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Fischer, Gundula

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# Gender and mechanization: Exploring the sustainability of mechanized forage chopping in Tanzania

Gundula Fischer[a,*], Simon Wittich[a], Gabriel Malima[b], Gregory Sikumba[c], Ben Lukuyu[d], David Ngunga[c], Jacqueline Rugalabam[e]

[a] International Institute of Tropical Agriculture (IITA), P.O. Box 10, Duluti, Arusha, Tanzania
[b] Nelson Mandela African Institute of Science and Technology (NM-AIST), P.O.Box 447, Arusha, Tanzania
[c] International Livestock Research Institute (ILRI), P.O. Box 30709, Nairobi, 00100, Kenya
[d] International Livestock Research Institute (ILRI), C/o Bioversity International, Plot 106 Katalima Road, Naguru, P.O. Box 24384, Kampala, Uganda
[e] University of Dodoma (UDOM), P.O.Box 259, Dodoma, Tanzania

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ABSTRACT

Mechanization is currently experiencing a revival in agricultural research and development, with a new emphasis on equity and sustainability. This study evaluates the introduction of forage chopper machines in seven villages in northern Tanzania from a farmer's perspective. Data collected through focus group discussions and a survey are used for a gender analysis of this technology within a broader sustainable intensification indicator framework. The results not only draw attention to unabated challenges to smallholder mechanization (such as high operational costs or weak supporting infrastructures), but also show how the technology's sustainability is contingent upon equity dynamics on the household and community levels. The evaluation framework proved suitable for a holistic assessment. A broader approach to gender issues would strengthen its interdisciplinary claim. Suggestions for promoting the chopper's sustainability include gender-sensitive training and the establishment of group models for machine operation based on agreed and fair regulations.

## 1. Introduction

Mechanization has often been viewed as an important strategy to raise the productivity and reduce the drudgery of agricultural operations. Research in sub-Saharan Africa (and other regions), however, has drawn attention to the complex dynamics surrounding the introduction of these technologies, including their gender implications (Pingali, 2007; Sims and Kienzle, 2006). Currently, agricultural mechanization is experiencing a revival with a stronger emphasis on equitable and sustainable solutions (Houmy et al., 2013).

First attempts to bring motorized implements to medium- and small-scale farmers in sub-Saharan Africa date back to the 1950s and 1960s, when public hiring schemes were launched, mainly for tractor-based services (Mrema et al., 2008). The major constraints these programs faced were unsuitable farm sizes, hiring fees unaffordable for most smallholders, dependence on public subsidies, inefficient administration, and a weak supporting infrastructure for transportation and repairs. As top-down approaches, the programs tended to neglect local conditions, including users' demand and preferences (Sims et al., 2016; Sims and Kienzle, 2006). As a result, “appropriate mechanization” emerged in the 1970s and 1980s with efforts to develop equipment that would match farmers’ realities. When these implements failed in the market and some challenges of the earlier schemes recurred, interest in agricultural mechanization in sub-Saharan Africa declined (Mrema et al., 2008; Agyei-Holmes, 2016). In the wake of structural adjustment, some argued that the private sector should provide equipment and services in a more sustainable manner (Pingali, 2007). In recent years, agricultural mechanization has resurfaced on the development agenda. Some reasons for this are the gap between an increasing demand for food (through population growth) and insufficient supply (Tittonell and Giller, 2013), agricultural labor shortages resulting from rural-urban migration (Houmy et al., 2013), and the new availability of low-cost motorized implements from emerging economies (Agyei-Holmes, 2016). At the same time, scientists are re-conceptualizing mechanization as part of sustainable development (Sims et al., 2016) and as socially embedded and highly gendered (van Eerdewijk and Danielsen, 2015). Based on lessons from the past, sustainable mechanization is described as a demand-driven, participatory and context-specific process that requires the involvement of all stakeholders (Houmy et al., 2013). A new emphasis is placed on establishing attractive business

* Corresponding author.
*E-mail address:* g.fischer@cgiar.org (G. Fischer).

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models, low-cost farmer-to-farmer arrangements, or asset sharing options with clearly defined user rights and responsibilities (Mrema et al., 2008; Sims et al., 2011; Baudron et al., 2015). All the same, for sub-Saharan Africa, detailed empirical insights into the strengths and weaknesses of such new models and arrangements are still hard to find. Based on earlier conceptualizations of sustainable development, Houmy et al. (2013) name three principles of mechanization sustainability: viability in the economic sphere, equity in the social sphere and durability in the environmental sphere. Although Sims and Kienzle (2016) further develop these ideas, they offer no clear delimitation or description of the principles involved.

Turning to gender and agricultural mechanization, the few available studies provide some, but not yet comprehensive evidence, of women's lower rate of access to, and adoption of, mechanized equipment, as compared to men. Female heads without a working-age male in the household seem to be the most disadvantaged (for an overview, see Croppenstedt et al., 2013 and Peterman et al., 2014). For male-headed households (MHHs), the gender gap is explained by men's decision-making power and control of productive resources, as well as their potential disregard for women's interests and labor time (Sims et al., 2016; Doss, 2001). Apart from this, lower educational levels and technical skills may prevent women from using farm machinery. This is due not least to the fact that extension services and technical training are often directed towards men. In addition, social norms may regard mechanized tasks as inappropriate for women (Croppenstedt et al., 2013; van Eerdewijk and Danielsen, 2015). However, these barriers do not restrain women in all cases. Mechanization frequently entails a renegotiation of labor with unpredictable outcomes: women may mechanize their own tasks or transgress into male domains, while elsewhere female jobs may be turned into male enterprises as soon as they become mechanized and profitable (World Bank, 2008; van Eerdewijk and Danielsen, 2015). More in-depth studies of various contexts are needed to better understand these processes of labor reallocation. At the same time, it remains open if, and where, labor-saving technologies come along with new labor requirements (for instance through increased output) and how these are tackled (Doss, 2001).

In respect of mechanized forage chopping, the focus of this paper, there are only two gender-related case studies to our knowledge. Both look at the introduction of non-motorized choppers in regions where forage processing is predominantly assigned to women and done with a machete. In one study, carried out in Tanzania (Lazaro et al., 1999), women's labor time decreased as a result of mechanization for both cutting and forage collection, the latter through the higher efficiency of ground feed. In addition, the availability of machines encouraged men and children to engage in forage processing. The researchers see a greater potential for technology uptake if manufacturers were to consider the differential technical needs of men and women in terms of operation. For Uganda, Kiyimba (2009) shows that women in MHHs had little control over the time they saved through mechanized chopping, and in some cases ended up spending more time working in their husbands' fields. She draws attention to the fact that the “impacts of the machine are partly determined by the household organization” (Kiyimba, 2011: p.39). Her observation of how male and female farmers adjust the choppers to their different needs confirms that gender needs to be considered in the machine design process. Both studies question whether farmers will benefit from higher milk productivity through mechanization if prices remain low and market networks underdeveloped (Lazaro et al., 1999; Kiyimba, 2011).

This paper investigates the gender implications and sustainability of an intervention in which researchers introduced forage chopper machines in seven villages in northern Tanzania in 2015 with the aim of improving the use of locally available feeds in agro-pastoralist households. Farmers established village groups to jointly operate the machines. The focus on mechanization, gender and sustainability seemed promising for two reasons: first, it relates to the refreshed debate on how to make agricultural mechanization not only more sustainable (after decades of challenges) but also more inclusive (Houmy et al., 2013). Second, detailed case studies on gender and mechanization are rare, but are needed in order to conceptualize mechanization sustainability. By adapting the Sustainable Intensification (SI) Indicator Framework developed by Musumba et al. (2017) for the analysis of results, this paper contributes insights to the current debate.

## 2. Materials and methods

### 2.1. Study approach

Our investigation focuses on an intervention that equipped farmer groups with motorized choppers. We make a gender analysis of the resulting changes as well as the sustainability of the technology. For this purpose we use the SI Indicator Framework (Musumba et al., 2017), which was developed to holistically assess the sustainability of innovations in the smallholder context through interdisciplinary research. Although highly quantitative in its approach, it encourages concurrent social science research with qualitative methods, such as focus group discussions. The framework consists of five sustainability domains and thus adds to the three sustainability principles mentioned before (Houmy et al., 2013). The five domains are productivity (in cropping and livestock systems), the economic domain (profitability, labor and market participation), the environmental domain (biodiversity and pollution), the human domain (nutrition, health and capacity to experiment), and the social domain (equity, social cohesion and collective action). Each domain is related to specific indicators. In this article we do not measure indicators, but use the five domains as analytical lenses. Based on farmers' perceptions, we evaluate the forage choppers’ performance and relate this to enabling and restricting conditions in the study context. Unlike the original framework, which assigns gender aspects to the social domain, we integrate them (wherever possible) into other domains using a more encompassing gender approach. This permits a more interdisciplinary exploration of various factors within and across the domains.

### 2.2. Study site

The study presented in this paper was conducted in Babati District, Manyara Region, in northern Tanzania. The intervention sites are divided by the Dabil-Dareda escarpment of the Rift Valley, providing diverse climatic and agro-ecological conditions. The dominating ethnic groups are Iraqw and Gorowa, both agro-pastoralists who mainly cultivate maize, legumes and rice, and keep cattle, goats, sheep and poultry (Snyder, 1996). The district's livestock population is above the Tanzanian average (URT, 2013), although herd sizes and milk production have been decreasing over the past decades due to agricultural expansion, droughts and diseases (Snyder, 2005). The Iraqw keep cattle not only for nutrition and income, but also for religious rituals and bride wealth, and engage in complex livestock loan practices that link wealthier and poorer households (Snyder and Cullen, 2014). Gender relations in livestock keeping remain almost unexplored, except for a limited study by Jonsson et al. (1993). It finds that women provide most of the labor for dairy production, while men take major management decisions, except in respect of income from the milk of local cows. Challenges to livestock keeping include a shortage of grazing lands and forage, triggering land use conflicts; low market prices for livestock products; management practices that do not enhance productivity; inadequate veterinary services, and the lack of availability of breeding facilities for grade cattle (Bee, 2007). Although Babati District has a long history and high rate of mechanized plowing (Kjaerby, 1989), manual food and feed processing still constitute the rule.

Against this backdrop, a team of scientists introduced forage chopper machines in seven villages in Babati District in 2015, with the aim of improving the use of locally available feeds. A prior analysis had shown that crop residues that could be fed to ruminant livestock were

in part wasted due to poor processing, and that, due to lack of grinding, chickens rarely received mixed supplements that could increase growth and reduce mortality rates. Three electric and four petrol-driven machines were purchased from a Kenyan supplier in nearby Arusha where repair services would be available. Before the machines were handed over to the farmers, the scientists conducted two trainings: the first revolved around improving feed in general, and the second served as Training of Trainers (ToT) for machine handling. The attendance list for the latter indicates 21 male and 13 female participants from the seven selected sites. After the ToT, village extension staff supervised the establishment of groups that were to operate the machines. Preconditions for group acceptance were a minimum of 15 members (counting one member per household only), the farmer-led formulation of written rules for machine access and payments for maintenance, for which each group was required to open a bank account. Extension officers encouraged groups to grant machine access to non-members (who should pay a contribution for maintenance), and to establish a gender balance among members and leaders. In late 2015, five of the machines were being operated under male leadership and two under a female chairperson. The ToT participants had agreed to arrange machine demonstrations on market days, to invite individual co-villagers to get to know mechanized processing, and to spread information about the machines. In mid-2016, social scientists joined the biophysicists to investigate gender issues in mechanized chopping on the household and group levels.

### 2.3. Sampling

Data collection for this article was carried out between July 2016 and May 2017 in six of the seven intervention villages. It consisted of gender-separate focus group discussions (FGDs) combined with participatory methods (activity profiles, linkage diagrams and matrix scoring/ranking), and a survey among a large number of the same participants. All in all, we conducted 12 FGDs with 71 farmers (39 men, 32 women) and had 53 survey respondents (28 men, 25 women). Sampling was purposive: Respondents had to come from households that had experience of using the machines. The researchers also accepted respondents who had employed the machines in the past but not necessarily at the time of the study. During the investigation it emerged that a small number of participants who had appeared as users during sampling actually had no access (see 3.6). This provided insights into farmer group dynamics that otherwise would not have been possible. Furthermore, we aimed at recruiting balanced numbers of men and women – a challenge due to the under-representation of female users in certain villages. Although purposive sampling is standard in qualitative research (such as for FGDs), it may have reduced the representativeness of the accompanying survey. As a result, quantitative results apply to the study sample only and may not be generalized, although the survey covered a major part of the village population that employs the technology.

### 2.4. Data collection and analysis

The FGDs concentrated on labor changes, benefits and challenges related to using the machines. To enhance discussions on labor, the participants established activity profiles. Before or after the FGDs, respondents were individually interviewed for the survey. The questionnaire captured demographic details, as well as information on intra-household decision-making, previous knowledge of the technology, training, and willingness to pay. For the matrix scoring and ranking exercises, participants compared manual and mechanized chopping in relation to SI Indicators from five domains (Musumba et al., 2017): productivity (of cattle and poultry), profitability (income from sales), feed quality (as a proxy for reduced greenhouse gas emissions), household dietary diversity (from own production and additional food purchase), and female work-load reduction. The language of investigation was Swahili. All FGDs were transcribed, and analyzed with the qualitative data analysis software Atlas.ti. Findings for each participatory method were compared and collated. Survey data were evaluated with SPSS (Statistical Package for the Social Sciences).

**Table 1**
Respondents' livestock and poultry keeping (n = 71).

| Livestock | Total Percentage of Households | Most Common Herd Size/ Number of Animals |
|---|---|---|
| - Local dairy cows | 42.3% | 4–6 |
| - Improved dairy cows | 64.8% | 1–3 |
| - Sheep | 42.3% | 1–3 |
| - Goats | 39.4% | 4–6 |
| - Pigs | 9.9% | 1–3 |
| **Poultry** | | |
| - Local poultry | 81.7% | 10–13 |
| - Exotic poultry | 4.2% | 3–6 |

## 3. Results

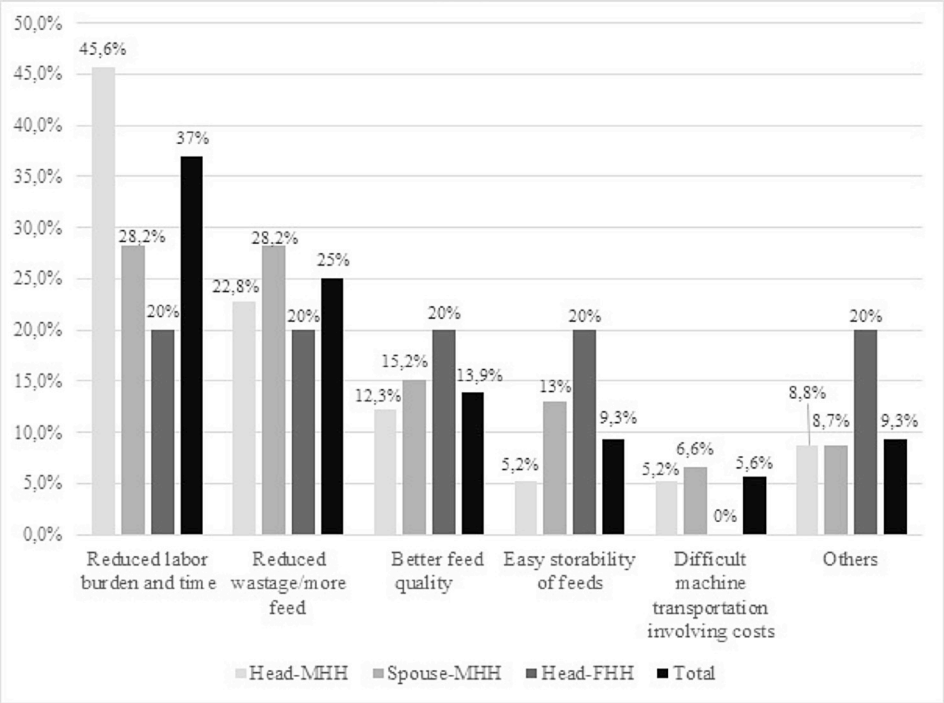
### 3.1. Sample description and general associations with the technology

Our sample consisted of 71 respondents, 39 of them male heads, 27 women in MHHs and 5 female heads. In terms of education, 78.8 percent of them had completed primary school, and 11.3 percent secondary school (all of the latter male). Age-wise, the participants ranged between 20 and 74 years with a mode of 36 years. 84.5 percent of the respondents employ the chopper machines. The livestock they keep and the most common herd size is detailed in Table 1, the contents of which are comparable to other studies in the target region (Snyder, 2005).

The most common farm size (mode) is two acres (mean 4.59 acres). 79,5 percent of the participants cultivate less than one acre for livestock feeds, such as Napier grass (crop residues not counted). Zero grazing is the most prominent system throughout the year, practiced by 48.9 percent of the respondents in the dry season and 45.8 percent in the rainy season. For poultry, 53.0 percent leave their chickens to merely scavenge, while 32.7 percent provide some supplementation. Feeds processed for ruminant livestock are maize stover, Napier grass, natural pasture, bean haulms, rice straw and pigeon peas. For poultry, the feed choppers are used for maize grain, maize bran, sunflower cake, low quality rice, and dried fish. Only slightly more than half of the respondents (53.3%) store all feeds in a permanent structure, while others use temporary shelters (31.1%), or leave the feeds in the open (13.3%).

In the survey, participants named up to three attributes they associate with the technology. This open-ended question was coded during analysis. The results (Fig. 1) for the most part refer to labor issues and feed characteristics. Fig. 1 reflects the low representation of female-headed households (FHHs) in the sample. The evaluation is therefore primarily based on data from MHHs.

82 out of 108 responses were concerned with a reduction in labor time and burden (37%), reduced wastage (25%), and better feed quality (13.9%). While men placed more emphasis on the reduced labor burden and time, women in MHHs mentioned this attribute as often as reduced wastage (and therefore more feed). This could be due to the fact that both attributes are closely related. Less wastage not only decreases the need to clean shelters, but also results in fewer trips to collect additional feed. Similarly, better feed quality was associated with the fact that cows need less attention. The only negative attribute that obtained multiple responses were difficulties in machine transportation. The results of this question reflect farmers' intense engagement with questions of labor, which translates into a larger body of data in the profitability domain (see 3.3).




*Multiple responses were possible. Total number of responses: 108 (57 Head-MHH, 46 Spouse-MHH, 5 Head-FHH). Percentages refer to the share of responses in the respective respondent category.*

**Fig. 1.** Attributes associated with the chopping machine technology.

### 3.2. Productivity

This domain relates to animal productivity in terms of milk, eggs and meat, as well as manure as an animal by-product. The forage chopper machine allows farmers to grind and mix feed ingredients. The participants evaluate ground and/or mixed feed rations as having a better quality and being more filling for poultry and livestock, thereby improving their health and productivity. While both men and women are interested in higher productivity, they also agree that women are often the first to notice changes because of their greater involvement in milking and feeding. Cows that receive machine-chopped fodder give more milk and develop more meat, respondents say. Similarly, poultry keepers report that the mixed and ground feed results in more eggs and heavier chickens. However, they also stress that certain ingredients not available on their farm, such as sunflower cake or larger amounts of maize bran, are often not affordable and limit increased productivity. In addition, some participants question the sustainability (*uendelevu*) of the described gains, and hint at the low number of improved breeding bulls in their environment, the dysfunctionality of artificial insemination services formerly provided by the government, the high susceptibility of poultry to diseases, and the limited availability of livestock officers in the villages. A clear attribution of productivity increases to chopped feed needs to be confirmed by biophysical research.

Changes in manure characteristics and quantity constitute a contested benefit. Some farmers compare the soft manure from ground fodder to conventional manure, which is more solid since it is mixed with feed residues. Two respondents use the soft manure in their gardens and praise it for its quick decomposition. Others prefer the conventional manure since its blend with feed leftovers makes for larger quantities. They see the adoption of the chopper machine as partly dependent on the availability and affordability of other fertilizers. At this point, farmers see an interconnection with input prices (profitability domain) and questions of fertilizer management, which fall under the environmental domain.

### 3.3. Profitability

Data in the profitability domain (also called economic domain) yield information on technology-associated changes in labor and income, and on operational costs.

#### 3.3.1. Labor

The respondents' descriptions of feeding activities provide insights into how mechanization interacts with gendered labor arrangements. They elaborated mainly on the processing of maize stover, the most important feed source in the dry season. In the FGDs, they established activity profiles that are collated in Table 2. Stover is cut and transported to the homestead after the harvest in June or July – an activity that may involve men, women and their children. Due to limited support from their children – older ones often not being available for work (migration, refusal) and younger ones attending school – some

**Table 2**
Activity profile for processing maize crop residues for livestock feed.

| Activity | Who commonly implements the activity? | | | |
|---|---|---|---|---|
| | Male adult in household | Female adult in household | Children and adolescents in household | Hired labor |
| Cutting, collecting in the field | X | X | X | X |
| Transport - Head | | X | X | |
| Transport – Cart, tractor, car, motorbike | X | | | X |
| Storing | X | X | X | X |
| Chopping - Manual | | X | X | |
| Chopping - Machine | X | | | X |
| Feeding | | X | X | |

respondents employ temporary labor. Three women with off-farm income buy maize stover, either because they do not own fields, or in addition to their own. While cutting and collecting is governed by flexible role arrangements, transport has a more pronounced gender division: women and children carry head loads of maize stover to the homestead. Where carts, tractors, cars or motorbikes are used, men tend to take over this activity, often in cooperation with hired laborers. Costs are identified as a key factor in household transport decisions.

> "*Costs are the challenge. (…) if we fail, we tell the wife to carry it on her head*", says one man, and another one adds that "*for a man to carry a head load is against our traditions*".

Women in MHHs who lack control over income describe their dependence on their husbands' good will to relieve them of the heavy loads. Once the stover reaches the homestead, it needs to be stored. This labor step is flexible in terms of gender allocation. Some respondents chop the stover before storing it; others store it without further processing and chop it little by little as needed for feeding.

Chopping is done manually or through the newly introduced machines. Manual chopping makes stover fit into the feed troughs and prevents cows from dropping and trampling on it. Almost exclusively women and children do this job. Stover is placed on a log or sack and cut with a machete (*panga*). In contrast, machine chopping tends to be done by men in the household or by temporary male laborers (sometimes in cooperation with the woman in charge of the livestock). One woman explains the shift of gender roles from manual to machine chopping:

> *"Men are attracted by the simplification of work. The time you use for cutting with the panga! Now you just throw into the machine, your job is only to fill the bags."*

All the same, this simplification requires additional work: for petrol-run choppers fuel has to be purchased. A vehicle has to transport the machine to the homestead. With stationary electric choppers, the material has to be loaded onto vehicles, taken to the machine, and later returned home. These requirements tie in with gender arrangements in the previous step, the transport of residues from the field to the homestead, where men already dominate mechanized options, as well as the opportunity to earn money through temporary employment. Another facilitating aspect for men's appropriation of mechanized labor is captured in Fig. 2. In spite of a high level of involvement of women in feed processing, male heads retain a good degree of decision-making power regarding which sources and methods to employ, thus importantly governing the labor process. This contributes to their better access to machine chopping as compared to their wives and limits women's capacity to experiment with the technology at the household level (an interconnection with the human domain, see 3.5). Mechanized chopping, however, does not completely replace manual chopping. In households in which both improved and local cattle are kept, the machine tends to be employed for the former and the *panga* for the latter. Respondents explain this with the lower milk productivity of local breeds, which does not justify efforts to improve their feed. As a result local breeds are more often herded and only partly fed in stables.

Apart from maize stover, natural pasture and planted grasses are chopped. Women and children do the daily work of feeding and watering, and at times walk long distances in search of water and forage, especially at the end of the dry season. In spite of this fact, male respondents explain the gender allocation of feeding in terms of their wives' "*constant presence at home*". Several female respondents express the wish to use power tillers, or motor tricycles to relieve them of grass and water carrying. A few women spend part of their income from milk sales on hiring labor for these jobs. Others receive help from their husbands who employ bicycles or carts for transportation. Others again resort to partially herding their livestock, but demand for pasture and water sources is high, as several village land use plans confirm. Although respondents view zero grazing as mitigating conflicts between cultivators and livestock keepers, the associated female labor burden is described as high. At this point an interconnection is established between labor (profitability domain), pasture and water availability (environmental domain) and social conflicts over natural resources (social domain).

Turning to poultry keeping, this is definitely regarded as a "*female project*". Feeding tends to be left to women and children, and includes the provision of water, maize bran, low quality rice and leafy vegetables. Where feed is improved and mixed, men indicate some involvement in the purchase of additional components (such as sunflower cake or dried fish) and in mechanized chopping. The general amount of work depends on the degree of caging, with most respondents leaving

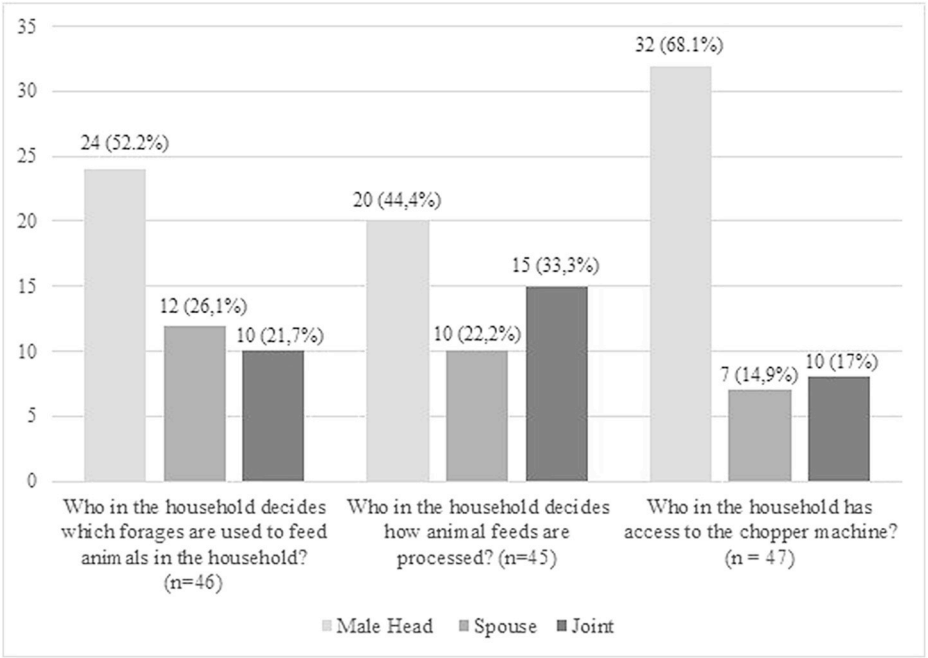



**Fig. 2.** Decision-making on feeds and access to chopper machines in MHHs.

their chickens (at least partly) to scavenge.

Women's feeding activities for ruminant livestock often conflict with their other duties. While some responsibilities demand their presence at home (such as childcare, or milking and watering stabled animals), others require them to leave the homestead (such as herding, or fetching grass and water for stabled animals). One woman says,

> *"If you have time to fetch water, you are lucky. If you cook, you don't fetch water. If you fetch water, you don't prepare ugali (maize porridge)".*

Female respondents depict long working days they find unmanageable. Some experience physical violence from their husbands if jobs are found unaccomplished; others speak of a more supportive environment. The balancing act between domestic and away-from-home activities needs to be kept in mind in order to understand the reduction of labor discussed in the following.

Machine chopping alleviates labor in three ways.

> First, "*it saves time*", says a man. "*You would cut these residues for a long time. If you pass them through the machine, they are processed in a short time*". Secondly, the "*work effort is less compared to cutting with the panga until you get tired*", remarks another man.

Thirdly, this reduction is further facilitated by a reorganization of work: for mechanized chopping some labor steps (such as soaking the sunflower cake or boiling the maize cobs) are no longer necessary. Further relief stems from the shift in gender roles: some women request husbands, adolescent male children or hired laborers to machine-chop while they devote themselves to other activities (however, this may come at the cost of new dependencies). In addition, several respondents with adequate storage facilities process larger amounts, which are then fed on a daily basis. The availability of stored feed mitigates women's balancing act between domestic and away-from-home activities. Especially in the mornings, cows are given stored fodder, thereby reducing the pressure to leave home early in order to herd animals or search for grass. As a result women can arrange their work schedules more flexibly.

Reduced wastage as a benefit is related to the fact that the machine grinds all parts of the maize stover (including stems and cobs). If unchopped, cobs and stems are hard for cows to chew, leading to fodder selection. At the same time, they not only drop larger pieces, but also trample and defecate on them, producing additional waste. Less waste results in less cleaning of shelters and less need to search for (or purchase) additional fodder. Another benefit is the reduced storage space machine-chopped feed needs. This relates especially to maize stover, where large quantities have to be preserved after the harvest. Some respondents lose crop residues due to mold, yet the construction of permanent dry stores constitutes a financial challenge. Here an interrelation emerges with the productivity domain in terms of lower post-harvest losses and higher efficiency of crop residues used as feed. In addition, grinding increases the transportability of stover: two male respondents describe how they employ petrol-run choppers on the harvested fields, resulting in fewer trips to take the residue home.

### 3.3.2. Income

Revenue from milk, eggs and poultry covers educational, medical and veterinary expenses. However, men's and women's access to money from sales, and their spending priorities, may differ. Decision-making on income constitutes an important arena for gender negotiations, as Fig. 3 demonstrates.

Male heads are more involved in decisions on income from ruminant livestock – either as joint or sole decision-makers – than their female partners. For poultry, women control revenue in more than half of the cases, and are additionally engaged in collective decisions. In what follows, this is discussed in the light of the FGD data. For ruminant livestock, a distinction needs to be made between income from milk and meat. This option was not available in the survey and could have

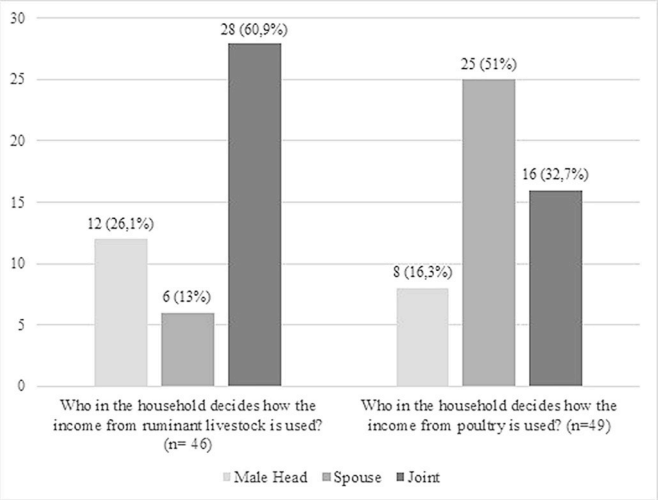



**Fig. 3.** Decision-making on income from livestock and poultry in MHHs.

produced more detailed insights. In FGDs there was a tendency for women to claim sole control over income from milk, but they were not always able to defend this.

> "*As a woman you do all of the work, but when it comes to milking, he stands behind you and counts the liters. (…) When you return home (after sale), (…) he puts the money into his pocket*", explains one woman.

Equally, two men who contribute labor to grass cutting accuse women of hiding the real price at which they sell milk. These women seek sole control over part of the income they would otherwise have to share, they say. These accounts not only speak of power struggles and distrust in some marriages, but also hint at close links between labor investments and justifiable claims on the resultant income. This connection is also cited when joint decision-making is described. Asked how money is used when a cow is sold, one male respondent explains:

> "*You will make a budget, the two of you, because you have cooperated in terms of work.*"

Other men view the revenue from livestock sales as too high for a woman to be involved, and give as reason that cows are owned by men and that patriarchy (*mfumo dume*) allows men to "*audit*" their wives' money but not vice versa. To summarize, in MHHs income from milk is more often subject to sole female control or joint decision-making, while income from livestock sales is appropriated by men or jointly decided upon. In the FHHs in our sample, there is joint-decision-making where a migrant husband retains control from a distance, but there are also women who are the sole decision-makers (where there is no male partner). The market for milk is depicted as unreliable, as a place where customers dictate low prices and often buy on credit. Transport and storage facilities are not available, but several women express their interest in collective marketing if a development actor can facilitate it. Here farmers' groups could serve as a platform for further collective action (related to the social domain).

Unlike milk, poultry products are described as having a high market demand. However, male income control appears to be low. Many men hold that they rarely notice when their wives sell eggs or chickens and that the only benefit they expect is to be served chicken meat once in a while. Yet, female revenue from poultry is used to fend off women's financial requests.

> "*When a woman asks her husband for money, he will say, go and sell an egg. Haven't your chickens laid eggs?*", says a male participant.

Although some men describe the shame they would feel to take a

chicken to the market, they acknowledge the prospects this business could hold for them:

> *"We as men usually depend on cows and goats. But nowadays our opportunities are blocked. Pastures are not enough."*

Development projects, together with the good market for poultry products, are therefore mentioned as fostering a stronger interest in this activity among men. The potential entry of men into this business could be further promoted by the labor they already invest in mechanized chopping. This raises the question (for ruminant livestock and poultry) whether higher male labor investments related to mechanized chopping could fuel increased male claims on revenue. Our data – collected less than two years after the machines were introduced – do not reveal changes in this field. However, respondents think that further income gains could stoke up gender struggles. In several FGDs women established connections between income gains and the labor alleviation they wish for through temporary workers. Women's low control of household labor – especially for the provision of grass and water – explains this interest in more reliable paid support. At the same time, low control of income was seen as threatening this plan. Interestingly, male respondents were less committed to reducing the household labor burden through paid work. In one village, they saw future income conflicts as revolving more around men marrying additional wives, and women spending more on clothes and on visits to relatives. The attribution of (real) income gains to the chopper technology needs further validation.

#### 3.3.3. Operational costs

Sharing one machine requires farmers to haul feed to the stationary electric chopper or to move the petrol-driven chopper to the homestead. Respondents distinguish three kinds of operational costs: transport costs for either the feed or the machine, costs of temporary labor to assist the chopping, and costs for petrol or electricity. They calculate that chopping the load of one cart (*mkokoteni*) with a petrol-driven machine requires 6500 Tanzanian shillings (equivalent to three US dollars or the sale of eight liters of milk at 800 Tanzanian shillings/liter). These consist of 2000 Tanzanian shillings (TSH) for transport, 2000 TSH for part-day temporary labor and 2500 TSH for one liter of petrol. Contributions for electricity (electric chopper) are 1500 TSH, but chairpersons accept payments in kind (often part of the ground fodder). Additional money is charged for potential machine repairs. Costs for transport and labor can be avoided or reduced. This happens when farmers possess their own vehicles or share the chopper with neighbors. The proximity of members to each other was not considered during group formation in 2015, and in some cases resulted in transportation over several kilometers. Therefore, respondents proposed making proximity a precondition for the establishment of future groups, and that choppers on wheels (or choppers fixed on platforms with wheels) would make transport easier. Some farmers reduce costs by chopping large amounts of feed in one go (a suitable storage place being a requirement) or by replacing temporary paid labor by unpaid labor. However, for women the exchangeability of paid and unpaid labor depends on their confidence in using the machine (without male support), and on the way labor and income are controlled within the household. One of the female heads who has control over income has nevertheless abandoned using the chopper: her income from milk sales is too small to be able to afford machine transport and petrol, while at the same time she assesses her own ability to operate the chopper as low. Having no adolescent children to support, she has returned to using the *panga* and uses the small income she has from selling milk to improve her children's diet. This suggests complex interrelationships between household dynamics, training, operational costs and the dysfunctional dairy market in the study area.

### 3.4. Environment

Data in the environmental domain are related to feed quality, fertilizer management practices and zero grazing. Farmers' linkages between environmental issues and the technology remain vague. Therefore, further research (especially using biophysical methods) is needed.

As presented in Fig. 1, 13.9% of the survey respondents associate the chopper with better feed quality, which they see as resulting from grinding (livestock and chicken ingest and digest feed more easily) and from mixing various fresh and dried ingredients during chopping. Feed processing and forage mix as proxies for green house gas emissions need to be examined by livestock scientists. Another point for further investigation is the changed composition and volume of manure from chopped feed (see 3.2). Farmers view the partial or complete replacement of manure with chemical fertilizers as dependent on the availability and affordability of the latter. However, implicitly this also raises questions of fertilizer management practices and their impact on the soil. Finally, in a situation of land pressure in the investigated area, it is open as to how zero grazing (promoted through the technology) interacts with soil erosion and the increased use of crop residues as feed. The respondents themselves did not elaborate on this. They made clear that zero grazing is only partially practiced, with local breeds still being herded. Overall, stall-feeding was depicted as resulting in less community conflicts and a potential increase in the workload of female livestock keepers.

### 3.5. Human domain

This domain relates to the availability of animal products for home consumption, dietary diversity (as supplementation of certain food groups through purchase) and the capacity of men and women to experiment with the technology, all of which are "dependent on social interactions (such as within the household or community)" (Musumba et al., 2017: p.7).

The farmers indicate that they use some income from selling milk, eggs and chickens to purchase additional food for the household, such as fruit. However, school fees and stationery, as well as medical and veterinary expenses are given higher priority. Dietary improvements are explained as mainly stemming from the consumption of their own produce, with consumption patterns varying considerably. A small group of men refers to a "*traditional privilege*" that allows them to be the main consumers of milk and eggs in their households. Other respondents give larger shares to children or equal shares to all household members. Most participants balance production for income and for consumption depending on household needs and on the market.

> "*The milk we sell has a low price to an extent that it is not profitable. But (…) if you do not produce, the children will lack good food*", says a woman.

It is important to note that not all respondents view mechanized chopping as having an impact on household nutrition. As one man states:

> *"Changes in the quality of my food at home haven't been brought about by the panga or by the machine. I don't see any difference."*

It seems that increases in productivity and income do not necessarily lead to improved nutrition, and that where this is the case, the farmers do not always perceive the relationship as important.

Looking at the capacity to experiment, gender dynamics in households and farmer groups emerged as playing an important role. Access to the machine constitutes a prerequisite to experimenting with the technology and evaluating it. As Fig. 2 shows, 68.1% of the heads in MHHs had access to the technology, as opposed to only 14.9% of the spouses. In 17.0% of the households both partners had machine access. This result differs in one particular village, where a slightly higher number of female survey respondents (25%) have access to the machine and indicate that they are confident in using it, leading to a lower dependence on their husbands, as confirmed by male co-villagers.

Turning to the farmer groups, men did not mention having problems with the technical set-up of the choppers. Women's ability to handle the implement, however, was contested.

> "*For now, men have some knowledge of how to use the machine, but women still do not have it. You know, the machine is a technical device. It is not easy (for them) to get used to it*", explains a male participant.

Two men add that handling the choppers is dangerous, and thus needs special skills and should not be left to women and children. In the village that stands out through women's more confident machine operation, men speak of precautions for children but describe their female co-villagers' good technical skills. Women in this group confirm that they can easily start their petrol-driven chopper by pulling a cord. It is exactly the same model that causes women problems in two other villages. They claim not to possess the physical strength needed for pulling the cord, and would prefer electric choppers with starting buttons, but their villages have not yet been connected to the grid. Some women employ male temporary laborers exclusively for starting the chopper, while they manage the subsequent chopping themselves. Apart from this, respondents mention other reasons why women are less involved in operating the machines, the most prominent one being training. One woman remembers the chopper demonstrations in her village:

> *"They (men) were standing there and doing their job. Women were supposed to watch. They were not given priority in the sense of come to the front and have a try. This is why we say we are not able and we employ people."*

This account is in line with reports from other sites and confirmed by the survey results captured in Table 3.

Women in our sample had less previous knowledge of the technology, and participated less in trainings than their male counterparts. Female respondents say this is due to fewer invitations being extended to them, a high domestic workload that keeps them away from meetings, their disinclination to expose themselves to training, and in some cases the absence of women in group leadership. This last point – read as gender-sensitive leadership – contributed to the higher confidence of female machine users in the said one village. The chairman of the group, his wife and three female trainers offer ongoing support to women who want to use the chopper.

### 3.6. Social domain

This domain deals with collective action and the resolution of conflicts pertaining to agriculture. While the original sustainability framework (Musumba et al., 2017) assigns gender issues to this domain, we integrate them into all domains.

In the data, respondents mention benefits as well as challenges arising from collective machine operation. Insights into conflict-laden group dynamics, however, were limited by the selected methodology. The questionnaire's structured nature did not allow individuals to elaborate on arguments. Likewise, the setting of the FGDs (organized by the donor with other farmer group members present) discouraged participants from engaging in open disputes. Therefore, in future studies the available data should be supplemented by individual in-depth interviews.

Benefits experienced at the household level are in part linked to group operation. In one village, female poultry keepers meet on scheduled days to jointly use the machine. This is to support each other in machine handling, and to improve feed quality, as they explain. On the planned day each member brings the feed material she has best access to. After grinding and mixing all the material, the feed is shared proportionally to what each member has contributed. In another village, livestock keepers have embarked on a discussion on how to further alleviate labor through mechanization, for instance through the joint purchase of a motor tricycle for grass transportation. We may conclude that collective operation may bring benefits. Nevertheless, ownership at household level still seems to be preferred: 92.3% of the male survey participants and 100% of the female participants (both in MHHs and FHHs) indicate a willingness to buy a chopper for their exclusive use. However, a total of 66.7% of the women said they could not afford to buy a machine. In contrast, 77.3% of their male counterparts saw the machine as being within their financial reach. In the FGDs, men claimed to have a higher amount of money at their disposal than the women, but concurred with them that the machine could only be purchased by a group. At the time of the study, the chopper was being sold at 1.7 million Tanzanian shillings, equivalent to 750 US dollars or four cows, as calculated by respondents. This result points to the challenges in respect of collective operation.

As outlined in 2.2, groups were required to have a minimum size (15 farmers) with a gender balance among members and the leaders, to establish a written constitution (regulating machine access and financial contributions), and to grant access to non-members. Our results reveal that groups differ in the extent to which they adhere to these rules. Four aspects emerged as strongly associated with the accessibility of the machines: group size, commitment to public machine demonstrations, gender balance, and clear rules for machine use by members and non-members. With regard to these aspects, two villages constitute the extreme ends on a continuum of accessibility, with the others located somewhere in between. A group we will call A has the highest accessibility. It has 20 members with fairly well balanced gender proportions (8 female, 12 male). There are public machine demonstrations that have produced a considerable demand. Non-members can access the chopper through the chairperson. Financial contributions by members and non-members are stipulated and known. Group A has the most confident female machine users (and has been mentioned several times as outstanding). By contrast, group B consists of couples from five households. Only men participated in the ToT. During the FGDs in this village, it became obvious that some respondents (who had been perceived as users during sampling) actually had no access to the machines. A female member of the chopper group, when questioned about accessibility, said:

> *"Nobody has come and asked to use the machine. (…) We could have a meeting or a demonstration to attract people, but maybe we should request a second machine first because this one was given to the five households."*

To better investigate the group dynamics, the FGD facilitator invited four female non-users at the end of the discussion to stay behind for a separate and confidential talk. Here, the women explained that the introduction of the chopper "*was kept secret*" at the beginning. As soon as non-members demanded machine access, they were told that the rules had not yet been agreed upon. After almost a year, this situation had not changed. Other village groups constitute nuances between the extremes A and B.

**Table 3**
Previous knowledge of the technology and participation in training.

| Previous knowledge of chopper machine (n = 52) | MHH | | | FHH | Total |
|---|---|---|---|---|---|
| | Male Head | Spouse | Head and Spouse | Female Head | |
| - Previous knowledge | 13 (48.1%) | 3 (13.6%) | – | 1 | 17 (32,7%) |
| - No previous knowledge | 14 (51.9%) | 19 (86.4%) | – | 2 | 35 (67,3%) |
| Participation in trainings on chopper machine (n = 42) | 25 (59.5%) | 8 (19.0%) | 6 (14.3%) | 3 (7.1%) | 42 (100%) |

**Table 4**
Mechanized forage chopping in the light of the five sustainable intensification domains.

| | Productivity | Profitability | Environment | Human Domain | Social Domain |
|---|---|---|---|---|---|
| Performance | • Higher productivity (meat, milk and eggs)<br>• Changed manure composition and volume contested<br>• Improved animal health<br>• Higher efficiency of crop residues for feed<br>• Lower post-harvest losses (better storability) | • Good income and income control for female poultry keepers<br>• Dairy production minimally profitable<br>• High operational costs for choppers<br>• Female labor reduction | • Improved feed quality<br>• Changed manure composition and volume raise questions of fertilizer management | • Dietary improvements (dependent on household consumption patterns)<br>• Differential capacity of men and women to experiment with mechanized processing | • Group operation as potential platform for collective action<br>• Reduced conflicts between livestock keepers and cultivators<br>• Potential community conflicts linked to machine access and economic development |
| Enabling or Limiting Conditions | • Dysfunctional breeding institutions for grade cattle<br>• Poor veterinary services<br>• Functionality of maintenance services unclear<br>• Limited prevalence of adequate stores for crop residues | • Underdeveloped milk market<br>• Labor and income allocation as arenas for gender struggles<br>• Inadequate stores for feed result in higher operational costs and inflexible female labor schedules<br>• Proximity of group members reduces operational costs<br>• More training for women could reduce their operational costs<br>• High input prices (feed supplements, fertilizer to substitute manure) | • Limited pasture, water sources and gazetted grazing areas<br>• Zero-grazing potentially linked to higher female workload | • Women's access to machines and capacity to handle them relates to gender dynamics at household and farmer group level | • Clear rules on machine access and contributions |

Conflicts as described for group B may be the reason why some men anticipate future tensions between wealthier machine users and members of the community experiencing less economic development.

> "*Things will be good, but you will feel that the community looks bad upon you. Now you start fearing being bewitched*", one man says.

Some respondents say that local healers are likely to be consulted to protect the new wealth. Forecasts of community conflicts involving envy and superstition (*ushirikina*) may be seen as potentially limiting respondents' engagement with mechanized production. This could be countered by open access to the choppers based on agreed and fair rules and contributions.

## 4. Discussion: mechanized forage chopping and its sustainability

In this part of the paper we first discuss the technology's performance as seen by farmers and link it to enabling and limiting conditions in the study context (Table 4). After this, we evaluate the SI Indicator framework in terms of its usefulness for gender-sensitive technology assessments. Finally, we consider how the chopper's sustainability could be promoted in the given environment.

### *4.1. Mechanized forage chopping: performance, enabling and limiting conditions*

In terms of productivity, the farmers compared animals fed on manually chopped and machine-chopped feed and observed productivity gains in the case of the latter, a claim that needs to be confirmed by further research. Respondents were also concerned about the changing characteristics of manure. The health of animals fed on machine-chopped feed was considered improved. Chopping was seen as resulting in a higher efficiency of crop residues for feed, and in better storability, leading to lower post-harvest losses. However, the overall productivity was seen as being threatened by dysfunctional livestock breeding institutions and poor veterinarian services at the village level. These limitations are also stated in the unpublished land use plans of three of the intervention villages. The availability of maintenance services was only marginally discussed (the choppers still being relatively new), but could affect the sustainability of production in future.

Turning to profitability, poultry keepers reported good income from sales, which in most cases women had control over. Cattle keepers, however, found that the dysfunctional dairy value chain rendered their activities minimally profitable. This is supported by other studies on dairy production in northern Tanzania (Kilelu et al., 2017). In addition, labor and income allocation were described as arenas for gender struggles: although men's appropriation of mechanized chopping may relieve women, it may also create new dependencies on male household or temporary labor. At the same time, women saw intensified production as only sustainable if accompanied by further mechanization or paid support. Some anticipated that a high initial labor investment on their part would increase income, which they would partly use for paid support – a plan many women felt their husbands would not consent to. Both cattle and poultry keepers spoke of high operational costs for the choppers. These costs were seen as being reducible through group formation based on proximity, increased training in chopper handling (especially for women, to reduce their dependence on paid labor), and the construction of adequate stores to avoid feed losses (a link to the productivity domain) and to enable farmers to chop larger quantities in one go. High input prices were described as limiting the supplementation of feed and the partial or complete substitution of manure with other fertilizers.

Looking at the environment, feed quality, the chosen indicator for the matrix scoring exercises, was meant to serve as a proxy for reduced green house gas emissions (from a biophysical perspective). Farmers attested to better quality, but women associated this indicator with less labor, since animals were perceived as needing less attention.

Respondents raised the point that changes in manure composition and volume could necessitate new fertility management practices. Limited pasture and water sources, as well as the lack of gazetted public grazing areas, question the sustainability of extensive or semi-intensive livestock keeping. However, zero grazing brings up new labor demands that often affect women's workload (Bain et al., 2018). “Many Iraqw object to stall-feeding as too labor intensive”, Snyder claims (2005: p.98).

In terms of dietary improvements (as part of the human domain), both men and women confirm dual production purposes, namely production for sale and consumption. Revenue is in part used to supplement a diet based on the farmers' own produce. Dietary improvements, however, depend on consumption patterns within the household that may not always be to the equal benefit of all. Milk production for child nutrition is highly valued, as confirmed by a study among Iraqw women, in which “no cattle” and “no milk” emerged as being among the respondents' major stressors (Pike and Patil, 2006). Not all respondents validated a connection between the chopper technology and household nutrition. The capacity of women to access and experiment with the machines emerged as being dependent on gender dynamics at the household and community level (cf. Achandi et al., 2018).

Turning to the social domain, the study reveals contradictory social dynamics. Operating the choppers in groups may serve as a platform for further collective action. Zero grazing (often associated with this technology) may reduce conflicts between livestock keepers and cultivators. All the same, new tensions may arise between those who have and those who do not have machine access and concurrent economic development or labor alleviation. Some participants referred to this by mentioning magic and superstition in relation to income gains. On a broader scale, Snyder (2005) discusses how Iraqw communities view witchcraft as thwarting development. Further research should establish group models that farmers may discuss and adopt for joint and equitable machine access.

### 4.2. Evaluating the framework

The objective of the SI indicator framework is “to provide indicators for assessing the relative sustainability of an innovation across the five domains” (Musumba et al., 2017: p. 3). It encourages a holistic and interdisciplinary approach to evaluating the performance of technologies in the context of sustainable intensification.

With its holistic aspirations, the framework enabled us to explore the sustainability of the chopping technology and its associated dynamics. It takes into account the proposal made by Houmy et al. (2013) to reconceptualize the sustainability of mechanization and broadens it by adding two domains (the human and the productivity domains). The clear outline of the framework's domains served as an integrating structure and an analytical lens for the empirical data we collected. Interconnections established between domains contributed to a dynamic picture of the chopper's performance under both enabling and limiting conditions.

Our engagement with farmers allowed us to generate hypotheses confirmed as being relevant to their realities. These hypotheses need to be validated by further research, especially by biophysical data. A more comprehensive survey could complement the evaluation. As Musumba et al. (2017) write, “research to assess SI innovations needs to be interdisciplinary, drawing upon the theories and methods of the biophysical and social sciences”. The interdisciplinary character of the framework could be further strengthened by integrating gender analysis into every domain (as we have done in this article) instead of assigning gender to the social domain. A first step towards integration could consist of making sex-disaggregation for gender analysis a standard (Doss and Kieran, 2013) for data collection across domains – wherever information on farmers is gathered. This would not only foster interdisciplinary cooperation and gender mainstreaming, but could also reduce costs. Gender integration does not render the social domain redundant. In our case, the latter contains results relating to collective action and conflicts that do not duplicate other domains' gendered results. Without integrated gender analysis, researchers are at risk of relegating gender to the social domain and pursuing a multi-disciplinary instead of an interdisciplinary gender mainstreaming approach to technology evaluation.

An additional point linked to the framework's interdisciplinary character is the following: comparing the volume of data we collected across domains, there are less detailed insights in the productivity and environmental domains than in the other domains. The profitability domain yielded most information, followed by the human and social domains. This may be explained by the farmers' concern with labor and income issues, as well as with social dynamics at household and community levels. Questions in the environmental domain did not appear to be a priority for the respondents. This is in itself a result. However, the uneven data distribution may also relate to the fact that productivity and the environment are strongholds of biophysical research within the framework, while the areas in which farmers are mainly engaged fall into the more “traditional” field of social science research. In spite of this, social scientists (including the authors of this paper) could in future think about additional or new ways (methods, indicators, etc.) to better populate those domains that “traditionally” do not belong to their disciplinary focus.

The results generated by using the framework draw attention to the unabated importance of known challenges to mechanization, such as high operational costs or weak supporting infrastructures. At the same time, they raise issues which the sustainable mechanization debate has just started to consider. These are, among others, equity aspects that pervade many domains, and the question of how groups can operate machines.

### 4.3. Suggestions for future research and development

After description and analysis of the empirical results, what are the lessons to be learned from this study? How could future research or development interventions build upon this research and make the technology more beneficial, equitable and sustainable for livestock and poultry keepers? The sustainability of the technology in the given environment could be promoted by the following measures:

1. Use of household methodologies (Bishop-Sambrook and Farnworth, 2014) to address gender negotiations on income and labor, as well as household patterns of consumption and machine access in support of equitable solutions.
2. Strengthening of the public and private supporting infrastructure (breeding, veterinary and maintenance services) to keep up and enhance productivity.
3. Development of market networks, especially for the dairy value chain, in order to raise profitability, while at the same time considering female participation and gains (Coles and Mitchell, 2011).
4. Establishment of group models considering proximity, while at the same time granting broad access to non-members based on clear regulations and fair contributions, to reduce operational costs and community conflicts.
5. Development of gender-sensitive training units for chopper handling, as well as for gender-sensitive group leadership, in order to decrease women's operational costs and their dependence on male labor.
6. Activities to improve existing feed storage facilities, or to build new ones, by using low-cost or free materials available on farms to increase profitability, reduce (female) labor and enhance more flexible labor arrangements.
7. Establishment or strengthening of manufacturer-farmer exchange for the inclusion of gender aspects in the development and modification of the machines.

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None.

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