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# Mobile phone use and agricultural productivity among female smallholder farmers in Tanzania

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Evidence shows that mobile phones can improve agricultural productivity in Sub-Saharan Africa, yet few studies examine gender disparities in mobile phone ownership and use, and how they relate to the gender gap in agricultural productivity. This research gathers survey data on 279 male and female household heads in four villages in Iringa, Tanzania, and investigates the associations between gender, agricultural productivity, and phone ownership and use. Our study finds that many farmers use phones to conduct agricultural activities, with virtually all male respondents using their privately-owned phones compared to only two-thirds of female respondents. Moreover, many women have positive perceptions and trust in the benefits of using phones for agricultural activities. Lastly, phone owners have higher self-reported maize yields compared to non–phone owners. Our results suggest that mobile phones may be a valuable tool in bridging the agricultural gender gap.

**Keywords:** Africa, Agriculture, Gender, Mobile Phones, Tanzania, Women.

## Introduction

Women play an important role in the agricultural sector in Sub-Saharan Africa (FAO 2011; UN Women 2015; Doss et al. 2018). However, there is a gender gap in agricultural productivity (UN Women 2015). While ownership and use of mobile phones can improve agricultural productivity at multiple scales (Chavula 2014; Aker et al. 2016; Sekabira and Qaim 2017; Asongu and Boateng 2018; Issahaku et al. 2018; Quandt et al. 2020), there is still a disparity in phone ownership and use between men and women (GSMA 2017). Against this backdrop, it is critical to investigate the associations between gender, agricultural productivity, and phone ownership and use in order to design more effective technology-focused interventions and policies, which can improve agricultural productivity and promote women's empowerment. Drawing on empirical data from Iringa, Tanzania, this paper seeks to understand phone ownership and use among female smallholder farmers by asking three research questions: (RQ1) To what extent do male and female farmers use mobile phones for agricultural purposes, and whose phones do they use?; (RQ2) What is the relationship between female farmers' ownership of phones and their perceptions of the benefits of phones for agriculture?; and (RQ3) How does the agricultural yield of phone owners compare to the yield of non–phone owners?

### *Women and agriculture*

Although women play a major role in the global agricultural sector, they usually register lower yields on their farms than men (Agarwal 2015; Khachaturyan and Peterson 2018), and they often have limited access to land, information, technology, capital, credit, and other inputs (FAO 2011). According to a United Nations study, the gender gap in agricultural productivity ranges from 4 to 25 percent, depending on the country and the crop (UN Women 2015). This study also found that gender gaps stem from women's limited access to information and technology, among other factors (Huyer 2016; Sheahan and Barrett 2014). Women's limited access to agricultural technology has also been cited as an important constraint to improved agricultural productivity (Theis et al. 2018; Quisumbing 1995). Moreover, legal systems, gender norms, and inheritance systems may significantly hinder women from accessing land (Doss et al. 2018), and land controlled by women is often of poorer quality and smaller in size than farm plots controlled by men (FAO 2014; Perez et al. 2015).

The context is similar in Tanzania, with women facing technological, economic, and social constraints to improved agricultural productivity. In Tanzania, for instance, women-managed farms are on average about 0.6 hectares, while the average for all farm plots is more than one hectare (UN Women 2015).The agricultural sector in Tanzania accounts for more than 25 percent of the country's GDP and employs 80 percent of the work-

force (Martin and Kahamba 2017). The FAO (2011) reports that women make up 42.2 percent of the global agricultural labor force, and, in Tanzania, they provide just over 50 percent of the labor for household crop production. Unequal ownership of land is also a problem in Tanzania, where only 16 percent of land is legally owned by women, in contrast to 44 percent owned by men, and 39 percent jointly owned (Doss et al. 2015; Kieran et al. 2015). However, it has been proposed that empowering women may increase agricultural productivity and close the agricultural gender gap (FAO 2014). In Tanzania alone, bridging the agricultural gender gap could increase the agricultural GDP by $85 million, increase the total GDP by $105 million, and lift 80,000 people out of poverty (UN Women 2015).

### *Mobile phones for improved agricultural productivity*

A growing body of literature supports the idea that the use of Information and Communication Technologies (ICTs) in the agricultural sector can improve agricultural production, with a rich body of work specifically focusing on the benefits of mobile phones (Ogutu et al. 2014; Strong et al. 2014; Tata and McNamara 2018; Aker and Ksoll 2016; Fu and Akter 2016; Quandt et al. 2020). However, there is mixed empirical evidence linking mobile phone use and agricultural productivity, with some studies showing positive correlations and others yielding more neutral results (Camacho and Conover 2011; Chavula 2014; Fafchamps and Minten 2012; Issahaku et al. 2018; Sekabira and Qaim 2017). For example, Quandt et al. (2020) found positive associations between phone use and reported maize yield, when phone use is measured by use of phones for a variety of agricultural activities. However, the same study found mixed results when phone use is measured by number of contacts, calls, and SMS sent in the last 24 hours.

Despite the mixed nature of these results, several studies have identified possible mechanisms behind the positive relationships between phone use and increased agricultural productivity. These mechanisms include the use of mobile phones for connecting farmers to buyers (Sife et al. 2010), acquiring agricultural inputs (Martin and Abbott 2011), reducing transaction costs and time associated with agricultural activities (Asif et al. 2017; Mwantimwa 2017), and accessing agricultural information (Aker et al. 2016; Dannenberg and Lake 2013). For example, GSMA (2019) found that mobile phones yield efficiency gains in the agricultural sector, by addressing information gaps for farmers and enabling more efficient interactions between key players in the value chain. Mobile phones can also improve coordination of agricultural input and output supply chains and facilitate farmers' access to financial services (Aker et al. 2016). Lastly, mobile phones can link smallholder farmers to urban and regional product markets (Krone et al. 2014).

However, impact studies on mobile phones often do not distinguish between user groups, while use and impacts of mobile phones can vary considerably between different groups (Steinfield et al. 2015; Baumüller 2018). Indeed, an exclusive focus on averages can conceal how the impact of mobile phones may differ (Aker et al. 2016), for example, between genders or even among women. In the context of Tanzania, research on mobile phones in agriculture does not usually differentiate between groups of farmers (Sife et al. 2010; Nyamba and Mlozi 2012; Tumbo et al. 2012; Temba et al. 2016). In light of these knowledge gaps, it has been argued that future research on mobile phones for smallholder farmers should differentiate between user groups (Baumüller 2018). This paper aims to contribute to enhancing our understanding of the differential impacts and benefits of mobile phones by exploring gendered differences through the three major research questions presented above.

### *Women and mobile phones*

In 2016, women in Sub-Saharan Africa were 17 percent less likely to own a mobile phone than men (GSMA 2017). Moreover, women often experience lower access to phones due to their lack of key resources such as money, electricity, and phone credit (Summers 2019), as well as due to social and cultural constraints (FAO 2018). Despite these constraints, phones can help women to gain more independence (Onyejekwe 2011) and greater participation in household decision-making (Hoan et al. 2016). The adoption of mobile phones can also challenge and redefine traditional gender norms and customs (Chib and Hsueh-Hua Chen 2011; Tenhunen 2008). However, some researchers cast doubts on these positive predictions and find that the use of mobile phones can reinforce existing gender inequalities. Focusing on Maasai women in Tanzania, Summers et al. (2020) show that men often control women's access and use of mobile phones, monitor whom they talk to, and take away their wives' phones whenever they disapprove of their activities, thus reinforcing unequal marital and gender relationships.

It is important to note here that Tanzania is undergoing a digital transformation, which is reflected by the growing number of phone subscribers and the increasing geographic coverage of cheap, higher bandwidth data. The number of registered mobile money customers grew from 14,000 in 2008 to 28.1 million in 2014 (TCRA 2014), and about 42 percent of Tanzanians were subscribed to a mobile service in 2018 (GSMA 2019). By the end of 2018, 2G, 3G, and 4G covered about 90 percent, 61 percent, and 25 percent of Tanzania's population respectively (GSMA 2019). These transformations are exerting a profound impact on key social, cultural, and economic sectors by improving efficiency both within and across sectors (GSMA 2019).

### *Gendered perceptions of mobile phones*

This research, and particularly RQ2, explores gendered perceptions of mobile phones and their benefits. Rogers (2003) highlights the critical role that perceptions of any new innovation or technology, including of its benefits, play on the rate of adoption. It has been well documented that people act on their perceptions (Enns and Bersaglio 2015), suggesting that a better understanding of women's perceptions of mobile phones could help to design more effective technology-based agricultural interventions targeting both men and women.

A pivotal factor influencing individuals' perceptions of any new technology is trust. This generally refers to both trust in

the source of information, and the trustworthiness of that information (Aker et al. 2016). Trust in mobile phones and the information provided through them can play a critical role in promoting mobile phone-based ICT interventions for improved agricultural productivity (Aker et al. 2016; Mittal and Tripathi 2009).

## Methods

### *Study area*

The study was conducted in the villages of Kibena, Lyamgungwe, Malagosi, and Mgama, located in the Iringa region in southern Tanzania (Figure 1). Iringa was selected as the study site because it is a major agricultural area within Tanzania, includes a wide road network (Tumaini 2017), and is the target of many agricultural and ICT-specific interventions (Kapinga and Montero 2017). In Iringa, about 90 percent of households earn a living through agriculture and/or livestock production (Kihupi et al. 2015). Until the 1970s, maize was the dominant agricultural crop, yet smallholders have recently diversified their crop selection (including crops such as beans, sunflowers, pumpkins, tomatoes, and cassava) in response to increasingly unreliable rainfalls (Kihupi 2015). The rainy season is between November and May, registering 500 to 1500 mm of annual precipitation (Tumaini 2017). A government-funded assessment found that in 2017 in Iringa, 64 percent of adults and 90 percent of households owned a mobile phone (Chimilila et al. 2017), but that there is little to no national or regional data on phone ownership by gender.

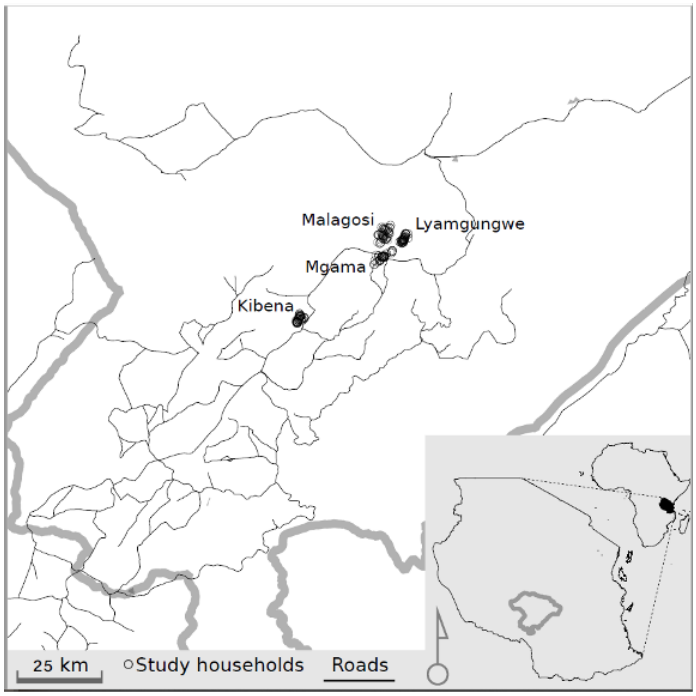


**Figure 1** Study area in Iringa region, Tanzania. Survey households (black points) were randomly selected in study communities in Iringa Region (outlined).

The four study villages were selected because they are representative of the various agroecological systems that exist across the region, and they provide diversity in terms of population size and access to infrastructures such as paved roads and electricity. More precisely, the study villages are largely comprised of the Hehe and Bena ethnic groups. The four villages are relatively similar in terms of ethnic composition and agricultural factors, albeit there are moderate differences with respect to population, area, development, and access to main roads. In all four villages, the majority of agriculture is rain fed and maize is the primary staple crop. Cell phone service is reliable and at least one of the four major networks in Tanzania (Tigo, Vodacom, Airtel, and Halotel) is available.

Despite Iringa's high agricultural productivity, several challenges still exist. For instance, as of 2012, about 10 percent of the population in Iringa was below the extreme poverty line (Martin and Kahamba 2017). In Iringa and the greater Southern Highlands area, 35 percent of landowners are women, which is higher than other regions in Tanzania (FAO 2014). Sikira et al. (2016) found that in Iringa, half of the women reported that the final decision on sale of land resided with men, while the other half claimed that they retained some decision-making power. These findings suggest that some women still have some decision-making power over the land owned by men, or, at least, that they have a voice in the decision-making process. Moreover, due to the prominence of agriculture in Iringa, there is a need for better access to agricultural information. However, Mubofu and Elia (2017) found that there are major barriers hindering increased access to agricultural information, including inadequate number of extension officers, inadequate funding for projects, unavailability of electricity, political interference, and lack of information centers. Many of these barriers could be potentially overcome by increasing access to information and communication services through mobile phone use.

### *Data collection and analysis*

In July 2017, during the maize harvest, our team conducted a standardized household survey of women and men smallholder farmers, with a sample size of 279. Due to the critical timing of the survey, important agricultural information, such as yield values, was still fresh in the minds of respondents. In each village, we randomly selected 40 households from the village registers or rosters. The survey was conducted in Kiswahili, Tanzania's official language and the common language of survey respondents, by trained Tanzanian enumerators. Enumerators worked in pairs, one female and one male, and each enumerator only surveyed respondents of their same gender. In each household, we aimed to survey both a male and a female household member, preferably the male and female household heads, or, if absent, another adult household member. In some cases, however, this was not possible, for instance when there were no household members of either gender who were 18 years of age or older, or when no household member was present. In such cases, only one household member was surveyed per household. Local guides helped enumerators

to locate the households and introduce the research project to their members. The survey included questions about demographics, self-reported agricultural productivity, phone ownership and use, type of phone owned/used, and perceptions of the benefits of phones for agricultural practices. The survey asked respondents to self-identify their gender as male, female, or other. We here refer to gender instead of sex, given that traditional gender roles are still dominant in Tanzania and gender norms dictate roles within marriage, household, and agriculture. Women and men received the same survey, as the goal was to directly compare female and male responses on agricultural yields and phone ownership and use. Survey respondents were compensated with a phone voucher of approximately $1.

Survey data were transferred from the paper survey forms into Microsoft Excel by undergraduate student research assistants and analyzed with help of Microsoft Excel and R software programs. Statistical significance was determined through Welch two sample t-tests. Key variables analyzed included gender, agricultural yields, phone ownership, and phone use.

## Results

### *Demographics*

Demographics are useful to obtain a clearer picture of respondents' characteristics. Specifically, 53.6 percent of respondents were female and 46.4 percent were male. The average age of respondents was 41.1 years. The majority of respondents (84 percent) had completed primary school, while only 13.1 percent had completed secondary school. The vast majority of respondents (94.6 percent) had a phone in their household. Phone owners spent, on average, less than $1 of phone credit each week.

### *Uses of mobile phones for agricultural activities (RQ1)*

Table 1 presents survey results of respondents' self-reported agricultural yields, and phone ownership and use, stratified by gender (RQ1). Here, ownership is defined as personally owning a mobile phone of any type. The majority of respondents had basic feature phones, and only 6.3 percent owned a smartphone. General phone use was measured by number of SMS and calls sent and received in the previous 24 hours. As expected, more men owned phones than women, and men were also more likely to report higher numbers of SMS and phone calls. Table 1 also includes self-reported maize yields for men and women in "good" and "bad" years, as defined by respondents themselves, and disaggregated by phone owners and non–phone owners, which will be discussed in a subsequent section (RQ3).

To understand how respondents use their phones for agriculture, we asked yes/no questions about phone use for nine different agricultural activities. These questions are important because just owning a mobile phone does not reveal whether individuals actually use their phones for farming activities. Table 2 lists these questions and stratifies respondents into the following categories: all respondents, all men, all women, female respondents who own a phone, and female respondents who do not own a phone. Addressing RQ1, we find that a higher percentage of men reported using mobile phones for several agricultural activities compared to women, but this result was not consistent across all nine activities. For example, 73 percent of men and only 55 percent of women reported using phones to discuss agriculture

| Variable | All | Men | Women | Men vs. Women[1] |
|---|---|---|---|---|
| Personal ownership of a mobile phone (%) | 75.3 | 89.1 | 63.1 | – |
| SMS sent in the previous 24 hours (#) | 6.6 | 9.4 | 3.3 | *** |
| SMS received in the previous 24 hours (#) | 8.1 | 11.3 | 4.3 | *** |
| Calls made in the previous 24 hours (#) | 4.4 | 6.6 | 1.8 | *** |
| Calls received in the previous 24 hours (#) | 4.5 | 6.2 | 2.4 | *** |
| Maize yield in a "good" year (# of bags/ hectare)[2, 3] | 5.5 | 6.2 | 4.9 | *** |
| Maize yield in a "good" year for *phone owners* (# of bags/ hectare)[2, 3] | 5.9 | 6.3 | 5.25 | – |
| Maize yield in a "good" year for *non–phone owners* (# of bags/ hectare)[2, 3] | 4.3 | 4.8 | 4.2 | – |
| Maize yield in a "bad" year (# of bags/ hectare)[2, 3] | 2.9 | 3.2 | 2.5 | *** |
| Maize yield in a "bad" year for *phone owners* (# of bags/ hectare)[2, 3] | 3.0 | 3.4 | 2.6 | ** |
| Maize yield in a "bad" year for *non–phone owners* (# of bags/ hectare)[2, 3] | 2.3 | 2.2 | 2.4 | – |

[1]Statistical significance was determined with a Welch t-test between men and women and represented as follows: *** = p-value<0.001, ** = p-value<0.01, and * = p-value <0.05.
[2] Maize yields were self-reported from respondents and not empirically measured.
[3] Bags are a common agricultural measurement in Tanzania, which in Iringa region were reported by locals to be approximately 65 kg. However, the approximate weight of a bag does vary by region.

**Table 1** Phone ownership, phone use, and agricultural yields, stratified by gender (n = 279).

| Agricultural activities | All (n=279) | Men (n=130) | Women (n=149) | Women phone owners (n=94) | Women non–phone owners[1] (n=55) |
|---|---|---|---|---|---|
| Gathering information on agricultural practices | 54 | 69 | 42 | 48 | 31 |
| Talking to the agricultural extension agent | 55 | 67 | 45 | 46 | 44 |
| Discussing with friends and relatives about agriculture | 63 | 73 | 55 | 66 | 36 |
| Selling crops | 61 | 69 | 54 | 63 | 38 |
| Buying seeds or fertilizer[2] | 54 | 60 | 48 | 52 | 42 |
| Accessing weather information for planting | 41 | 45 | 36 | 41 | 29 |
| Using mobile money services for purchasing fertilizers, seeds, or selling crops[2] | 42 | 42 | 41 | 46 | 33 |
| Hiring labor | 45 | 44 | 47 | 53 | 36 |
| Hiring or borrowing equipment | 43 | 41 | 44 | 48 | 36 |

[1] These women who use a phone but do not own their own phones rely on the phones of others to conduct these activities. This is explained in greater depth in subsequent sections.

[2] Buying seeds/fertilizer through a mobile phone was divided into general use of a mobile phone and use of a mobile phone by using mobile money. In general, using a mobile phone to purchase seeds and/or fertilizer may mean calling an agricultural input dealer for prices, arranging for a family member to purchase agricultural inputs in person for you by calling them, or arranging transportation of agricultural inputs by calling a car or motorbike taxi driver.

**Table 2** Answers to the question "Do you use a phone for agricultural purposes?" Numbers reported are the percentage of yes responses.

| Whose phone do you use for the following agricultural activities? | Men | | Women | | | | |
|---|---|---|---|---|---|---|---|
| | Own phone | Others' phone[1] | Own phone | Husband's phone | Child's phone | Neighbor's phone | Other relatives' phone |
| Discussing with friends and relatives about agriculture | 98 | 2 | 67 | 24 | 6 | 1 | 1 |
| Selling crops | 98 | 2 | 68 | 24 | 5 | 1 | 1 |
| Talking to the agricultural extension agent | 98 | 2 | 56 | 31 | 6 | 5 | 2 |
| Buying seeds or fertilizer | 97 | 3 | 64 | 27 | 4 | 3 | 1 |
| Gathering information on agricultural practices | 98 | 2 | 66 | 26 | 5 | 2 | 2 |
| Hiring labor | 100 | 0 | 66 | 27 | 4 | 3 | 0 |
| Hiring or borrowing equipment | 98 | 2 | 63 | 29 | 5 | 3 | 0 |
| Using mobile money services for purchasing fertilizers, seeds, or selling crops | 100 | 0 | 59 | 34 | 3 | 2 | 2 |
| Accessing weather information for planting | 96 | 4 | 66 | 28 | 3 | 1 | 1 |

[1]"Others' phone" included a neighbor's, brother's, or father's phone.
**Note:** Percentages are rounded to the nearest whole number.

**Table 3** Answers to the question "When using a mobile phone for agricultural purposes, whose phone do you use?"

with friends and relatives, while 44 percent of women and 41 percent of men reported using phones to hire or borrow agricultural equipment.

Notably, women who owned phones were more likely to use them for agricultural purposes than women who did not own a phone. However, the percentage of women who did not own phones, but still used them for agricultural purposes was surprisingly high. This suggests that despite not owning a phone, many women were actively participating in agricultural activities by using other people's phones. In order to shed light on this finding, respondents who reported using a phone for agricultural activities were then asked whose phone they used for each of the nine activities (Table 3).

Table 3 shows that irrespective of the agricultural activity, men consistently used their own phone to conduct agricultural activities, while roughly one-third of women relied on the phones of others, including their husbands, children, neighbors, and other relatives. Notably, the majority of women used their husbands' phones for agricultural activities. These findings highlight that while phone ownership can benefit women, having access to a phone within or nearby the household can also provide some benefits. These data also underscore the unequal power relationship between men and women, since men can ultimately decide whether or not to allow their wives to use their phones.

### *Mobile phone ownership and perceptions of the benefits of mobile phone use for agriculture (RQ2)*

This section addresses RQ2 and aims to better describe how mobile phone ownership and use can influence perceptions of the benefits of mobile phones. Survey respondents were asked if the use of a mobile phone reduced the amount of time spent on buying inputs or selling crops and the amount of money spent on farming activities, and if it increased profits from farming compared to before using a mobile phone (Table 4). Table 4 shows that positive perceptions of the benefits of mobile phones were generally higher for men than for women, and that women phone owners had also more positive perceptions of these benefits compared to women who did not own phones. More precisely, a high percentage of respondents had positive perceptions of the benefits of mobile phones on increased agricultural profits (64 percent of all respondents, 69 percent of men, and 60 percent of women). While a greater percentage of women who owned phones thought that phones can benefit agriculture, the percentage of women who did not own phones but still had positive perceptions is higher than expected. This again suggests that even those women who did not own phones still perceived phones to be beneficial.

Lastly, respondents were asked if they trust mobile phones to help them with various agricultural problems and tasks. As reported in Table 5, an overwhelming majority of women (80 to 90 percent, both phone owners and non–phone owners) trusted mobile phones to help them with growing, buying, and selling crops. Respondents trusted phones less when it came to soil fertility and land ownership/titling, yet this finding could be explained by the lower first-hand experience with these tasks. Overall, these results suggest that in the context of Iringa: (1) trust in mobile phones was not hindering women from using mobile phones, and (2) mobile phone ownership was not necessary in order to build trust in the effectiveness of mobile phones for agricultural activities.

### *Phone ownership and increased agricultural productivity (RQ3)*

Lastly, addressing RQ3, respondents were asked to self-report their typical maize yield in both "good" and "bad" years. The interpretation of what constitutes a "good" and "bad" year was left up to respondents. As seen in Table 1, the average self-reported maize yields were higher for men, irrespective of phone ownership, and higher for respondents (both genders) who owned phones compared to respondents who did not own phones. Additionally, in both "good" and "bad years, women phone owners reported higher yields than men non–phone owners. For instance, in a "good" year, non–phone owners reported yields of 4.8 bags/hectare (among men) and 4.2 bags/hectare (among women), while phone owners reported 6.3 bags/hectare (among men) and 5.25 bags/hectare (among women). Lastly, t-tests were conducted to determine whether the differences in

| Survey questions | All respondents, irrespective of phone ownership | | | Women with and without phones | |
|---|---|---|---|---|---|
| | All | Men | Women | Women phone owners | Women non–phone owners |
| Has the use of a phone *reduced the amount of time* you spend on buying inputs or selling crops? | 47 | 57 | 39 | 41 | 36 |
| Has the use of a phone *reduced the amount of money* you spend on farming activities? | 50 | 49 | 50 | 57 | 39 |
| Has the use of a phone *increased profits* from farming compared to when you did not have a phone? | 64 | 69 | 60 | 68 | 47 |

**Table 4** Perceptions of the benefits of phone use for agriculture. Numbers are the percentage of respondents who said yes to each question.

| Female respondents | Trust | Type of Problem | | | | |
|---|---|---|---|---|---|---|
| | | Growing crops | Soil fertility | Buying crops | Selling crops | Land ownership and titling |
| Phone owners | No | 15 (14) | 24 (22) | 10 (9) | 10 (9) | 29 (27) |
| | A little | 3 (3) | 9 (8) | 1 (1) | 1 (1) | 5 (5) |
| | Somewhat | 7 (6) | 3 (3) | 5 (5) | 4 (4) | 4 (4) |
| | A lot | 75 (69) | 64 (59) | 84 (77) | 85 (78) | 61 (56) |
| Non–phone owners | No | 6 (3) | 21 (11) | 11 (6) | 9 (5) | 32 (17) |
| | A little | 4 (2) | 4 (2) | 0 (0) | 0 (0) | 4 (2) |
| | Somewhat | 2 (1) | 4 (2) | 0 (0) | 4 (2) | 0 (0) |
| | A lot | 89 (47) | 72 (38) | 89 (47) | 87 (46) | 64 (34) |

**Note:** These answers are for female respondents who both own and do not own a mobile phone. The first numbers are percentages, rounded to the nearest whole number. The numbers in brackets are the number of respondents.

**Table 5** Trust in mobile phone use for agricultural activities.

yield between phone owners and non–phone owners were statistically significant ($p < 0.05$) in both "good" and "bad" years. Results shows that reported maize yields are significantly higher for phone owners compared to non–phone owners in both "good" ($p = 0.0181$) and "bad" years ($p = 0.0424$).

## Discussion

Our empirical findings from four Tanzanian communities in Iringa suggest that mobile phones may play a role in bridging the gender gap in agricultural production. Results on the three research questions highlight that mobile phones can significantly help women with their agricultural activities. Women who owned phones reported higher maize yields (Table 1), were actively engaged in using mobile phones for agricultural activities (Tables 2 and 3), and had positive perceptions and trust in the use of mobile phones for agricultural activities (Tables 4 and 5). Crucially, even women who did not possess mobile phones themselves still had positive perceptions, and they used other people's phones for agricultural activities (Tables 3, 4, and 5). However, it is critical to emphasize that men often have control over women's access to and use of mobile phones (Table 3), ultimately hampering the full realization of the potential of mobile phones to bridge the gender gap in agricultural productivity (Summers et al. 2020).

### *Mobile phone use and the gender gap in agricultural productivity*

While our results show that women who owned phones reported higher yields than non–phone owners, it is important to acknowledge that these results are based on self-reported yields and phone use (this issue is addressed explicitly in the Limitations section below). Using different measurements, Quandt et al. (2020) draw similar conclusions, confirming the existence of statistically significant associations between mobile phone use for agricultural activities and increased maize yields in Tanzania (analogous results are also obtained by Chavula 2014; Issahaku et al. 2018; Sekabira and Qaim 2017). Further, this is one of the first studies to disaggregate mobile phone users by gender, as suggested by Baumüller (2018). While our survey asked about the specific uses of phones for agriculture, our aim was not to further investigate the links and mechanisms behind mobile phone use and increased agricultural productivity, since this has already been done in detail in other work (see Aker et al. 2016; Asif et al. 2017; Dannenberg and Lake 2013; Krone et al. 2014; Martin and Abbott 2011; Mwatimwa 2017; Sife et al. 2010). While our results suggest that mobile phones can be a crucial tool for reducing the gender gap in agricultural productivity, more research and empirical evidence is needed in order to better support this conclusion. Specifically, a larger scale survey which looks at multiple regions and countries, as well as the use of qualitative interviews, could help to explore these linkages more in-depth.

### *Gendered mobile phone use and access*

Studying women's access to and use of mobile phones can help to investigate whether mobile phones can address the gender gap in agricultural productivity. The results from this study highlight that women have access to and use mobile phones for agricultural activities, yet phone use and access are still seriously limited. Specifically, while several women in this study were found to own and/or use mobile phones for agriculture, approximately one-third of women depended on others for gaining access to these devices (Table 3). This may leave women at the will of others, since, as suggested by Burrell (2010), sharing mobile phones often disproportionately excludes women. The relationships between mobile phone use and women's empowerment are complex, given that they are not solely determined by personal choices, but they are often deeply influenced by cultural norms and husbands' attitudes (Summers 2019). Men often serve as the gatekeepers of mobile phone access and use for women (Summers et al. 2020), and this study also highlights this important point. While the adoption of mobile phones can help to challenge traditional gender norms (Chib and Hsueh-Hua Chen 2011), previous

work suggests that ICTs are enablers of change, but that they are not necessarily triggers of change (McNamara 2003; Owusu et al. 2017). This study only looks at women's access to mobile phones at a given point in time, but previous research has shown that women's access to mobile phones can change over time (Summers et al. 2020). Thus, crucial avenues for future research include studying women's dynamic access to mobile phones over time and the role that their husbands may play in facilitating or constraining their access to mobile phones.

#### *Women have positive perceptions of the benefits of mobile phones*

As shown by Rogers (2003), major barriers to technology adoption include perception and trust in any new technology; this is why exploring women's perceptions of mobile phone use for agricultural activities was a key component of this research. One of the major constraints in Sub-Saharan Africa's agriculture is inefficiency (Ogbeide and Ele 2015), with agricultural yields only registering slight increases since the 1960s (Masters 2009). Our study suggests that many female smallholder farmers view mobile phones as a tool that could potentially increase agricultural efficiency (Tables 4 and 5). These findings are consistent with previous work in Tanzania and elsewhere. A study by Sife et al. (2010) in Tanzania, for instance, found that mobile phones can strengthen social networks, increase people's ability to deal with emergencies, cut down on travel costs, maximize the outcomes of necessary travel, and improve the efficiency of certain activities, such as buying or selling crops. Notably, over 70 percent of respondents indicated that the use of mobile phones had a positive impact on transportation challenges (Sife et al. 2010). While the study by Sife et al. (2010) did not directly focus on agriculture, our results point to similar conclusions in the agricultural context. Moreover, James (2018) found that mobile phones cut travel time and costs in Tanzania more than in other African countries, largely due to poor road conditions and the lack of public transportation in the country. Research from Aker (2008) and Muto and Yamano (2009) emphasized that farmers receive higher prices for their crops due to the use of mobile phones. More broadly, Mwantimwa (2017) found that 88.3 percent of Tanzanian respondents own and use mobile phones because these devices can ease communication, access to information, and financial transactions. In short, not only do these previous results highlight the importance of perceptions, but they also suggest possible reasons why mobile phones are perceived to be beneficial for agricultural activities (Tables 2 and 4). However, while positive perceptions and trust in mobile phones are necessary elements, they are only two of the several factors influencing the adoption of mobile phones by female farmers in Tanzania as well as elsewhere.

#### *Women who do not own phones still benefit from them*

Crucially, this study suggests that women do not need to own a phone in order to use and trust it, and to perceive its positive impact on agricultural activities (Tables 2, 4, and 5). Indeed, also women who did not own phones had positive perceptions of these devices, since they had access to other people's phones. This highlights the importance and prominence of phone sharing in developing economies. For example, in Sub-Saharan Africa, there were 444 million unique mobile subscribers in 2017, while the total number of SIM connections amounted to 747 million (GSMA 2018). Thus, not only phone *ownership*, but also phone *access*, and *presence* of a phone within the household and in neighboring households are important factors in the context of mobile phone-based agricultural interventions. However, as Summers et al. (2020) point out, the fact that many women rely on others to access and use mobile phones can be a major constraint, since it forces women to navigate complex and unequal social relationships with their husbands, children, neighbors, or other relatives. This dependence on others for mobile phone access may limit the impact that mobile phones can have on reducing the gender gap in agricultural productivity, given that there may be social and personal costs associated with using other people's phones.

#### *Limitations*

There are two major limitations in this study. First, agricultural yield was not measured directly, but it was estimated by respondents themselves, and it only included maize yields. This may have raised some problems related to respondents' wrong reports of maize yields; in future research, it would be more accurate to measure maize yields directly. It would also be beneficial to look at the yields of other major crops, such as beans, sunflowers, and tomatoes, in order to better explain the complex relationships between gender, mobile phone use, and agricultural yield. Second, measuring the nature and volume of phone use over long periods of time is challenging, and respondents' ability to recall phone use over time can be problematic. To circumvent these issues, we measured phone use in two different ways: through the number of texts/calls in the past 24 hours and through yes/no responses. Yet, neither of these are perfect measures of phone use and future research should seek better measures.

## Conclusions and recommendations

The aim of this research was to better describe the associations between gender, agricultural productivity, and phone ownership and use in the face of severe gender disparities. Our research suggests that mobile phones can be valuable in bridging the gender gap in agricultural productivity. When interpreted alongside other recent research, these results can help to inform technology-focused interventions and policies for improved agricultural productivity, while also pointing out avenues for future research on how to decrease the gender gap in agricultural productivity. Paying attention to how impacts may differ between groups of people, such as men and women (Baumüller 2018), is critical to having the most impact on the greatest number of individuals, without leaving out any specific group such as women. Given women's important role in smallholder agriculture, addressing the barriers in phone ownership, access, and use may be important for improving agricultural productivity glob-

ally. However, mobile phones are no panacea for reducing poverty and improving agricultural productivity, and they need to be supported by investments in physical infrastructures, electricity, and education (UN Women 2015).

On the basis of our results, we put forth two recommendations for both future agricultural interventions aimed at improving agricultural productivity, as well as for impact assessments and research that seek to understand the differential impacts of mobile phones (Aker et al. 2016).

***1. Women are ready for ICT-based interventions for agriculture***

The results presented in this paper support the idea that, at least in the four villages that were part of this research, female farmers may be ready to be targeted beneficiaries of ICT-based agricultural interventions. Positive perceptions of the benefits of a new technology (Rogers 2003), as well as trust (Aker et al. 2016), are critical aspects of technology adoption. In our study areas, results show that there are high percentages of female farmers with both positive perceptions and trust in mobile phones. Thus, targeting ICT-based interventions for agriculture towards female farmers would likely be well received by women.

***2. More research is needed to understand how mobile phone use by women can bridge the gender gap in agricultural productivity***

While our study begins to describe the role of mobile phones in increasing agricultural productivity, more research is needed in order to draw more generalizable conclusions. This includes both larger scale, longitudinal research, which can help to understand broader trends across different contexts, as well as mixed-methods and qualitative research, which can allow to delve deeper into the mechanisms linking mobile phone use and agricultural productivity. For instance, exploring agricultural yields before and after a mobile phone focused intervention aimed at women could provide more accurate evidence. Moreover, investigating whether the results of our study similarly apply to other contexts could provide more robust evidence in favor of ICT-projects targeted at female farmers. Lastly, qualitative interviews could reveal relevant causal pathways linking mobile phone access and improved agricultural yields, as well as explain the role of social networks in connecting agricultural stakeholders and actors.

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***Competing interests***

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