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Socio-economic Factors Affecting the Sustainability of Chololo Pits Technology in Semi-Arid Dodoma: The Case of Chamwino District, Tanzania

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Abstract

Introduced in Tanzania by the World Agroforestry (ICRAF), *chololo* pits is a technology that help conserve moisture in the soil and improve soil fertility, hence increasing crop production and mitigating drought effects. However, socio-economic factors are increasingly affecting farmers' practising *chololo* pits in the semi-arid Dodoma Region, hence the need to understand these factors that affect the sustainability of this technology. Therefore, the aim of this paper is to investigate the socio-economic factors affecting the sustainability of the technology of *chololo* pits in the semi-arid Chamwino district, Dodoma region, in Tanzania. Data were collected through a documentary review, household interviews, focus group discussions, key informant interviews and field observation. The findings indicate that the cost of labour for the construction of pits (92.1%, n=337), and land ownership (92.1%, n=337), were the major factors affecting the sustainability of the practice in the study area. Other minor economic factors scoring less than two digits were capital and household income; and social factors including group membership, sources of labour and education level. To enhance the sustainability of the practice, four strategies were suggested by stakeholders: use of improved seeds (75.7%), use of user-friendly pitting tools (65.5%), farmers' capacity building (47.1%), and up-scaling the practice (24.8%).

Keywords: *ethno-farming, socio-economic factors, sustainability, cholola pits, semi-arid, Dodoma*

1. Introduction

Sustainable crop production has remained a challenge in many parts of arid and semi-arid parts of the world (Mswima, 2020; Mswima & Kaswamila, 2022). Moisture limitations, as a result of climate change in these parts of the world, have brought challenges such as environmental stress, deterioration of vegetation cover, losses in agricultural production, loss of arable land, soil erosion, and increased stress on economies, amongst others (Adhikari et al., 2015). These impacts have affected the sustainability of crop production in semi-arid and arid areas as they have reduced overall crop productivity by, for example, 30% in Asia, and 13% in Africa (Saylor et al., 2017).

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To reverse the situation, farmers in these parts of the world have developed different ethno-farming practices to cope with experienced moisture limitations resulting from the impacts of climate change. For example, in Latin America, practices such as agroforestry, intercropping, crop rotation, cover cropping, traditional organic composting and integrated crop-animal farming are prominent ethno-farming practices that have been adopted (Demissew et al., 2015). Likewise, farmers in the semi-arid regions of India use ethno-farming practices such as the use of locally adapted varieties; enhancing the organic content of soils through compost, green manures, cover crops, etc.; wide use of local knowledge and practical means to 'harvest' water and conserve soil moisture (e.g., crop residue retention and mulching), and more effective use of irrigation water to increase water holding capacity. These practices have also contributed to maintaining soil fertility, and hence maximizing and securing household food supplies. Such practices have also managed to increase crop production in this part of the world, which has in turn ensured food availability and income in the pockets of farmers (Stephen, 1991).

In different parts of Tanzania, as a result of moisture limitations caused by climate change, farmers have come up with different ethno-ecological practices. Such practices as *ngolo* in the southern parts, *vinyungu* in Iringa region, and *chamaz*i in the West Usambara Mountains have played an important role in ensuring household food security, and have been a source of income for farmers (Maro, 2017). Similarly, the practice of *chololo* pits, which is popular in the semi-arid parts of Dodoma (Kihila, 2017) has enabled farmers to overcome crop moisture challenges, and hence increase crop production. Much of the documentation efforts concerning ethno-farming practices are geared towards the aspects of their significance in reducing moisture limitations, increasing yields, reducing soil erosion and maintaining soil fertility (Tenge & Kaswamila, 1994). However, very little is known about the sustainability of the *chololo* practice in semi-arid areas, especially under changing climatic conditions. This paper seeks to explore socio-economic factors that affect the sustainability of the practice of *chololo* pits, and thus limiting local agential capacity to mitigate the impacts of climate change.

2. Context and Methods

2.1 The Study Site

This study was conducted in Chamwino district, Dodoma region, and involved four (4) villages: Buigiri, Manchali, Handali, and Mvumi (Figure 1). In the district, the *chololo* practice is one of the dominant ethno-ecological practices. Others include zero tillage, tie-ridging and slash-and-burn (*kuberega*). The district is one of the seven districts of Dodoma region. It is bordered to the north by Chemba district; to the east by Manyara region, Kongwa and Mpwapwa districts; to the south by Iringa region; and to the west by Singida region, Bahi and Dodoma districts.

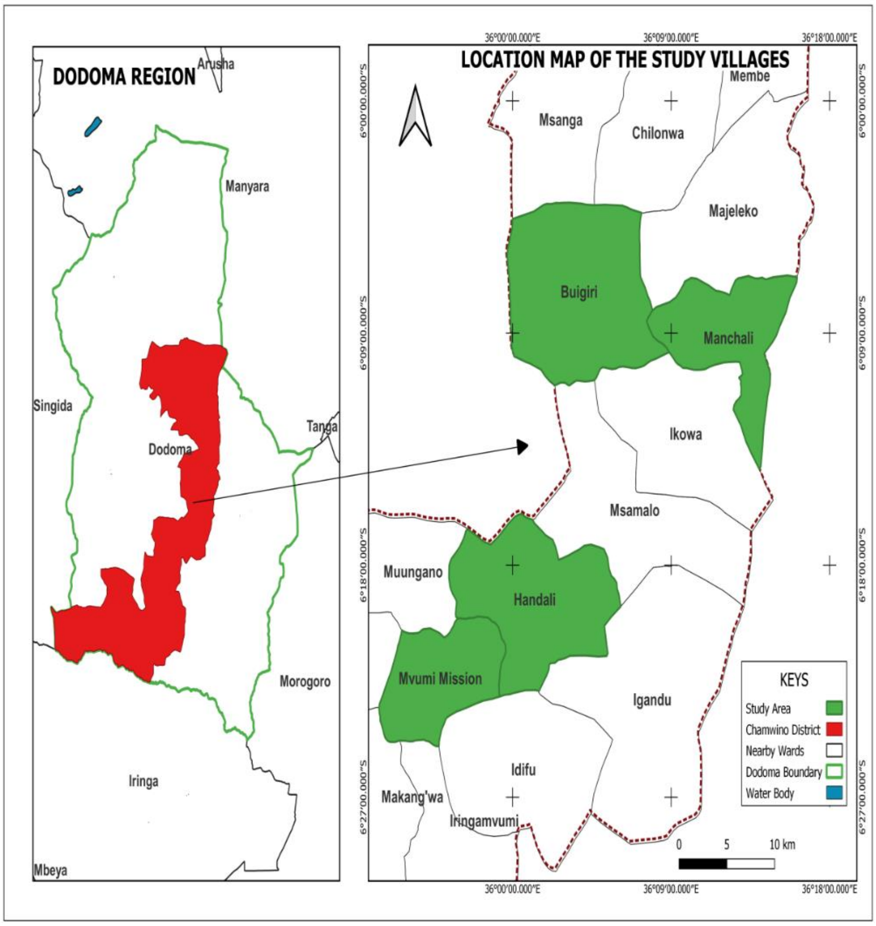

Figure 1: The Study Area
Source: Researcher, 2021

The district has a dry savannah type of climate, which is characterised by unimodal and erratic rainfall that falls between late November and mid-April. The annual average rainfall is about 500–700mm, and the mean monthly temperature is about 22.6°C (Swai et al., 2020). The district experiences long dry seasons from mid-April to late November each year.

Agriculture and livestock keeping are the main economic activities in the district. The food crops grown include sorghum, maize, and cassava; while cash crops include grapevines, sunflower, simsim, groundnuts, bulrush millet and paddy. The area can be broadly described as a plateau, with an overall eastward slope and low relief intensity. The main physiographic features of the district include mountains, inselbergs and hills, foot slopes, lowland plains, intermediate plains, lakes, river valleys, escarpments, drainage and water resources.

Intrusive basement complex rocks, mainly granites, underlie the geology of the area. The granitic rocks enclose disconnected fragments of older basement rocks, and are believed to be of the late Precambrian age. In addition, basic and ultrabasic intrusive rocks may occur as younger dykes penetrating the granites. The most common granitic rocks are grey, non-schistose and rarely porphyritic granites. Near the older basic rocks, there is evidence of the enrichment of dark minerals, as well as an abundance of streaks and bands of dark schists. The basement complex rocks are covered by a mantle of loose or cemented superficial deposits of alluvial, colluvial and residual origin; and of tertiary or quaternary age. The drainage system of the district is notable for its lack of permanent surface water bodies; and a runoff/river network that is largely seasonal, flowing only during rainy seasons and a few weeks thereafter. Hence, the area is heavily reliant on groundwater.

2.2 Data Collection

Different methods and tools were used in collecting data to increase data validity and reliability. The methods included a household survey involving household heads, key informant interviews (KIIs), focus group discussions (FGDs), physical visits and secondary data review. About 337 respondents were involved in this study. Household interviews were conducted through a structured questionnaire. Key informant interviews involved village and ward leaders and agricultural extension officers, as they were important in gaining additional information on the socio-economic factors affecting the sustainability of *chololo* pits. Field visits were essential for physically ascertaining and/or confirming issues raised during the data collection exercise.

2.3 Data Analysis

Quantitative data were analysed using the SPSS, version 20; and Excel spreadsheet; and were summarised through tables, frequencies, percentages and means. On the other hand, qualitative data were analysed through content analysis.

3. Results and Discussion

3.1 Economic Factors Affecting the Sustainability of the Chololo Pits Practice

Table 1 presents the economic factors affecting the sustainability of the *chololo* pits practice. According to the findings, the majority of respondents had the opinion that the high labour cost involved in the preparation of farm and pitting was affecting the sustainability of the *chololo* pits practice in the area. Sustainability in the context of this paper is what focuses on producing long-term crops while having minimal effects on the environment, maintaining the economic stability of farms, and helping farmers improve their techniques and quality of life (Kaswamila, 2006b). Other economic factors (in order of importance) include low level of household income and yields level, as discussed below.

Table 1: Economic Factors Affecting the Sustainability of the Chololo Practice

Economic factors	Respondents (%)				
	Handali (n=91)	*Mvumi (n=64)*	*Buigiri (n=126)*	*Manchali (n=56)*	*Average (%)*
Cost of labour and construction	91.1	89.5	92	90	90.7
Yields	3.2	3.2	2.4	3.6	3.1
Household income	5.7	7.3	5.6	6.4	6.2

Source: Field Survey, 2021

3.1.1 Cost of Labour and Construction of the Chololo Pits

The cost of labour and construction is very crucial as it determines the production of crops. The findings indicate that high labour is needed during the construction of *chololo* pits, which may lead to farmers incurring high costs in terms of the labour required. On average, the majority of respondents from the four villages (90.7%) viewed this factor as the major factor affecting the sustainability of the practice. Field results indicate that costs range to around TZS400,000 per hectare. By all standards, and taking the high poverty level of the farmers, this becomes an expensive venture. Studies done by Roba et al. (2022) indicated that pitting practices are more labour-intensive. Getare et al. (2021) also observed that Zai pits in west Africa are more labour-intensive. Similarly, Gamba's study (2020) on the resilience and economic benefits of Climate Smart Agriculture Practices in semi-arid Tanzania depicted that most farmers said that the major disadvantage of *chololo* pits is the high initial cost of labour for digging them. Farmers, however, appreciated that despite the initial labour cost, the advantages in successive seasons/years prevailed over the initial high costs.

3.1.2 Household Income

Household income was found to be crucial in the construction of *chololo* pits. On average, 6.9% of the respondents had the opinion that the low level of household income was one of the factors affecting the sustainability of the practice. The construction of pits demands farmers' financial ability, which was unfortunately low: most farmers in the study area are poor to afford the associated costs. A high poverty level was evident in the study area, as some farmers were unable even to buy seeds during the planting season. For example, during FGDs and KIIs in Mvumi village, it was argued that planting seeds were provided by the Research, Community and Organisational Development Association (RECODA), an NGO operating in the area.

Temu et al. (2022), reveal that low household income is a challenge towards the sustainability of pitting farm practices. On the other hand, in their study on *Zai* pits for heightened sorghum production in drier parts of upper eastern Kenya, Muchai et al. (2021) articulated that inadequate funds for constructing and maintaining *Zai* pits emerged as one of the limiting factors for out-scaling of the structures in all the agro-ecological zones. To address this sustainability challenge, the use of efficient and user-friendly tools for pitting are suggested.

Therefore, in Tanzania, the Small Industries Development Organisation (SIDO), Tanzania Commission for Science and Technology (COSTECH), and the various agriculture research institutions, should be at the forefront of designing such tools. In addition, the government, in collaboration with financial institutions, should provide soft loans to farmers to enhance their financial capital base.

3.1.3 Crop Yields

Chololo pits have the ability to increase yields and improve water-holding capacity as a result of fertilizing the prepared pits with organic matter and/or farmyard manure. Despite the water retention ability and relative increase of yields, focus group discussants had the opinion that yield levels can be enhanced further. One focus group discussant, who preferred anonymity, had this to say:

> *"The practice is very helpful during drought periods, as it has the ability to retain water for quite some time. However, the sorghum and finger millet yield level is as low as 0.3–0.4 tons/ha; thus measures to improve productivity levels are required."*

According to Mlay et al. (2017) and URT (2017), crop yields mostly grown under pit farming systems range between 0.5 tons/ha to 1.1 ton/ha, and are classified as low. According to Mlay et al. (ibid.), the yield levels in brackets for cereal crops in Dodoma region are: sorghum (1 ton/ha), millet (0.8 tons/ha), maize (1.1 tons/ha) and finger millet (0.56 tons/ha). These yields are below the national average yields of 1 ton/ha for sorghum, and 1.1 tons/ha for maize (ibid). In their study in the semi-arid Kongwa district, in Dodoma region, Gamba et al. (2019) found that although *chololo* pits increased soil capacity in retaining rainwater and increasing cereal production, however, the average farmers' yields were below the potential yields. Possible reasons for low yield could not explained, but this could be due to insufficient plant population (inappropriate spacing), untimely weeding, and pests and diseases. They further noted that maize yield was enhanced when *chololo* pits were integrated with Gliricidia *sepium*. According to Emannuel et al. (2022), *chololo* pits increases crop production by 12 per cent compared to other methods of soil and water conservation such as stone /earth terraces and contour ditches.

3.2 Social Factors Affecting the Sustainability of Chololo Pits

Table 2 presents the social factors affecting the sustainability of *chololo* pits. Field findings indicate that land ownership is the most limiting factor. Other factors include group membership, source of labour, and levels of education.

Table 1: Social Factors Affecting the Sustainability of the *Chololo*Pits Practice

Social Factors	Respondents (%)				Average (%)
	Handali (n=91)	Mvumi (n=64)	Buigiri (n=126)	Manchali (n=56)	
Land ownership	92.1	88.7	90	91	92.1
Group membership	5.5	6.8	3.2	4.8	5.5
Source of labour	4.1	3.2	3.8	3.2	4.1
Level of education	1.2	2.2	1.7	1.6	1.2

Source: Field Survey, 2021

3.2.1 Land Ownership

The results of the respondent's household survey in Table 2 reveal that many farmers (92.1%) are affected by land ownership. In the study area, the common and popular land ownership system is the customary land tenure system. Unfortunately, this type of land tenure has not helped small-scale farmers to access loans from financial institutions due to the lack of reliable collaterals such as customary certificates of right of occupancy (CCROs). However, some financial institutions unfortunately do not accept CROs as collaterals, thus worsening the problem even for the few with CROs. Sanga's (2009) study in Mbozi district found a similar situation: that farmers applied for loans using CCROs, but banks imposed conditions such as low value of land; which together with the small sizes of farms, made the majority of poor farmers fail to secure loans.

In a study in Buhongwa and Kimara, Mbilinyi et al. (2022) found that land regularisation had insignificant implications to credit access, mainly because most land owners with certificates of right of occupancy had no enabling environment to link legally documented plots with formal financial institutions to support household activation of investment on land. According to Benjamin et al. (2020), properly arranged land ownership systems influence agricultural productivity and production through effective land security and investment demand. For instance, a limited land ownership system hinders socioeconomic investment, contributing to slow economic growth in most developing countries (Mishra & Sam, 2016). Therefore, a proper land ownership system among farmers in Tanzania is vital due to its role in contributing to development, particularly in rural areas (Aikaeli & Markussen, 2022). It has been documented that farmers with proper land ownership systems tend to invest more in their lands; leading to sustainable agricultural productivity (Lasway & Selejio, 2021).

3.2.2 Farmer Group Membership

The results in Table 2 further show that, on average, 5.5% of the respondents said that the lack of group membership affects the sustainability of *chololo* pits. Farmer group is a method of organizing people together to solve their individual or collective problems(Meiguran et al., 2016). This method is used by governments, NGOs and others worldwide to improve agricultural productivity and productivity of other sectors (ibid.). The use of this approach to deliver services to small-holder farmers has proven to be an effective institutional device for lowering the delivery of costs of services, and for promoting small-scale farmer self-development. They are important in mobilising small-scale farmer for collective self-help actions aimed at improving their own economic and social situations, and that of their communities (Otieno et al., 2021).

In the study area, farmers who are members of *chololo* pits practice social groups are more motivated, have access to learning opportunities, get improved seeds from RECODA, and normally exchange information among themselves on the sustainable use of *chololo* pits in their farms. Other studies have also shown a positive relationship between *chololo* pits practices and membership in farmer organisations (Emmanuel et al., 2022). For instance, Meiguran et al. (2016) had similar views, arguing that membership in a farmer group in Kenya increased the chance of a farmer practising greenhouse farming and artificial insemination. The increased likelihood of sustainable crop production through *chololo* pits when farmers belonged to a group suggests that the groups were sources of information on water and soil conservation (Kimaru-Muchai et al., 2021).

Therefore, belonging to a social group among *chololo* pits practitioners in Chamwino in Tanzania is vital due to its role in contributing to sustainable crop production, particularly in the semi-arid areas of central Tanzania (Aikaeli & Markussen, 2022). It has been documented that farmers who are members of farmers' social groups tend to have more knowledge and experience of the *chololo* pits practice, leading to sustainable agricultural productivity (Emmanuel et al., 2022). Meiguran et al. (2016) recommends that the government facilitates farmer groups and transform them into cooperatives so as to gain legal identity to transact business, increase their bargaining power, and intensify their collective voices in policy engagement.

3.3.2 Source of Labour

The field findings indicate that the major sources of labour are mainly from individuals (9%) and family members (20%) (Figure 2). It was observed that an individual required about 12 days to fully prepare and dig pits for one hectare.

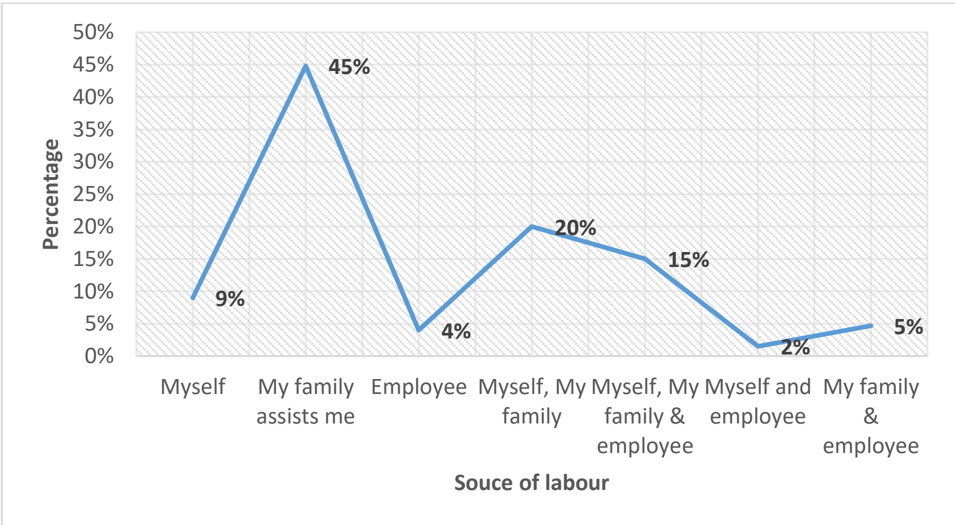

Figure 2: Source of Labour to Dig Chololo Pits
Source: Field survey, 2021

The high labour demand for pitting and for transporting manure has led most small-holders farmers to dig fewer pits compared to the recommended number of pits per hectare. This affects the sustainability of *chololo* pits in terms of crop production, and the expansion of the *chololo* pits practice. According to Lasway et al. (2020), families with large family sizes enjoyed enough labour for digging and maintaining *chololo* pits, hence encouraging the expansion of more *chololo* pits for sustainable crop production. To reduce the challenge of the availability of labour and enable a sustainable *chololo* pits practices, farmers are encouraged to join groups from where they can assistance from group members.

3.2.4 Level of Education

On average, 1.2% of the respondents argued that the level of education influenced the *chololo* pits practice. In other words, knowledgeable people—with formal or informal education—are better positioned to do things in a better way, and vice versa (Kaswamila, 2006a). Unfortunately, most *chololo* pits farmers in the study area have low education, which has somehow affected their efficiency when it comes to integrating *chololo* pits practices with modern farming methods such as the use of improved seeds, fertilisation of pits, and the control pests and diseases. Mango et al. (2017) revealed that a low level of education indicated a low level of understanding of the technologies needed to be integrated into the *chololo* pits practice. This is because education exposes one to information, and hence creates awareness and enhances the adoption of pitting agricultural practices. This integration with modern knowledge can be done gradually, step-by-step, through farmer social groups; and through farmer's field schools involving both farmers and experts.

3.3 *Strategies Taken to Improve the Sustainability of Chololo Pits Practice*

Chololo pits stakeholder's suggestions on the strategies to improve the sustainability of the practice are indicated in Table 3. These include the use of improved seeds, use of user-friendly tools, capacity building and up-scaling of the practice.

Table 3: Strategies to Improve the Sustainability of the Chololo Pits

Strategies	Respondents (%)				Average (%)
	Handali (n=91)	***Mvumi (n=64)***	***Buigiri (n=126)***	***Manchali (n=56)***	
Use improved seeds	87.6	75.8	67.4	78	75.7
User-friendly planting tools	54.9	78.1	39.6	89.2	65.5
Capacity building	39.5	56.2	28.5	64.2	47.1
Upscaling of the *chololo* pits' practice	20.8	29.6	15.0	33.9	24.8

Source: Field survey, 2021

3.3.1 Use Improved of Seeds

The results show that many of the respondents (75.7%) suggested the use of improved seeds so as to increase crop production among the farmers who engage in the use of *chololo* pits. Findings from the study show that improved seeds enhanced crop (maize and sorghum) yield. The farmer's reported an estimated increase of yield in the range of 0.5–0.6tons/ha. This estimate seems to be relatively lower than the optimal ones. According to Rowhani et al. (2011), maize cereal yield in semi-arid areas normally ranges between 1.0–1.1tons/ha. In a recent study by Gamba et al. (2020) in Kongwa district, Tanzania, where the *chololo* pits practise was integrated with the planting of Grevelia *sepium*, yields increased to 3.6tons/ha.

3.3.2 User-friendly Planting Tools

The results show that, on average, more than half of the respondents (65.5%) said that user-friendly tools can improve crop production. The results also suggest that stakeholders and farmers were of the opinion that the *chololo* practice is labour-intensive in terms of human labour required to clear land, dig pits, transport, and mix manure and the soil before each wet season. Salum (2019) and Mkonda (2021) suggest the designing and use of user-friendly tools and equipment that can be used during the planting, weeding, harvesting and post-harvest processes of farm products. Mswima and Kaswamila (2022) had similar views: that such user-friendly tools and equipment should be affordable, convenient to use, compatible with the culture, and locally available. Furthermore, Busisiwe et al. (2022) argue that user-friendly tools and equipment have been found to conserve soil and water, and increase crop production by maintaining the ecology of plants and the surrounding environments. Other strategies to improve the sustainability of the *chololo* pits include capacity building (47.1%) and up-scaling of the *chololo* pits practice (24.8%).

4. Conclusion and Recommendations

4.1 Conclusion

This paper examined socio-economic factors affecting the sustainability of *chololo* pits in a changing climate. The aim was to explore various social and economic factors affecting the sustainability of *chololo* pits. The findings show the cost of labour involved in the construction of pits and land ownership are the major factors currently negatively affecting the sustainability of *chololo* pits practice in the study area. To enhance the sustainability of the practice, *chololo* pits stakeholders recommend the use of improved seeds, use of user-friendly pitting tools, capacity building and up-scaling of the *chololo* pits practice.

4.2 Recommendations

Based on the results of this study, there is a need for relevant government institutions to provide improved quality seeds, such as drought-resistance and high-yield seeds, to farmers. The target group should also be encouraged to use simple and friendly pitting tools such as small hand oxen-drawn or engine-driven machines for making pits. Likewise, the government—in collaboration with the NGOs and CBOs—should provide farmers with more knowledge on the *chololo* pits practice through seminars and farm-field schools. These practices will be scaling up the use of *chololo* pits, and increasing crops yields to farmers who engage in the application of *chololo* pits.

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