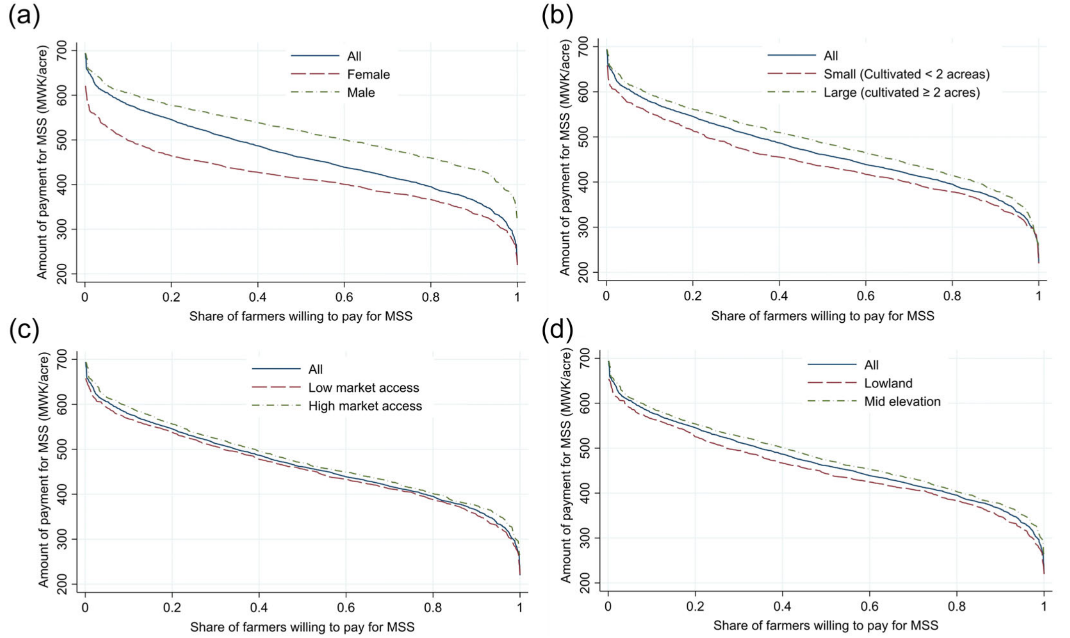

FIGURE 6 Demand for mechanized maize shelling service (MSS) by gender (a), area of cultivated land (b), market access (c), and agroecology (d).

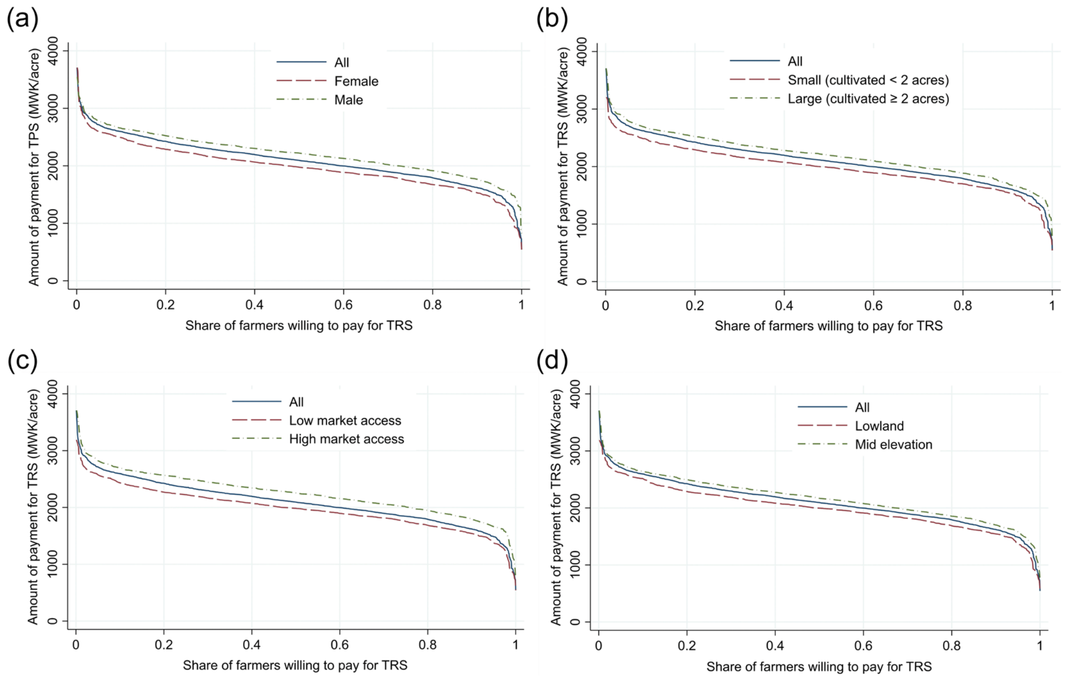

FIGURE 7 Demand for transport service (TRS) by gender (a), area of cultivated land (b), market access (c), and agroecology (d).

50 kg shelled grain, which is 33% higher than the prevailing market rate (350 MWK per 50 kg). A study conducted in Ghana also shows that farmers are willing to pay for maize shelling services (Houssou et al., 2016). The WTP for men for maize shelling services is 25% higher than for women. The demand curves for 2WT-based maize shelling services decline with the service price for all categories—sex, size of cultivated land, market access, and agroecology. In general, all the curves are inelastic (Figure 6). The demand curves' inelasticity shows the demand's low sensitivity to service charges.

The crops for which households want to have transportation services from the farm to the homestead are given in the last five rows of Table 2. Ninety-six percent of the sample farmers indicated they wished to obtain transport services for their maize from farm to homestead. A study in Ethiopia also shows that farmers are interested in obtaining transport services for their produce (Workneh et al., 2021). The proportions of farmers that stated the need for transportation services are meager for other crops could be due to the low production quantity.

Table 6 presents the WTP for transport service for agricultural produces using a 2WT-powered cart. The overall average of WTP for the transport service is 2096 MWK per trip which is 5% higher than the prevailing market rate (2000 MWK) and depends on the sex of the respondent, age group, and the size of cultivated land, market access, and agroecology. On average, the WTP values are less than the prevailing market price for women and those with low asset endowments, especially in lowland agroecology and low market access areas. The average value of WTP shows no demand for transportation services by female-headed households, households cultivating 1 acre or less, households in low market access areas, households in lowland agroecology, and households with farm assets worth less than 23,000 MWK.

Figure 7 shows that the demand curves for 2WT-powered transport services for agricultural produce decline with the service rates for all categories—sex, size of cultivated land, market access, and agroecology. The results show that 48% of women and 73% of men are willing to pay the prevailing market rate (2000 MWK per acre) for 2WT-based agricultural produce transportation from the farm to the homestead.

TABLE 5 Predicted mean WTP for maize shelling service (MSS) by sex of respondent, size of cultivated land, market access, and agroecology.

Items	Number of observations	Mean	Standard deviation
Overall	1504	467.27	83.01
Sex			
Female	753	416.18	64.11
Male	751	518.50	66.65
Youth			
Young youth (<25 years)	151	472.34	71.45
Old youth (25–34 years)	346	482.20	73.97
Non-youth (>34 years)	1007	461.38	86.85
Land size			
Total cultivated land: <2 acres	687	443.32	77.74
Total cultivated land: ≥2 acres	817	487.41	82.00
Market access			
Low market access: ≥2 h of travel time	861	459.89	82.18
High market access: <2 h of travel time	643	477.17	83.16
Agroecology			
Lowland (lower shire and lakeshore, mid and upper shire)	646	452.37	81.04
Mid-elevation (includes highland)	858	478.49	82.76
Farm asset (in MWK)			
1st quartile: ≤500	16	366.19	45.12
2nd quartile: (500–22,500]	737	430.09	69.31
3rd quartile: (22,500–56,200]	377	490.88	73.43
4th quartile: >56,200	374	521.07	78.33

Abbreviation: WTP, willingness to pay.

7 | CONCLUSIONS AND POLICY IMPLICATIONS

The main objective of this study is to investigate the labor constraints and the farmers' WTP for agricultural mechanization services such as land preparation, maize shelling, and transporting agricultural produce from farm to homestead. Family labor is the primary source of agricultural labor in Malawi. However, more than 40% of households use hired labor, implying a farm labor shortage. The results show that farmers face severe labor shortages for weeding, land preparation, and transporting agricultural produce. The WTP estimates also show that, on average, the WTP are 11%, 33%, and 5%, higher than prevailing market rates for mechanized land preparation, maize shelling, and transportation services. The WTPs vary by sex, age group, cultivated land size, farmer asset value, market access, and agroecology for all the services. Men are more likely to pay higher amounts for all the mechanization services than women. Men are willing to pay 26%, 25%, and 11% more than women for land preparation, maize shelling, and transportation services. Moreover, 40% of female and 90% of male farmers are willing to pay more than or equal to the prevailing market rate for mechanized land preparation services.

TABLE 6 Predicted mean WTP for transportation service (TRS) by sex of respondent, size of cultivated land, market access, and agroecology.

Items	Number of observations	Mean	Standard deviation
Overall	1504	2096.26	396.65
Sex			
Female	753	1977.62	392.04
Male	751	2215.21	364.54
Youth			
Young youth (<25 years)	151	2045.99	389.60
Old youth (25–34 years)	346	2111.00	387.08
Non-youth (>34 years)	1007	2098.73	400.73
Land size			
Total cultivated land: <2 acres	687	1979.49	376.17
Total cultivated land: ≥2 acres	817	2194.44	386.91
Market access			
Low market access: ≥2 h travel time	861	1981.50	372.44
High market access: <2 h travel time	643	2249.92	375.77
Agroecology			
Lowland (lower shire and lakeshore, mid and upper shire)	646	1995.18	388.51
Mid-elevation (includes highland)	858	2172.36	385.78
Farm asset (in MWK)			
1st quartile: ≤500	16	1725.25	383.92
2nd quartile: (500–22,500]	737	1946.74	365.54
3rd quartile: (22,500–56,200]	377	2193.45	328.39
4th quartile: >56,200	374	2308.78	388.28

Abbreviation: WTP, willingness to pay.

This study shows the high demand for mechanization services for land preparation, maize shelling, and transportation among men and women farmers, suggesting a need to promote 2WT-based affordable mechanization services. In Malawi, opportunities exist to promote hired agricultural mechanization services. First, the number of medium and large-scale farmers has been increasing from time to time which can be used to promote hire mechanization services. Second is the availability of government initiatives and plans to support and strengthen large commercial farmers that can serve as anchor farms for sounding communities. Promoting mechanization services by introducing low-cost small 2WT through medium-scale farmers who can provide the hiring service while operating their agricultural activities is also possible. However, more works are needed to evaluate the profitability and practicality of hire tractors service in the Malawian rural setup.

Finally, our study has a limitation. We used the stated-preference technique that can cause a hypothetical bias, and thus the estimates of the WTP for the mechanization services could be inflated compared to the actual amount. However, we informed the respondents that the amounts they pay for the services are based on their need for the services, affordability, and other necessary expenditures that they needed to prioritize. Besides, we informed the respondents about the unavailability of credit services; instead, they will pay for the services using their available money to reduce the hypothetical bias.

ACKNOWLEDGMENTS

This study is part of the project "Understanding and Enhancing Adoption of Conservation Agriculture in Smallholder Farming Systems of Southern Africa (ACASA)," grant P1925. The authors are grateful to the Norwegian Agency for International Development (NORAD) for the financial support of the ACASA project. The authors also thank Mr. Joseph Kanyamuka, Mrs. Joyce Mifonu, and Mr. Happy Banda for their time training enumerators and supervising the fieldwork and survey participants.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The study was approved by IITA Internal Review Board (IRB) and National Committee on Research Ethics in the Social Sciences and Humanities" of Malawi. Find attached the documents.

ORCID

Adane Tufa http://orcid.org/0000-0001-9801-6526
Julius Manda http://orcid.org/0000-0002-9599-5906

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1002/agr.21841.

REFERENCES

Adu-Baffour, F., Daum, T., & Birner, R. (2019). Can small farms benefit from big companies' initiatives to promote mechanization in Africa? A case study from Zambia. *Food Policy*, *84*(May 2018), 133–145. https://doi.org/10.1016/j.foodpol.2019.03.007

Aker, J. C., & Ksoll, C. (2016). Can mobile phones improve agricultural outcomes? Evidence from a randomized experiment in Niger. *Food Policy*, *60*, 44–51. https://doi.org/10.1016/j.foodpol.2015.03.006

Alwang, J., & Siegel, P. B. (1999). Labor shortages on small landholdings in Malawi: Implications for policy reforms. *World Development*, *27*(8), 1461–1475. https://doi.org/10.1016/S0305-750X(99)00065-0

Anseeuw, W., Jayne, T., Kachule, R., & Kotsopoulos, J. (2016). The quiet rise of medium-scale farms in Malawi. *Land*, *5*(3), 19. https://doi.org/10.3390/land5030019

Asenso-Okyere, K., Asante, F. A., Tarekegn, J., & Andam, K. S. (2011). A review of the economic impact of malaria in agricultural development. *Agricultural Economics*, *42*(3), 293–304. https://doi.org/10.1111/j.1574-0862.2010.00515.x

Asfaw, S., Pallante, G., & Palma, A. (2018). Diversification strategies and adaptation deficit: Evidence from rural communities in Niger. *World Development*, *101*, 219–234. https://doi.org/10.1016/j.worlddev.2017.09.004

Bandyopadhyay, R., Ortega-Beltran, A., Akande, A., Mutegi, C., Atehnkeng, J., Kaptoge, L., Senghor, A. L., Adhikari, B. N., & Cotty, P. J. (2016). Biological control of aflatoxins in Africa: Current status and potential challenges in the face of climate change. *World Mycotoxin Journal*, *9*(5), 771–789. https://doi.org/10.3920/WMJ2016.2130

Baudron, F., Misiko, M., Getnet, B., Nazare, R., Kaumbutho, P., Baudron, F., Misiko, M., Getnet, B., Nazare, R., & Sariah, J. (2020). A farm-level assessment of labor and mechanization in Eastern and Southern Africa.

Baudron, F., Misiko, M., Getnet, B., Nazare, R., Sariah, J., & Kaumbutho, P. (2019). A farm-level assessment of labor and mechanization in Eastern and Southern Africa. *Agronomy for Sustainable Development*, *39*(2), 17. https://doi.org/10.1007/s13593-019-0563-5

Baudron, F., Sims, B., Justice, S., Kahan, D. G., Rose, R., Mkomwa, S., Kaumbutho, P., Sariah, J., Nazare, R., Moges, G., & Gérard, B. (2015). Re-examining appropriate mechanization in Eastern and Southern Africa: Two-wheel tractors, conservation agriculture, and private sector involvement. *Food Security*, *7*(4), 889–904. https://doi.org/10.1007/s12571-015-0476-3

Belton, B., Win, M. T., Zhang, X., & Filipski, M. (2021). The rapid rise of agricultural mechanization in Myanmar. *Food Policy*, *101*(April), 102095. https://doi.org/10.1016/j.foodpol.2021.102095

Benin, S. (2015). Impact of Ghana's agricultural mechanization services center program. *Agricultural Economics*, *46*, 103–117. https://doi.org/10.1111/agec.12201

Benson, T., Mabiso, A., & Nankhuni, F. (2016). Detailed crop suitability maps and agricultural zonation scheme for Malawi: Spatial information for agricultural planning purposes (No. 17; Issue June).

Bignami-Van Assche, S., Van Assche, A., Anglewicz, P., Fleming, P., & van de Ruit, C. (2011). HIV/AIDS and time allocation in rural Malawi. *Demographic Research*, *24*(27), 671–708. https://doi.org/10.4054/DemRes.2011.24.27

Bishop-Sambrook, C. (2005). Contribution of farm power to smallholder livelihoods in sub-Saharan Africa. Agricultural and dood engineering technical report no. 2.

Budhathoki, N. K., Lassa, J. A., Pun, S., & Zander, K. K. (2019). Farmers' interest and willingness-to-pay for index-based crop insurance in the lowlands of Nepal. *Land Use Policy*, *85*(October 2018), 1–10. https://doi.org/10.1016/j.landusepol.2019.03.029

Daum, T., & Birner, R. (2017). The neglected governance challenges of agricultural mechanisation in Africa—Insights from Ghana. *Food Security*, *9*(5), 959–979. https://doi.org/10.1007/s12571-017-0716-9

Daum, T., & Birner, R. (2020). Agricultural mechanization in Africa: Myths, realities and an emerging research agenda. *Global Food Security*, *26*(May), 100393. https://doi.org/10.1016/j.gfs.2020.100393

Diao, X., Cossar, F., Houssou, N., & Kolavalli, S. (2014). Mechanization in Ghana: Emerging demand, and the search for alternative supply models. *Food Policy*, *48*, 168–181. https://doi.org/10.1016/j.foodpol.2014.05.013

FAO. (2023). Food and Agricultural Organization (FAO) of the United Nations crop production database. Available at: http://www.fao.org/faostat/en/#data/QC

FAO-AUC. (2018). Sustainable agricultural mechanization: A framework for Africa. Addis Ababa.

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries : A survey. *Economic Development and Cultural Change*, *33*(2), 255–298.

Fu, X., & Akter, S. (2016). The impact of mobile phone technology on agricultural extension services delivery: Evidence from India. *The Journal of Development Studies*, *52*(11), 1561–1576. https://doi.org/10.1080/00220388.2016.1146700

Giller, K. E., Murwira, M. S., Dhliwayo, D. K. C., Mafongoya, P. L., & Mpepereki, S. (2011). Soyabeans and sustainable agriculture in Southern Africa. *International Journal of Agricultural Sustainability*, *9*(1), 50–58. https://doi.org/10.3763/ijas.2010.0548

Guo, X., Liu, H., Mao, X., Jin, J., Chen, D., & Cheng, S. (2014). Willingness to pay for renewable electricity: A contingent valuation study in Beijing, China. *Energy Policy*, *68*, 340–347. https://doi.org/10.1016/j.enpol.2013.11.032

Hamilton, S. F., Richards, T. J., Shafran, A. P., & Vasilaky, K. N. (2022). Farm labor productivity and the impact of mechanization. *American Journal of Agricultural Economics*, *104*(4), 1435–1459. https://doi.org/10.1111/ajae.12273

Hanemann, M., Loomis, J., & Kanninen, B. (1991). Statistical efficiency of double-bounded dichotomous choice contingent valuation. *American Journal of Agricultural Economics*, *73*(4), 1255–1263. https://doi.org/10.2307/1242453

Henriksson, R., Vincent, K., Archer, E., & Jewitt, G. (2021). Understanding gender differences in availability, accessibility and use of climate information among smallholder farmers in Malawi. *Climate and Development*, *13*(6), 503–514. https://doi.org/10.1080/17565529.2020.1806777

Hodjo, M., Schwab, B., Kere, M., Millogo, V., & Srivastava, A. (2021). Demand for agricultural mechanization in the Hauts-Basin region in Burkina Faso. *Journal of Agribusiness*, *39*(1), 39–64.

Houssou, N., Aboagye, P. O., & Kolavalli, S. (2016). *Meeting Ghanaian farmers' demand for a full range of mechanization services* (Issue September). http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/130752

Houssou, N., Diao, X., Asante-Addo, C., & Kolavalli, S. (2017). Development of the capital service market in agriculture: The emergence of tractor-hire services in Ghana. *The Journal of Developing Areas*, *51*(1), 241–257. https://doi.org/10.1353/jda.2017.0014

Huan, M., Dong, F., & Chi, L. (2022). Mechanization services, factor allocation, and farm efficiency: Evidence from China†. *Review of Development Economics*, *26*(3), 1618–1639. https://doi.org/10.1111/rode.12892

Jaleta, M., Krivokapic-skoko, B., Baudron, F., & Erenstein, O. (2014). Drivers of agricultural mechanization and mechanized conservation agriculture: Synthesis from experience of successful countries. 1–28.

Jiang, D., Bai, D., Yin, Z., & Fan, G. (2019). Willingness to pay for enhanced water security in a rapidly developing shale gas region in China. *Water (Switzerland)*, *11*(9), 1–14. https://doi.org/10.3390/w11091888

Joshi, P. K., Khan, M. T., & Kishore, A. (2019). Heterogeneity in male and female farmers' preference for a profit-enhancing and labor-saving technology: The case of direct-seeded rice (DSR) in India. *Canadian Journal of Agricultural Economics/ Revue canadienne d'agroeconomie*, *67*(3), 303–320. https://doi.org/10.1111/cjag.12205

Kilic, T., Palacios-López, A., & Goldstein, M. (2015). Caught in a productivity trap: A distributional perspective on gender differences in Malawian agriculture. *World development*, *70*, 416–463. https://doi.org/10.1016/j.worlddev.2014.06.017

Kirui, O. K., & Braun, J. V (2018). Mechanization in African agriculture: A continental overview on patterns and dynamics (Issue 169). https://doi.org/10.2139/ssrn.3194466

Kotu, B. H., Mutungi, C., Manda, J., & Gaspar, A. (2023). Farmers' willingness to invest in mechanized maize shelling and potential financial benefits: Evidence from Tanzania. https://doi.org/10.1002/agr.21801

Kumwenda, I., Nyekanyeka, A., Gausi, U., Phiri, B., Kamwendo, P., Msokera, T., & Kadazi, F. (2020). Farm mechanization and potential role of robotics in Malawi. *Proceedings of the 3rd INFER Symposium on Agri-Tech Economics for Sustainable Futures*, *September*.

Leonardo, W. J., van de Ven, G. W. J., Udo, H., Kanellopoulos, A., Sitoe, A., & Giller, K. E. (2015). Labour not land constrains agricultural production and food self-sufficiency in maize-based smallholder farming systems in Mozambique. *Food Security*, *7*(4), 857–874. https://doi.org/10.1007/s12571-015-0480-7

Loomis, J. B. (2014). 2013 WAEA keynote address: Strategies for overcoming hypothetical bias in stated preference surveys. Published by: Western Agricultural Economics Association 2013 WAEA Keynote Address: Strategies for Overcoming Hypothetic Bias in Stated Preference Surve. 39(1), 34–46.

Van Loon, J., Woltering, L., Krupnik, T. J., Baudron, F., Boa, M., & Govaerts, B. (2020). Scaling agricultural mechanization services in smallholder farming systems: Case studies from sub-Saharan Africa, South Asia, and Latin America. *Agricultural Systems*, *180*(December 2018), 102792. https://doi.org/10.1016/j.agsy.2020.102792

Lopez-Feldman, A. (2012). Introduction to contingent valuation using Stata. (Issue MPRA Paper No. 41018).

Ma, W., Renwick, A., & Grafton, Q. (2018). Farm machinery use, off-farm employment and farm performance in China. *Australian Journal of Agricultural and Resource Economics*, *62*(2), 279–298. https://doi.org/10.1111/1467-8489.12249

Ma, W., Zhu, Z., & Zhou, X. (2021). Agricultural mechanization and cropland abandonment in rural China. *Applied Economics Letters*, *29*(6), 526–533. https://doi.org/10.1080/13504851.2021.1875113

Malawi Government. (2016). *National agriculture policy*. Ministry of Agriculture, Irrigation and Water Development.

Mbalule, J. C. (2000). The use of animal power for weed control in Malawi. In Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, The Netherlands. ISBN 92-9081-136-6. (Vol. 51, Issue Figure 1).

Mekonnen, A., Gebreegziabher, Z., Beyene, A. D., & Hagos, F. (2020). Valuation of access to irrigation water in rural Ethiopia: Application of choice experiment and contingent valuation methods. *Water Economics and Policy*, *06*(1), 1950007. https://doi.org/10.1142/S2382624X19500073

MMP. (2018). Mechanized: Transforming Africa's agriculture value chains. Malabo Montpellier Panel (MMP), 55 pages. http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/132766

Mrema, G. C., Baker, D., & Kahan, D. (2008). Agricultural mechanization in sub-Saharan Africa: Time for a new look. In Food and Agriculture Organization of the United Nations, Rome.

Murray, U., Gebremedhin, Z., Brychkova, G., & Spillane, C. (2016). Smallholder farmers and climate smart agriculture: Technology and labor-productivity constraints amongst women smallholders in Malawi. *Gender, Technology and Development*, *20*(2), 117–148. https://doi.org/10.1177/0971852416640639

Ngoma, H., Marenya, P., Tufa, A., Alene, A., Chipindu, L., Matin, M. A., Thierfelder, C., & Chikoye, D. (2023). Smallholder farmers' willingness to pay for two-wheel tractor-based mechanisation services in Zambia and Zimbabwe. *Journal of International Development*, *May*, *2022*, 1–22. https://doi.org/10.1002/jid.3767

Nguyen, H. Q., & Warr, P. (2020). Land consolidation as technical change: Economic impacts in rural. *World Development*, *127*, 104750. https://doi.org/10.1016/j.worlddev.2019.104750

Nguyen, H. T., Ariyawardana, A., & Ratnasiri, S. (2020). Forest plantation owners' willingness to pay for hybrid nursery stock: The case of Acacia hybrids in Central Vietnam. *Forest Policy and Economics*, *116*(February 2019), 102184. https://doi.org/10.1016/j.forpol.2020.102184

Nxumalo, K. K. S., Antwi, M. A., & Rubhara, T. T. (2020). Determinants of use of farm mechanization services in emerging farmers, North West Province, South Africa. *Journal of Agribusiness and Rural Development*, *56*(2), 221–228. https://doi.org/10.17306/j.jard.2020.01316

Olasehinde-Williams, G., Adedoyin, F. F., & Bekun, F. V. (2020). Pathway to achieving sustainable food security in Sub-Saharan Africa: The role of agricultural mechanization. *Journal of Labor and Society*, *23*(3), 349–366. https://doi.org/10.1111/wusa.12483

Pakhtigian, E. L., & Jeuland, M. (2019). Valuing the environmental costs of local development: Evidence from households in Western Nepal. *Ecological Economics*, *158*, 158–167. https://doi.org/10.1016/j.ecolecon.2018.12.021

Paudel, G. P., KC, D. B., Rahut, D. B., Khanal, N. P., Justice, S. E., & McDonald, A. J. (2019). Smallholder farmers' willingness to pay for scale-appropriate farm mechanization: Evidence from the mid-hills of Nepal. *Technology in Society*, *59*(July), 101196. https://doi.org/10.1016/j.techsoc.2019.101196

Pingali, P. (2007). Chapter 54 agricultural mechanization: Adoption patterns and economic impact. *Handbook of Agricultural Economics*, *3*(06), 2779–2805. https://doi.org/10.1016/S1574-0072(06)03054-4

Sheahan, M., & Barrett, C. B. (2017). Ten striking facts about agricultural input use in Sub-Saharan Africa. *Food Policy*, *67*, 12–25. https://doi.org/10.1016/j.foodpol.2016.09.010

Sims, B., & Heney, J. (2017). Promoting smallholder adoption of conservation agriculture through mechanization services. *Agriculture (Switzerland)*, *7*(8), 1–22. https://doi.org/10.3390/agriculture7080064

Sims, B., & Kenzle, J. (2006). Farm power and mechnization for small farms in sub-Saharan Africa.

Sims, B., & Kienzle, J. (2016). Making mechanization accessible to smallholder farmers in sub-Saharan Africa. *Environments-MDPI*, *3*(2), 1–18. https://doi.org/10.3390/environments3020011

Takane, T. (2008). Labor use in smallholder agriculture in Malawi: Six village case studies. *African Study Monographs*, *29*(4), 183–200.

Takele, A., & Selassie, Y. G. (2018). Socio-economic analysis of conditions for adoption of tractor hiring services among smallholder farmers, Northwestern Ethiopia. *Cogent Food & Agriculture*, *4*(1), 1453978. https://doi.org/10.1080/23311932.2018.1453978

Takeshima, H. (2015). Drivers of growth in agricultural returns to scale: The hiring in of tractor services in the Terai of Nepal. *IFPRI-Discussion Papers*, No.01476, vi+32 pp. http://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/129749/filename/129960.pdf

Takeshima, H. (2017). Custom-hired tractor services and returns to scale in smallholder agriculture: A production function approach. *Agricultural Economics*, *48*(3), 363–372. https://doi.org/10.1111/agec.12339

Takeshima, H. (2018). Mechanize or exit farming? Multiple-treatment-effects model and external validity of adoption impacts of mechanization among Nepalese smallholders. *Review of Development Economics*, *22*(4), 1620–1641. https://doi.org/10.1111/rode.12407

Tozer, P. R., Galinato, S. P., Ross, C. F., Miles, C. A., & McCluskey, J. J. (2015). Sensory analysis and willingness to pay for craft cider. *Journal of Wine Economics*, *10*(3), 314–328. https://doi.org/10.1017/jwe.2015.30

Tsusaka, T. W., Twanje, G. H., Msere, H. W., Mwakasungula, B. M., Gondwe, L. K., Madzonga, O., Dambuleni, K., & Okori, P. (2017). Ex-ante assessment of adoption of small-scale post-harvest mechanization: The case of groundnut producers in Malawi. *Socioeconomics Discussion Paper Series-International Crops Reearch Institute for the Semi-Arid Tropics (ICRISAT)*, *44*, 27.

Tufa, A. H., Alene, A., Cole, S. M., Manda, J., Feleke, S., Abdoulaye, T., Chikoye, D., & Manyong, V. (2022). Gender differences in agricultural technology adoption and crop productivity: Evidence from Malawi. *World Development*, *159*(15), 1–15. https://doi.org/10.1016/j.worlddev.2022.106027

Tufa, A. H., Alene, A. D., Manda, J., Akinwale, M. G., Chikoye, D., Feleke, S., Wossen, T., & Manyong, V. (2019). The productivity and income effects of adoption of improved soybean varieties and agronomic practices in Malawi. *World Development*, *124*, 104631. https://doi.org/10.1016/j.worlddev.2019.104631

Vemireddy, V., & Choudhary, A. (2021). A systematic review of labor-saving technologies: Implications for women in agriculture. *Global Food Security*, *29*(April), 100541. https://doi.org/10.1016/j.gfs.2021.100541

Wodon, Q., & Beegle, K. (2006). Labor shortages despite underemployment? Seasonality in time use in Malawi. In World Bank Working Paper (Issue 73. 97–116).

Workneh, W. A., Ujiie, K., & Matsushita, S. (2021). Farmers' agricultural tractor preferences in Ethiopia: A choice experiment approach. *Discover Sustainability*, *2*(1), 11. https://doi.org/10.1007/s43621-021-00021-2

World Bank. (2012). World development report 2012: Gender equality and development, The State of the Middle East. The World Bank. https://doi.org/10.4324/9781315065977-44

Zheng, H., Ma, W., Guo, Y., & Zhou, X. (2022). Interactive relationship between non-farm employment and mechanization service expenditure in rural China. *China Agricultural Economic Review*, *14*(1), 84–105. https://doi.org/10.1108/CAER-10-2020-0251

Zheng, H., Ma, W., & Zhou, X. (2021). Renting-in cropland, machinery use intensity, and land productivity in rural China. *Applied Economics*, *53*(47), 5503–5517. https://doi.org/10.1080/00036846.2021.1923642

Zhou, X., & Ma, W. (2021). Does agricultural mechanization reduce vulnerable employment? Evidence from cross-country panel data. *Economics Bulletin*, *41*(2), 294–303.

Zhou, X., & Ma, W. (2022). Agricultural mechanization and land productivity in China. *International Journal of Sustainable Development & World Ecology*, *29*(6), 530–542. https://doi.org/10.1080/13504509.2022.2051638

Zhou, X., Ma, W., & Li, G. (2018). Draft animals, farm machines and sustainable agricultural production: Insight from China. *Sustainability (Switzerland)*, *10*(9), 1–16. https://doi.org/10.3390/su10093015

Zhou, X., Ma, W., Li, G., & Qiu, H. (2020). Farm machinery use and maize yields in China: An analysis accounting for selection bias and heterogeneity. *Australian Journal of Agricultural and Resource Economics*, *64*(4), 1282–1307. https://doi.org/10.1111/1467-8489.12395

How to cite this article: Tufa, A., Alene, A., Ngoma, H., Marenya, P., Manda, J., Matin, M. A., Thierfelder, C., & Chikoye, D. (2023). Willingness to pay for agricultural mechanization services by smallholder farmers in Malawi. *Agribusiness*, 1–29. https://doi.org/10.1002/agr.21841

APPENDIX

Table A1, Tables A2a-A2c

TABLE A1 Description of study districts.

Agroecology	District	Prevalence of CA	Market access
Lower shire valley (<250 m asl) and lakeshore, mid and upper shire (200–760 m asl)	Nsanje	High	Low
	Balaka	High	High
	Nkhotakota	High	Low
Mid-elevation upland plateau (760–1300 m asl) and highlands (>1300 m asl)	Dowa	High	High
	Rumphi	High	Low
	Chitipa	High	Low
	Zomba	High	High

Abbreviation: asl, above sea level.

TABLE A2a Bid structure and responses of elicitation of willingness to pay for land preparation (MWK per acre) using 2-WT pulled plow/ripper.

	Bid amount in MWK			% response[a]			
	Initial	Follow-up for "no" response	Follow-up for "yes" response	NN response	NY response	YY response	YN response
Bid 1	17,625	16,500	18,750	3.17	0.26	3.57	0.73
Bid 2	18,750	17,625	19,875	3.44	0.20	3.37	1.46
Bid 3	19,875	18,750	21,000	3.44	0.73	2.65	1.46
Bid 4	21,000	19,875	22,125	3.24	0.99	3.24	0.93
Bid 5	22,125	21,000	23,250	3.57	0.79	2.98	1.06
Bid 6	23,250	22,125	24,375	4.37	0.53	2.71	0.79

TABLE A2a (Continued)

	Bid amount in MWK			% response[a]			
	Initial	Follow-up for "no" response	Follow-up for "yes" response	NN response	NY response	YY response	YN response
Bid 7	24,375	23,250	25,500	4.37	0.40	2.18	1.59
Bid 8	25,500	24,375	26,625	4.30	0.20	2.25	1.06
Bid 9	26,625	25,500	27,750	3.64	0.20	2.58	2.12
Bid 10	27,750	26,625	28,875	5.75	0.60	1.65	1.06
Bid 11	28,875	27,750	30,000	4.03	0.46	1.85	1.72
Bid 12	30,000	28,875	31,125	4.56	0.79	2.12	0.86

[a]NN represents "no" response to the initial bid and "no" response for the follow-up bid; NY represents "no" response to the initial bid and "yes" response for the follow-up bid; YY represents "yes" response to the initial bid and "yes" response for the follow-up bid; YN represents "yes" response to the initial bid and "no" response for the follow-up bid.

TABLE A2b Bid structure and responses of elicitation of willingness to pay for maize shelling service (MWK per 50 kg grain) using 2WT operated sheller.

	Bid in MWK			% of response[a]			
	Initial	Follow-up for "no" response	Follow-up for "yes" response	NN response	NY response	YY response	YN response
Bid 1	250	200	300	2.25	0.46	3.77	1.19
Bid 2	300	250	350	2.78	0.60	3.37	1.46
Bid 3	350	300	400	2.78	1.06	2.65	1.72
Bid 4	400	350	450	3.11	0.86	3.31	1.26
Bid 5	450	400	500	3.70	0.73	2.91	1.26
Bid 6	500	450	550	3.51	1.32	2.71	0.73
Bid 7	550	500	600	3.77	0.46	2.31	2.12
Bid 8	600	550	650	4.17	0.60	1.98	1.19
Bid 9	650	600	700	4.17	0.53	1.98	1.85
Bid 10	700	650	750	5.09	0.99	1.52	1.26
Bid 11	750	700	800	5.49	0.53	0.93	1.32
Bid 12	800	750	850	4.63	1.06	1.59	0.99

[a]NN represents "no" response to the initial bid and "no" response for the follow-up bid; NY represents "no" response to the initial bid and "yes" response for the follow-up bid; YY represents "yes" response to the initial bid and "yes" response for the follow-up bid; YN represents "yes" response to the initial bid and "no" response for the follow-up bid.

TABLE A2c Bid structure and response for elicitation of willingness to pay for transporting service per full cart of maize.

	Bid in MWK			% of response[a]			
	Initial	Follow-up for "no" response	Follow-up for "yes" response	NN response	NY response	YY response	YN response
Bid 1	1400	1300	1500	2.31	0.33	4.56	0.53
Bid 2	1500	1400	1600	2.71	0.07	4.50	0.99
Bid 3	1600	1500	1700	2.45	0.46	3.90	1.46
Bid 4	1700	1600	1800	2.84	0.20	4.30	1.26
Bid 5	1800	1700	1900	2.98	0.40	4.17	1.06
Bid 6	1900	1800	2000	3.04	0.20	3.84	1.12
Bid 7	2000	1900	2100	3.17	0.26	3.97	1.19
Bid 8	2100	2000	2200	2.84	0.60	3.31	1.06
Bid 9	2200	2100	2300	3.31	0.26	4.10	0.99
Bid 10	2300	2200	2400	3.84	0.40	3.44	1.19
Bid 11	2400	2300	2500	3.37	0.26	3.77	0.66
Bid 12	2500	2400	2600	3.04	0.26	3.84	1.19

[a]NN represents "no" response to the initial bid and "no" response for the follow-up bid; NY represents "no" response to the initial bid and "yes" response for the follow-up bid; YY represents "yes" response to the initial bid and "yes" response for the follow-up bid; YN represents "yes" response to the initial bid and "no" response for the follow-up bid.

AUTHOR BIOGRAPHIES

Adane Tufa is an agricultural economist working for the International Institute of Tropical Agriculture (IITA) in Malawi. He holds a BSc degree in animal sciences from Alemaya University, Ethiopia; an MSc in agricultural economics from G. B. Pant University of Agriculture and Technology, India; and a PhD in agricultural economics from Wageningen University, Netherlands. His research areas cover adoption and impacts of climate-smart agricultural technologies, gender, youth, and value chain analysis. He has authored and coauthored more than 20 peer-reviewed publications. He was an assistant professor at Hawassa University in Ethiopia before he joined IITA in July 2015.

Arega Alene is a senior agricultural economist with the International Institute of Tropical Agriculture (IITA) based in Malawi and leads research programs on impact evaluation and strategic analysis of R&D investments and priorities. He joined IITA in 2003 as a postdoctoral fellow with the impact, policy, and systems analysis program. He has authored (or coauthored) over 60 peer-reviewed articles in agricultural economics and policy journals. An Ethiopian national, Dr. Alene holds a BSc in agricultural economics (with distinction) from Alemaya University of Agriculture in Ethiopia and a PhD in agricultural economics from the University of Pretoria in South Africa. His research interests include R&D impact evaluation, productivity analysis, agricultural policy, and international development.

Hambulo Ngoma is an agricultural economist at CIMMYT's Southern Africa Regional Office based in Harare, Zimbabwe. He holds a PhD in development economics from the School of Economics and Business, Norwegian University of Life Sciences, an MSc in applied and agricultural economics from the University of Malawi, and a BSc in agricultural economics from University of Zambia. Ngoma's workspaces span impact assessment, natural resource management, and climate change. His current research assesses adoption, scaling, and impacts of sustainable agricultural intensification practices in Southern Africa. He is formerly a postdoctoral associate of the Department of Agricultural, Food and Resources Economics of Michigan State University, and research fellow with the Indaba Agricultural Policy Research Institute (IAPRI) in Lusaka, Zambia.

Paswel Marenya is a senior scientist at the International Maize and Wheat Improvement Center (CIMMYT). Marenya holds an MSc in applied economics and a PhD in natural resources policy and management from Cornell University. His research focuses on maize-based smallholder systems in eastern and southern Africa and analyzing pathways and impacts of technology adoption within the framework of sustainable intensification. He has published research on farmer policy, farmer preferences for supporting technology adoption among maize farmers in Malawi, soil quality mediated returns to fertilizer, and the macro impacts of disease tolerant varieties. He is working on understanding the most effective investment priorities for strengthening climate-smart agriculture in eastern and southern Africa.

Julius Manda is an agricultural economist at the International Institute of Tropical Agriculture (IITA), based in Arusha, Tanzania. He received his MSc and PhD in development and agricultural economics from Wageningen University and Research Centre, The Netherlands. His research primarily focuses on adoption and impacts of new agricultural technologies on smallholder farmers' welfare, value chain analysis, and economic analysis of sustainable intensification practices. He was a senior planner in the ministry of health in Zambia before joining IITA in 2012 as an associate professional officer-agricultural economist.

Md Abdul Matin is a mechanization specialist at the International Maize and Wheat Improvement Center (CIMMYT), SARO, Zimbabwe. He has over 20 years of R&D experience in design, development, assessment, and commercialization of farm machinery for smallholder farmers. He completed his BSc Agri. Eng and MS in Farm power & machinery degrees from the Bangladesh Agricultural University and a PhD from the Agricultural Machinery Research & Design Centre, University of South Australia, Adelaide, Australia. Matin has intensive experience working with national agricultural research institutes, other government, and private sector partners (including manufacturers) in the mechanization value and supply chains.

Christian Thierfelder is a principal cropping systems agronomist working with CIMMYT's Sustainable Agrifood Systems program. Since 2009, Dr. Thierfelder has led CIMMYT's conservation agriculture systems research in Southern Africa with the aim to adapt conservation agriculture systems to the needs and environments of smallholder farmers. His research covers Malawi, Zambia, and Zimbabwe, and to a lesser extent Namibia. Thierfelder works with a wide range of national and international partners from research and extension in all target countries. Capacity building is a central part of his work, including farmers, extension officers, national researchers, and university students from all degree levels.

David Chikoye is the director for the Regional Hub for southern Africa and the Plant Production and Health Management thematic area. Dr. Chikoye obtained his BSc from the University of Zambia, Zambia; an MSc from the University of Manitoba, Canada; and a PhD from the University of Guelph, Canada. His professional background is research on weed management in the tropics. His main research interests include assessing the response of weed seedbanks to control options, promoting the use of cover crops for weed and fertility management, integrating the use of herbicides in smallholder farms, evaluating competition between improved crop varieties and weeds under different input levels, and promoting the uptake of improved weed, crop, and natural resource management options by farmers. Other experiences include leadership of a large, multidisciplinary research project focusing on demand-driven, participatory research utilizing bottom-up livelihoods approaches. Before joining IITA, he was a postdoctoral fellow at the University of Guelph and a lecturer at the University of Zambia.