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# Intensifying Inequality? Gendered Trends in Commercializing and Diversifying Smallholder Farming Systems in East Africa

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While the commercialization and diversification of agricultural and livestock systems have been identified as key global strategies for climate change adaptation and mitigation, less is known as to the large-scale gendered impacts that are implicated in these transformations among smallholder crop and livestock farmers. This study explores these gender impacts across different farming systems and gender-respondent-household typologies using data from the Rural Household Multiple Indicator Survey (RHoMIS) in 2,859 households in three East African countries—Ethiopia, Kenya, and Tanzania. Female control scores over incomes or foodstuffs produced through both on and off farm activities were highest in farming systems that had more land and more livestock. However, increasing commercialization—defined herein as the increasing importance of crop and livestock sales to farm households—resulted in an overall decline in female control across all farming systems and gender-respondent-household typologies. In contrast, crop and livestock diversification were positively associated with female control across gender-respondent-household typologies. Analysis of specific crops and livestock products across farming systems and respondent typologies revealed women have far greater control over decisions related to consumption than decisions related to sales, although the gap between the two were less pronounced in lesser-valued livestock products (chickens, eggs). However, the analyses suggest that as sale of crops and livestock increase, female control over these areas could likely diminish, regardless of specific activity. The authors conclude that approaches to adapt to or mitigate climate change that rely on increasing market orientation of smallholder production will likely intensify men's control over benefits from production, whereas diversification will likely have a more positive impact on female control. Thus, climate adaptation strategies promoting increased diversification will likely have a more positive impact on women smallholders than commercialization alone. The authors recommend that when commercialization is the target intervention, it must be accompanied by a gender differentiated analysis of trade-offs and risks to mitigate the potential negative consequences shown in this study.

**Keywords: gender, gender disaggregated data, climate change, adaptation and mitigation, commercialization, diversification, agriculture, livestock**

## INTRODUCTION

Commercialization and diversification of smallholder farm production have been identified as key global development strategies in assisting farmers adapt to and mitigate climate change[1]. The diversification of crop and livestock production is generally highlighted as a climate change adaptation strategy (Djurfeldt et al., 2018) whereas commercialization of farming systems is noted as both an adaptation strategy when related to increased income (Howden et al., 2007; Bryan et al., 2013) and as a mitigation strategy when related to livestock intensification (Gerber et al., 2013; Herrero et al., 2014)[2]. Diversification strategies in agriculture and livestock production include increasing the variety of production locations, crop and livestock species, enterprises, and income sources (Harvey et al., 2014; Waha et al., 2018). It is hypothesized that farmers willing to adopt these strategies are buffering themselves from the yield risks associated with variability in climatic conditions (Buechler, 2016) and the price risk of unpredictable commodity markets (Bradshaw et al., 2004). Commercialization strategies in agriculture and livestock production are theorized to increase farmer's income, a benefit linked to furthering the goals of poverty alleviation, enhanced food security, and emission reduction goals through intensified livestock production practices (Edmunds et al., 2013; Farnworth et al., 2017).

While these studies laud the impressive environmental and economic benefits associated with diversification and commercialization, less is known as to the large-scale gendered impacts that are implicated in these transformations among smallholder farmers. Because gender power relations are deeply embedded in livestock and agricultural systems (KIT, 2012; Orr et al., 2016; Tavenner and Crane, 2018a), these relationships influence how smallholder farmers are able to take up climate change adaptation and mitigation strategies. Recent research (Twyman et al., 2014) confirms that there can be considerable differences between men and women in making on-farm changes to adapt to climate change based on local cultural and gender norms. Notably, there is growing concern that these shifts in market and on-farm practices could potentially disenfranchise women by intensifying men's control over decision-making in these areas (Chanamuto and Hall, 2015; Rao, 2016).

Although the potential for female disenfranchisement in increasing commercialization and market orientation has been documented across a wide array of commodities and farming activities (Anderson et al., 2012; Njuki and Sanginga, 2013; Silvestri et al., 2015; Forsythe et al., 2016; Tavenner et al., 2018), robust statistical analysis of standardized indicators across farming systems investigating these relationships are severely lacking. This scarcity is noticeable considering the demand at the global policy level for generating gender equitable and socially inclusive development outcomes for the world's smallholder farmers (notable standardized indicators include the Women's Empowerment in Agriculture Index (WEAI) (Malapit et al., 2015), the Women's Empowerment in Livestock Index (Galiè et al., 2018), and the CCAFS Gender and Climate Change Survey (Bryan et al., 2018). Moreover, the issues of gender respondent bias and the social phenomenon of gendered reporting have also been largely ignored in quantitative agricultural and livestock studies, with a few exceptions (Deere et al., 2012; Twyman et al., 2015; Tavenner et al., 2018). This is surprising considering the long-standing recognition within feminist studies and the gender and development literature that gender takes its meaning from its intersection with other axes of social difference, including marital status (Carr, 2008; Nightingale, 2011; Ravera et al., 2016; Djoudi et al., 2017). While there is a growing area of quantitative scholarship around gender and climate change (Mason et al., 2014; Perez et al., 2015; Tibesigwa and Visser, 2016; Assan et al., 2018), these studies have used binary household headship as their level of gender data disaggregation and eschewed more in-depth respondent analysis.

To address these topical concerns and methodological gaps, this study aims to explore the relationships between female control and three on-farm climate change adaptation and mitigation strategies (commercialization, crop diversification, and livestock diversification) in East Africa using a large dataset collected using the Rural Household Multi-Indicator Survey (RHoMIS). East Africa is at the global vanguard of intensification of smallholder production, with Ethiopia, Kenya, and Tanzania each having national policies that explicitly promote this goal. These include the Livestock Master Plan (LMP) in Ethiopia (Shapiro et al., 2015), the Agricultural Sector Development Program Phase II in Tanzania (Michael et al., 2017), and the

[1] Climate change mitigation in livestock production is related to lowering the GHG emissions intensity in the sector to reduce the causes of climate change. Climate change adaptation is related to the adoption of social and/or technical practices that buffer production/profitability against climate driven shocks (i.e. drought, flood), to reduce the impact of climate change.

[2] While smallholder farmer intensification is driven by many factors, including but not limited to access to markets, technology, population density, and economic, political, and social change, this study focuses on crop and livestock commercialization and diversification as they are implicated in climate change adaptation and mitigation to align with *Frontiers* special issue research topic on "The Feasibility of Large-Scale Action for Adaption and Mitigation".

Big Four Agenda in Kenya (Office of the President GoK, 2018). Each of these policies effectively prioritize the productivity and commercialization of smallholder farmers, with plans to enhance large scale food production through innovations in livestock, fish, and crop systems. At the same time, concerns over the "climate-smartness" of this agenda are beginning to be addressed, for example, through the drafting of a Nationally Appropriate Mitigation Action Plan (NAMA) in Kenya (Farnworth, 2015).

The study explores three hypotheses investigating how the overall female control over the benefits of on and off farm activities is related to market orientation (representing the commercialization strategy of the household), crop diversity and livestock diversity, and how these relationships are mediated by the gender of the respondent giving the survey information and the household type:

HYP 1: Gender-respondent-household typology influences the intercepts and relationships between the female control indicator and other variables (i.e., a gender respondent bias is present). This hypothesis is underpinned by the extant literature that suggests the respondent's gender and household type can play important mediating factors in household survey response trends (Fisher et al., 2010; Kriel et al., 2014; Tavenner et al., 2018)

HYP 2: Market orientation is negatively related to female control (as market orientation increases, female control decreases). This hypothesis is underpinned by the extant literature that suggests as market orientation increases, women's control over agricultural and livestock production diminishes, even over those activities that may have formerly been under their control (Anderson et al., 2010; Quisumbing et al., 2015; Hakizimana et al., 2017).

HYP 3: Crop and livestock diversity are positively related to female control (as crop and livestock diversity increases, female control increases). Underpinning this hypothesis is the extant literature that suggests increasing diversity in these areas may lead to more equitable outcomes for women compared to a sole focus on intensifying production and market orientation in a few commodities (Cole et al., 2014; Djurfeldt et al., 2018).

The remainder of the paper is organized as follows. The next section describes the methods and materials used in the study, including some background on the RHoMIS survey tool and the rationale for the different indicators and comparisons. The results from the descriptive statistics, ANOVAs, and binomial regression analyses follow. The final section discusses the gendered trends emergent from the study in commercializing and diversifying smallholder farming systems, and the methodological and programmatic implications of these trends for farmers and policy makers.

# METHODS

## Data Sources

Data for this analysis was sourced from household characterization surveys in three countries: Ethiopia (496 households), Kenya (903 households), and Tanzania (1,460 households). Stratified random sampling of rural land-holding households were used in each given location: in Ethiopia surveys were executed in the north (Tigray) and the central highlands; in Kenya surveys were executed in Wote, Nyando, Baringo, and Kitui while in Tanzania data was sourced from Iringa, Dodoma, Tabora, Zanzibar, Lindi survey applications and one country-wide application focusing on livestock holders. Different institutes were leading the RHOMIS applications. TreeAID is a UK-based international NGO focusing on the African dryland systems, implementing tree-based solutions to improve the livelihoods of rural households. All other applications were led by organizations from the CGIAR, i.e., ILRI, ICRAF, and Bioversity International, that focus on research for development in low- and middle-income countries. All RHOMIS applications served as baselines for a range of different projects, listed in **Table 1**, aiming to characterize the diversity of livelihood strategies and welfare levels in the different sites. The difference between numbers reported under households surveyed and households analyzed is caused by missing gender differentiated information.

The household characterization data were collected with the RHoMIS survey tool. RHoMIS is a household survey tool with data storage and analysis functions included, designed to rapidly characterize the state and change in farming households by a series of standardized indicators. It was designed in response to an expressed need from development practitioners to improve current approaches in targeting and prioritization of intervention options and the monitoring of farm households (Hammond et al., 2017; Fraval et al., 2018). The standardized method of data collection facilitates the creation of libraries of datasets, survey implementations, and visualization tools for open-source use. The data used in this study has been compiled from various individual research projects—illustrating the benefit of using such harmonized data collection tools.

RHoMIS provide a rapid characterization of farming systems, including household and farm welfare and livelihood strategies (see Hammond et al., 2017 for an overview). This study examines the relationships between several of the farm and household level indicators and the female control indicator included in RHoMIS (van Wijk et al., 2016). We analyzed four indicators, and the information underpinning these indicators, in detail: female control; market orientation; crop diversity; and livestock diversity as well as standard farm (household) characteristics like farm area, livestock holdings, and income (in US$, purchasing power corrected).

The female control indicator of RHoMIS represents the control that women have over the benefits of on and off farm activities (i.e., cash or food) while market orientation, crop diversity, and livestock diversity were chosen as key indicators to represent the potential areas for climate action in smallholder farming systems. The RHoMIS female control indicator was created to quantify the extent of women in decision-making and household resource management (van Wijk et al., 2016). The indicator is constructed based on three questions asked for each farm product or income source: who usually decides what to eat, when to eat it, and who sells it (i.e., who does the selling and receives the associated income). Possible answers

**TABLE 1 |** RHoMIS household surveys used in this study.

| Country | Project | Region | Households surveyed | Households analyzed | Year of survey | Agro-ecosystem |
|---|---|---|---|---|---|---|
| Ethiopia | Bioversity International, SAIRLA | Tigray | 300 | 209 | 2017 | Mixed |
| | TreeAID | Central highlands | 300 | 287 | 2018 | Mixed |
| Kenya | CCAFS | Wote and Nyando | 320 | 306 | 2016 | Mixed |
| | Bioversity International, SAIRLA | Makueni | 330 | 237 | 2017 | Mixed |
| | SCAN-ICRAF: sanitation and nutrition monitoring | Baringo and Kitui | 400 | 360 | 2017 | Crop based |
| Tanzania | Bioversity International, SAIRLA | Southern Agricultural Zone | 600 | 485 | 2017 | Crop based |
| | ILRI- Livestock vaccination monitoring | Across country | 993 | 975 | 2017 | Livestock based |

are "household males," "household females," "children," and/or "other." The information was aggregated to an overall score by weighing each activity along the importance it has in the food availability indicator that quantifies potential supply of calories to the family of different on and off farm activities resulting in a final score between 0 and 1, where 1 implies that women in the household decide completely what happens with benefits generated by different on and off farm activities, 0.5 implies that 50% of the overall weight of the activities is being decided on by women, and 0 implies that women have no decision control over the benefits[3]. This indicator therefore does not deal with ownership of assets, but with the agency to decide what to do with the benefits that result from these resources (Hammond et al., 2017).

Market orientation is also calculated on the basis of the food availability indicator by calculating the relative importance of sales of farm produce over the total set of farm activities (Frelat et al., 2016; Ritzema et al., 2017). It also has a value between zero (no farm produce is sold) and one (all farm produce is sold), with various other intermediate values categorizing proportions of product sold. Crop and livestock diversity were calculated by simply summing the total number of different crops cultivated and livestock species kept on the farm (Waha et al., 2018).

## Data Analysis

To quantify possible effects of gender respondent bias and household type, we generated three gender-respondent-household types. The first separation we made was between female single households (in the data there were no male single households) and couple households. Then for the couple households we defined two types to account for possible respondent bias: male respondent and female respondent. Thereby we ended up with three types: male-coupled respondents, female-coupled respondents, and single-female respondents. This allowed us to analyse the effect of gender respondent bias on the female control indicator and its relationship with other indicators in detail (by comparing the results of the two coupled household types) and of household type (by comparing the results of the female single household type with the coupled household types while controlling for respondent bias).

We analyzed the female control information in different steps. In the first step we quantified the female control values across the respondent—household types and in relation to differences in the amount of productive resources that the farm households had available. We followed here the grouping of Hammond et al. (2017) and Fraval et al. (submitted): systems were divided into four categories based on land cultivated (measured in hectares) and livestock holdings (measured in tropical livestock units or TLU's) for each household. System 1 are those households that have less than one hectare of land and $<1$ tropical livestock unit. System 2 were those households that were characterized as having more land ($>1$ hectare) and less livestock ($<1$ tropical livestock unit). System 3 were those households that were characterized by less land ($<1$ hectare) and more livestock ($>1$ tlu). System 4 were the households with the both more livestock ($>1$ tlu) and land cultivated ($>1$ ha). For a detailed description on the rationale of these cut-off points, see Hammond et al. (2017). The differences between means in the female control indicator for each gender-respondent-household type and farming system type was compared using one-way ANOVA and the *post-hoc* Tukey Test (Tukey's Honest Significant Difference Test) in IBM SPSS Statistics 24.

In the second step we analyzed the female control indicator and its relationships with productive resources, market orientation and crop and livestock diversity in a continuous manner and assessed how these relationships are affected by respondent-household type. For this, after running descriptive statistics, binomial linear regressions were applied using R Statistics. Binomial regression was used to account for the bounded range of possible values of the female control indicator. Both main effects and first-order interaction terms were tested.

In the fourth step we analyzed the underlying causes of the female control relationships by quantifying the female control scores of individual crop and livestock products. We then evaluated how these individual activity scores and the

[3]See Frelat et al. (2016) for a detailed description.

overall female control relationships are implicated in smallholder diversification and commercialization strategies.

# RESULTS

## Descriptive Statistics

**Table 2** lists the descriptive statistics of gender respondent and system type by country. In all three countries the data included substantial sub-samples of all household-respondent combinations. The female-single is the smallest group, forming 7.5% of the sample in Tanzania, 16.5% in Ethiopia, and 17.5% in Kenya. Also, all production resource types occur in all countries, with System 1, little land-few livestock, forming the smallest group. The number of observations in each of the household-respondent types and system types allow for detailed statistical analyses across the groups.

## Inferential Statistics

**Table 3** presents the mean and standard deviations for each gender-respondent-household typology in each system. Despite the large uncertainties in all variables for all productive resource classes, there are several significant differences in indicator values and occurrences between the gender-respondent-household types and productive resource groups. Most important is that among female single households, System 1 (small land—few livestock) occurs more often than in the couple household groups, with 17% of female single households in that category vs. 4 and 6% in the other two categories. Also, in the two "more livestock" household groups, livestock holdings are smaller than in the couple households. Across the board, on- and off- farm income values in the female single households are lower than in the coupled households, but surprisingly enough this does not translate into lower food availability scores, indicating a larger dependence in the female single households on consumption of own farm produce rather than selling it to the market. Also, no significant respondent differences are present between the indicators quantified for the couple households, indicating consistency between the production and income values reported by male and female respondents.

**TABLE 2 |** Sample structure by respondent gender, household type and system type by country.

| Country | Ethiopia | | Kenya | | Tanzania | |
|---|---|---|---|---|---|---|
| | *n* | % | *n* | % | *n* | % |
| **Total *n* respondents** | 496 | 100 | 903 | 100 | 1,460 | 100 |
| Men | 326 | 65.7 | 300 | 33.2 | 1,065 | 72.9 |
| Women | 170 | 34.3 | 603 | 66.8 | 395 | 27.1 |
| **Respondent Type** | | | | | | |
| Male-coupled | 326 | 65.7 | 300 | 33.2 | 1,065 | 72.9 |
| Female-coupled | 88 | 17.7 | 445 | 49.3 | 285 | 19.5 |
| Female-single | 82 | 16.5 | 158 | 17.5 | 110 | 7.5 |
| **System Type** | | | | | | |
| 1-Small land—few livestock | 48 | 9.7 | 34 | 3.7 | 97 | 6.6 |
| 2-Large land—few livestock | 40 | 8.1 | 129 | 14.2 | 424 | 29.1 |
| 3-Small land—more livestock | 157 | 31.6 | 98 | 10.8 | 173 | 11.8 |
| 4-Large land—more livestock | 251 | 50.6 | 642 | 71.3 | 766 | 52.5 |

**Table 4** presents the mean scores for the female control indicator by system type across gender-respondent-household typologies. The differences between mean scores for each group were compared using one-way ANOVA and the *post-hoc* Tukey Test (Tukey's Honest Significant Difference Test) in IBM SPSS Statistics 24. Across systems, male respondents had lower mean scores for the female control indicator than did women in coupled or single households, and these differences were statistically significant across all systems ($p \leq 0.01$). There was also variation in mean scores between women in coupled vs. single households, with female-single respondents having higher scores than women in coupled households, except in system 3 where there was no difference between these groups. Aggregating across all systems and respondent types, female control scores were highest in the systems that had more livestock (systems 3 and 4).

Using continuous variables, **Table 5** presents the correlations between female control on one hand, and income, crop, livestock, and market orientation indicators on the other hand, using Spearman's Rho correlation test. The correlation coefficients and significance values are representative of the total data set of 2,859 farm households. Female control was negatively correlated with farm income, total income, value of farm produce, crop sales, livestock product sales, farm size, and market orientation. Female control was positively correlated with off-farm income, livestock diversity, and crop diversity.

To analyze whether these significant correlations are robust for respondent bias in coupled households, we used a binomial regression model (**Table 6**). Respondent gender has a significant effect on the reported female control score, with female respondents estimating their level of control to be significantly higher than male respondents. Livestock diversity and crop diversity were both positively related to the female control score, while market orientation has a highly significant negative relation with female control. None of the first-order interactions between respondent gender and these factors were significant, meaning that the livestock diversity, crop diversity, and market orientation effects on female control are independent of the gender of the respondent.

**Table 7** presents the results of the binomial regression on all gender-respondent-household types with the source of data (project) incorporated as a random effect on the intercept. The model was built in an additive fashion, aiming to present the most parsimonious model while minimizing the Akaike Information Criterion (AIC). As with model 1 (see **Table 6**) it shows the significant effect of respondent gender and the absence of significant first order interaction terms of respondent gender with other explaining variables. The results furthermore also show that livestock diversity and crop diversity were both positively related to the female control score, while market orientation has a highly significant negative relation with female control, similar to the results obtained for the coupled households only. However, **Table 7** also shows farm size (expressed as land cultivated) having a clear trend of a negative effect on female control ($p < 0.1$) while household type (i.e., couple vs. female

**TABLE 3** | Inferential statistics of farm characteristics, food availability, and income by respondent and system type.

| Data | N | Farm characteristics mean (SD) | | Food availability indicator mean (SD) | Income mean (SD) | | |
|---|---|---|---|---|---|---|---|
| | | Farm size (ha) | Livestock holdings (tlu) | (kcal per MAE per day) | Farm (USD per year) | Off-farm (USD per year) | Total (USD per year) |
| | | Mean (SD) | Mean (SD) | Mean (SD) in thousands | Mean (SD) in thousands | Mean (SD) in thousands | Mean (SD) in thousands |
| **MALE-COUPLED RESPONDENTS** | | | | | | | |
| All systems | 1,691 | 6 (30)[ab,ac] | 33 (431) | 46 (273) | 10 (99) | 2 (12)[ab] | 12 (100) |
| 1 Small land—few livestock | 72 | 0.5 (0.2)[ac] | 0.3 (0.3) | 11 (21) | 0.7 (1) | 0.5 (2) | 1 (2) |
| 2 Large land—few livestock | 360 | 3 (3)[ac,ab] | 0.2 (0.2)[ab] | 12 (24) | 2 (3)[ab,ac] | 0.5 (2)[ab] | 2 (4) |
| 3 Small land—more livestock | 262 | 0.5 (0.3) | 86 (1,090) | 65 (247) | 7 (20) | 3 (7) | 9 (21) |
| 4 Large land—more livestock | 997 | 8 (39)[ab] | 33 (58)[ab,ac] | 56 (331) | 15 (128) | 3 (15) | 18 (130) |
| **FEMALE-COUPLED RESPONDENTS** | | | | | | | |
| All systems | 818 | 3 (6)[ab] | 9 (16) | 48 (354) | 6 (39) | 7 (66)[ab] | 13 (103) |
| 1 Small land—few livestock | 49 | 0.6 (0.2)[bc] | 0.3 (0.3) | 8 (22) | 463(647) | 0.3 (0.8) | 0.8 (1) |
| 2 Large land—few livestock | 158 | 3 (2)[ab] | 0.2 (0.3) [ab] | 12 (30) | 1 (2)[ab] | 1 (5)[ab] | 2 (4) |
| 3 Small land—more livestock | 105 | 0.5 (0.2) | 8 (14) | 58 (199) | 6 (31) | 10 (73) | 16 (103) |
| 4 Large land—more livestock | 506 | 4 (7)[ab] | 13 (19)[ab] | 63 (440) | 9 (48) | 8 (78) | 17 (122) |
| **FEMALE-SINGLE RESPONDENTS** | | | | | | | |
| All systems | 350 | 2 (3)[ac] | 5 (15) | 44 (304) | 3 (29) | 2 (12) | 5 (32) |
| 1 Small land—few livestock | 58 | 0.4 (0.2)[ac,bc] | 0.2 (0.2) | 13 (21) | 0.6 (1) | 0.5 (2) | 1 (3) |
| 2 Large land—few livestock | 75 | 2 (2)[ac] | 0.2 (0.2) | 9 (13) | 9 (2)[ac] | 0.3 (0.9) | 1 (2) |
| 3 Small land—more livestock | 61 | 0.5 (0.2) | 5 (4) | 49 (86) | 2 (4) | 1 (4) | 4 (6) |
| 4 Large land—more livestock | 156 | 3 (3) | 9 (21)[ab,ac] | 70 (451) | 6 (43) | 3 (17) | 9 (48) |

[ab] *Significant difference in scores between male coupled and female coupled respondents* $p \leq 0.05$.
[ac] *Significant difference in scores between male coupled and female single respondents* $p \leq 0.05$.
[bc] *Significant difference in scores between female coupled and female single respondents* $p \leq 0.05$.

single) has a strong effect on female control. Furthermore, there is a significant first-order interaction between household type (couple vs. female single) and market orientation: where, in couple households there is a highly significant negative effect of market orientation on female control, but this effect is less of an influencing factor in female single households (the β coefficient—i.e., slope—of market orientation is −1.07 in coupled households and $-1.07 + 0.83 = -0.24$ in female single households). Farm size (expressed as land owned) appears to have a negative effect on female control but is not statistically significant ($p > 0.05$).

**Figure 1** shows the marginal effects predicted by the model presented in **Table 7**, with a strong negative market orientation effect on female control in coupled households, and the almost flat (and highly uncertain) relationship between market orientation and female control in female—single households. Also shown are the positive relationships between crop and livestock diversity and female control.

## Female Control Over Specific Crop and Livestock Activities

To assess whether these patterns of gendered relationships regarding market orientation differ across specific cropping and livestock activities, the aggregated female control indicator was deconstructed to show the individual sale and consumption variables that contribute toward the overall indicator. The graphs in **Figures 2**, **3** illustrate the differences in female control over decisions related to the sale and consumption of individual crops and livestock products (scale of 0–1).

**TABLE 4 |** Mean scores for female control indicator by system type across respondent-household typologies.

| Data | Mean score gender equity indicator (scale of 0–1) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Male-coupled | | Female-coupled | | Female-single | | Pooled respondents | |
| | *n* | score | *n* | score | *n* | score | *n* | score |
| All systems | 1,691 | 0.35 | 818 | 0.55 | 350 | 0.62 | 2,859 | 0.44 |
| **BY SYSTEM** | | | | | | | | |
| 1-Small land—few livestock[ab] | 72 | 0.35 | 49 | 0.41 | 58 | 0.50 | 179 | 0.42 |
| 2-Large land—few livestock[abc] | 360 | 0.25 | 158 | 0.45 | 75 | 0.59 | 593 | 0.35 |
| 3-Small land—more livestock[ab] | 262 | 0.38 | 105 | 0.60 | 61 | 0.60 | 428 | 0.46 |
| 4-Large land—more livestock[abc] | 997 | 0.38 | 506 | 0.59 | 156 | 0.68 | 1,659 | 0.47 |

[ab] *Significant difference in scores between male coupled and female coupled respondents p ≤ 0.01.*
[abc] *Significant difference in scores between male coupled, female coupled, and female single respondents p ≤ 0.01.*

**TABLE 5 |** Correlation table between female control indicator and income, crop, livestock, and market orientation indicators across all systems (*n* = 2,859).

| Variable name | Farm income | Off-farm income | Total income | Value of farm produce | Crop sales | Livestock product sales | Livestock diversity | Crop diversity | Farm size | Market orientation |
|---|---|---|---|---|---|---|---|---|---|---|
| Gender equity correlation co-efficient | −0.145 | 0.134 | −0.072 | −0.074 | −0.152 | −0.043 | 0.222 | 0.231 | −0.084 | −0.265 |
| *P*-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.05 | <0.001 | <0.001 | <0.001 | <0.001 |

**TABLE 6 |** Model 1: Binomial regression on female control—Subset of households with respondents in coupled households (*n* = 2,454).

| | Coefficient (s.e.) | Pr (>\|z\|)[‡] |
|---|---|---|
| Intercept | 0.47 | |
| Land owned (ha) | −0.01 | |
| Livestock holdings (TLU) | 0.00 | |
| Female respondent[†] | 0.58 | <0.01 |
| Log gross income (PPP) | −0.04 | |
| Off farm income—binary | −0.03 | |
| Livestock diversity | 0.18 | <0.01 |
| Crop diversity | 0.08 | <0.01 |
| Market orientation | −1.06 | <.001 |

[†] *Reference category = Male respondent.*
[‡] *z = β/s.e.*

**TABLE 7 |** Model 2: Binomial regression on female control—All households (*n* = 2,859).

| | Coefficient (s.e.) | Pr(>\|z\|)[‡] |
|---|---|---|
| Intercept | −0.19 (0.26) | |
| Land owned (ha) | −0.01 (0.00) | <0.10 |
| Livestock holdings (TLU) | 0.00 (0.00) | |
| Single female[†] | 0.62 (0.25) | <0.05 |
| Female respondent in couple household (yes) | 0.46 (0.07) | <0.001 |
| Log gross income (PPP) | −0.02 (0.02) | |
| Off farm income (yes) | −0.07 (0.11) | |
| Livestock diversity | 0.17 (0.04) | <0.001 |
| Crop diversity | 0.08 (0.02) | <0.001 |
| Market orientation | −1.07 (0.21) | <0.001 |
| Market orientation: single female | 0.83 (0.40) | <0.05 |

[†] *Reference category = coupled.*
[‡] *z = β/s.e.*

**Figure 2** illustrates female control over decisions related to crop sales and crop consumption across all farming systems and gender-household-respondent typologies. The crops included in the analysis were barley, beans, cassava, cowpea, green gram, groundnut, maize, millet, pigeon pea, rice, sorghum, teff, and wheat. These results indicate that female control over crop consumption is far greater than female control over decisions related to crop sales across all crops. Across all sites, female control over sales was greatest for green gram and lowest for the common staples maize, rice, and sorghum. Female control over consumption was greatest for pigeon pea and lowest for green gram. Corroborating these data and the results of the linear regression for female control and market orientation, we can conclude that as crop sales increase, female control over sales and consumption decisions will likely decrease.

**Figure 3** presents the differences in women's control over sales vs. consumption for livestock and their associated products. In contrast to the large discrepancies in women's control over consumption decisions compared to sales decisions across crops, that pattern appears to be less dramatic in livestock production. For live sales of livestock, female control was highest for chicken (above 0.60 female control score), while these values are much lower for goats and cattle live sales

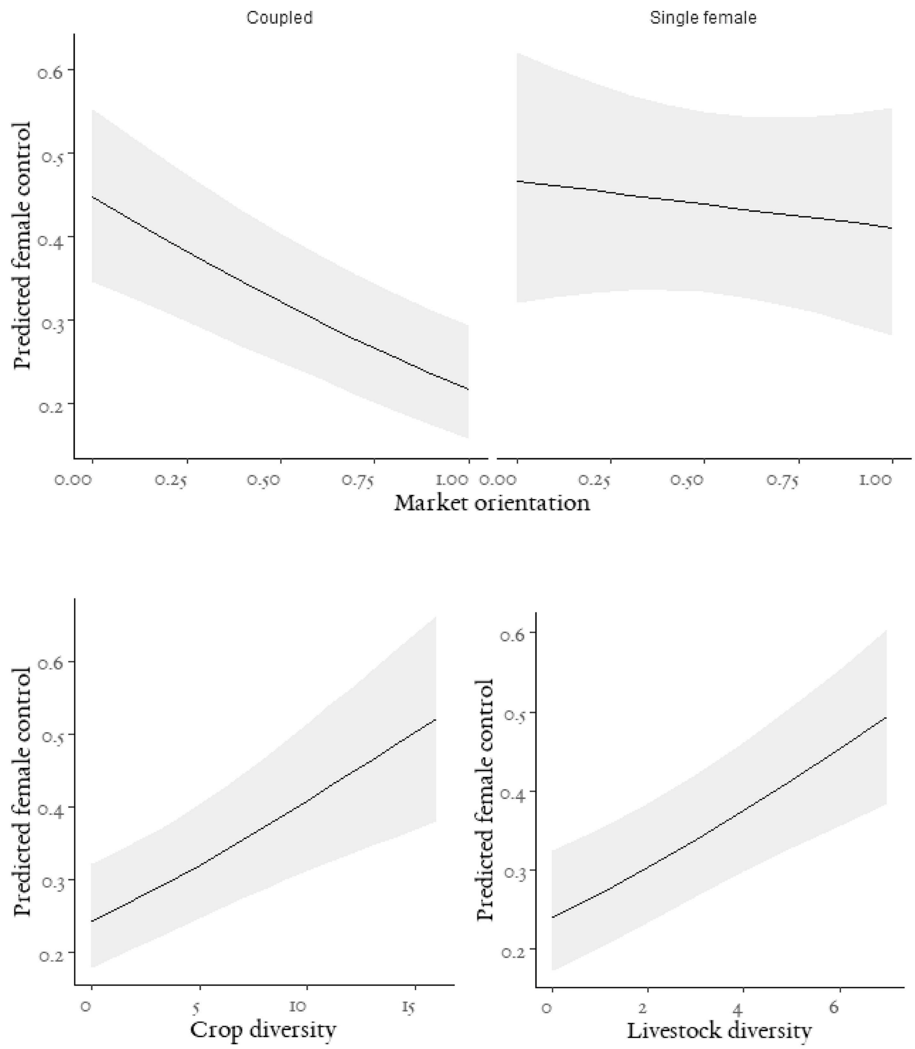


**FIGURE 1 |** Predicted marginal effects.

(both had female control scores of <0.30). For dairy products, there was a significant negative relationship between female control over sale of milk and total milk production, which suggests that as total milk production increases, female control over sales decrease. For meat products, women have the highest control over chicken meat—with generally chicken meat being less lucrative than cattle or goat meat. Female control over decisions related to goat and cattle meat were significantly lower, but with no significant differences between sales and consumption decisions. Overall, results show that female control over decisions related to sales of livestock and its products are significantly higher in lower-value livestock products (chicken, eggs) and milk than in cattle and goats (live animals and meat). Taken together with the results of the linear regressions, we can conclude that as sales of live and processed cattle and goats increase, female control over these livestock components in the farming system is likely to decrease.

## DISCUSSION

This study investigated the relationships between female control and three on-farm climate change adaptation and mitigation strategies (commercialization, crop diversification, and livestock diversification) in East Africa using a large dataset collected with the Rural Household Multiple Indicator Survey (RHoMIS). The discussion is divided into three parts. The first section outlines the key results of the study related to how gender-respondent-household typology influenced the relationships between female control and other indicators, the differences between "coupled" and "single female" households, and the relationships between female control and farm household characteristics in different household types. The second section details the programmatic implications of these findings for interventions aimed at commercializing or diversifying smallholder production. The third section discusses the methodological implications gleaned from this analysis and

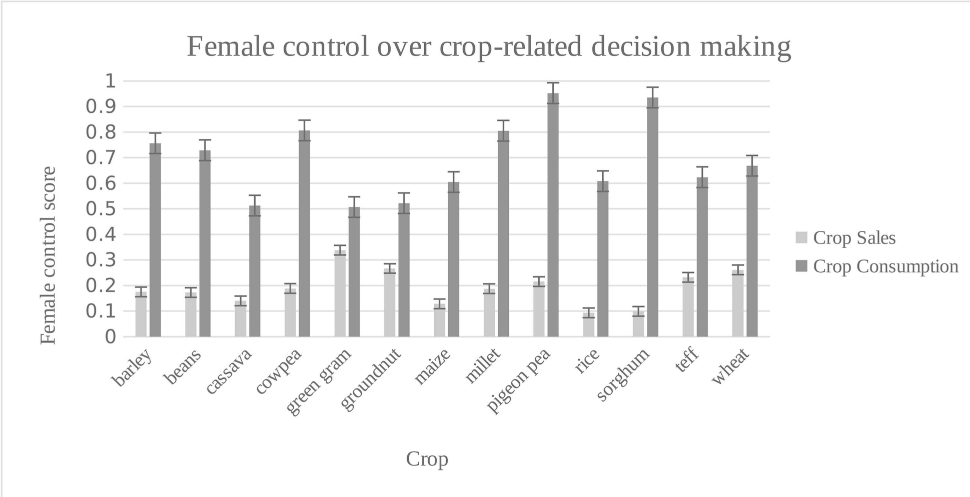


**FIGURE 2 |** Female control over crop-related decision making across all systems and gender-respondent-household typologies.

recommendations for future gender analyses in agricultural household survey research. These are followed by a final section detailing the limitations of the study and proposed directions for future research.

## Does Gender-Respondent and Household Typology Influence the Relationships Between Female Control and Commercialization and Production Diversity Indicators?

Our findings confirm our first hypothesis that there were often statistically significant differences between the three gender-respondent-household typologies (man in coupled household, woman in coupled household, and woman in single household) across farming systems that influenced the relationships between indicators. Male-coupled respondents consistently showed lower female control scores than either of the women-respondent-household typologies, although the respondent sex did not show interactions with the negative market orientation and positive production diversity relationships. The analyses also indicated that female control scores increase with larger farms. This contrasts with the commonly observed trend (Fischer and Qaim, 2012; Fehr and Moseley, 2017) that female control decreases with large farm operations. This finding could be due to the combination of consumption and sales decisions into a single indicator and the greater number of potential decisions to be made in larger farm operations. ANOVA results also showed single-female households had lower on and off-farm incomes than coupled households, but interestingly this dynamic did not translate into lower food availability scores, indicating a larger dependence on consumption of own produce rather than selling to a market. This dynamic could help explain the relatively high female control scores among single-female households. By way of illustration, since equal weight was given to sales and consumption decisions in the female control indicator, intrahousehold relationships between male children and single-female heads regarding control of sales decisions may have been diluted through aggregation.

In addressing our second hypothesis that market orientation is negatively related to female control, our analyses demonstrated that there were indeed strong, negative, and statistically significant relationships between female control and market orientation across farming systems and gender-respondent-household typologies. Commercialization was negatively associated with female control in coupled households, but relatively flat in single-female households. The first binomial regression model showed that respondent gender had a significant effect on the reported female control score, with female respondents valuing their control higher than male respondents. Livestock diversity and crop diversity were both positively related to the female control score, while market orientation had a highly significant negative relation with female control. None of the first-order interactions between respondent gender and these factors were significant, meaning that the livestock diversity, crop diversity and market orientation effects on female control were independent of the gender of the respondent. The results of the second binomial regression were quite similar to the results obtained for the coupled households only, but differed for two items: farm size (expressed as land owned) which showed a clear trend of having a negative effect on female control ($p < 0.1$) but more importantly the results also showed a significant first-order interaction between household type (couple vs. female single) and market orientation: among couple households there was a highly significant negative effect of market orientation on female control, an effect that disappeared in female single households.

Furthermore, our analysis of individualized crop and livestock products revealed that women have far greater control over

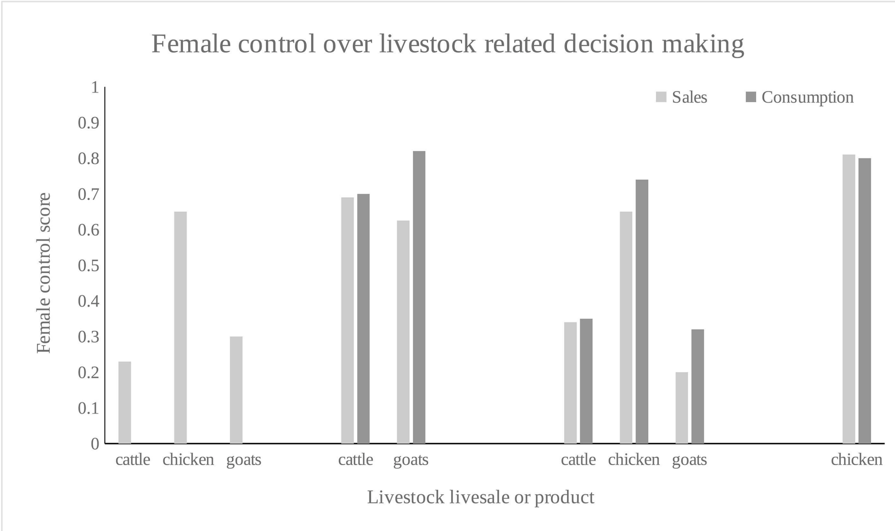


**FIGURE 3 |** Female control over livestock-related decision making across all systems and gender-respondent-household typologies.

decisions related to consumption than decisions related to sales, although the gap between the two were less pronounced in lesser-valued livestock products (chickens, eggs) and cow's milk. While our analysis showed that certain activities in lesser-valued livestock products (chickens, eggs) had high levels of female control, these data coupled with the regression analyses suggest that as sale of crops and livestock increase, female control over both consumption and sale decisions could likely diminish in general, with only a few exceptions with some livestock activities.

Our final hypothesis that crop and livestock diversification would be positively related to female control was not rejected. Regression analyses showed positive and significant relationships between diversification and female control across farming systems and gender-respondent typologies. In other words, our analyses suggest that diversification as a farming strategy is more likely to have a positive impact on women than commercialization. This finding has significant implications for large-scale climate change adaptation and mitigation strategies seeking to minimize gendered inequalities, as well as national-level policies on smallholder intensification, discussed below.

## What Are the Programmatic Implications of These Findings for Interventions and Policies Aimed at Commercializing or Diversifying Smallholder Production?

Understanding the trade-offs associated with smallholder transformations is an increasingly important approach for evaluating system-level outcomes of agricultural production and for prioritizing and targeting management interventions in multifunctional agricultural landscapes (Klapwijk et al., 2014; Thornton et al., 2018). However, holistic analysis of the gendered social dimensions of these trade-offs and how they relate to climate-smart agriculture and livestock systems remain an underexplored topic[4] (Salmon et al., 2018; Totin et al., 2018). These findings indicate that climate change interventions aimed at intensifying farming systems must recognize that these agricultural and livestock transformations may intensify gender inequality. While commercialization tends to weaken women's control by focusing on sales rather than consumption decisions, diversification may allow women to have greater control through the inclusion of more "marginal" crops (e.g., vegetables and legumes) and livestock (chickens, eggs) in the farming system, resulting in a positive relationship with female control. These gendered patterns of crop and livestock control are related to the cultural systems of meaning that ascribe gendered power and importance to different agricultural activities and commodities (Hovorka, 2012). From a programmatic perspective, these patterns must be understood within their specific socio-cultural context to inform gender-responsive, individualized interventions, or comprehensive national-level policies.

Taken together, crop and livestock diversification need to be understood as part of overall livelihood diversification strategies (Waha et al., 2018) and as a critical component of farmers' adaptation to a changing climate (Mohapatra et al., 2018). This study highlights the importance of diversification as a potential buffer to the often-detrimental effects of commercialization activities on women crop farmers and livestock keepers. Understanding the gendered trade-offs implicated in making these changes is critical to advancing socially inclusive and gender equitable climate adaptation and mitigation strategies.

Beyond diversification, a small but growing field of development research is dedicated to testing potential "gender safeguards" to minimize the detrimental impacts of commercialization activities on women's livelihoods (Jost et al., 2014; Farnworth and Colverson, 2015; Westholm and

[4]See Kristjanson et al. (2017) for a preliminary synthesis of the analytical progress on gender and climate-smart agriculture.

Arora-Jonsson, 2018). For example, a recent case study in Kenya's low emissions dairy development sector (Tavenner and Crane, 2018b) found that bundling direct payments to women with non-financial incentives, such as increased access to veterinary services, could help offset the impacts of women's loss of control over milk incomes under commercialization. Interventions and policies aimed at addressing the social and economic trade-offs made under mounting commercialization in agricultural and livestock systems will require locally-relevant and gender-responsive information to inform potential safeguards.

### What Are the Methodological Implications of These Findings for Gender Analyses in Agricultural Household Survey Research?

In assessing the differences in reporting between respondent types, there are at least three mechanisms which can help explain gender bias in household surveys (see Tavenner et al., 2018 for full discussion). The first is that men and women may have the same information about the household's practices but report these differently for reasons of social acceptability (also known as social desirability bias) or strategic gain (real or imagined) (Matheson and McIntyre, 2014). The second mechanism is that men and women may simply have different information available to them when they report on practices, because of their different roles and levels of participation in various farming and non-farm activities (Tall et al., 2014). The third mechanism involves non-sampling errors that occur due to contextual interpretations of survey questions and interviewer decision in the data collection process (Kriel and Risenga, 2014).

While we cannot decipher the precise reason why these data revealed gender respondent bias, our analysis has shown that using the RHoMIS dataset helped compare and draw general conclusions about relations and trade-offs between farming practices and female control across gender-respondent-typologies using harmonized quantitative data. This methodology represents a more intersectional approach to quantitative gender analysis that accounts for another axis of social differentiation (in this case, marital status), which ultimately yielded greater insights into large-scale (regional) gendered trends, and the significant differences that often occur along these axes. Crucially, our analysis showed that the RHoMIS can be used to capture the negative, unintended consequences of development processes on gender relations (van Wijk et al., 2016).

### Potential Limitations and Directions for Future Research

The challenge of aggregating complex data from different organizations in numerous countries with diverse cultural contexts posed the inherent danger of influencing the variations in our results. And yet, despite these potential variations, this analysis yielded robust relationships across project sites. However, interpreting the results from this study was complicated by the aggregated female control indicator itself. The aggregation of female control as a singular value expressed as a combination of consumption and sales decisions may have obscured the gendered power dynamics that operate at market vs. consumption levels. Future research would also benefit from collecting data on what type of market (informal/formal) farmers are selling their agricultural produce or livestock and their associated commodities to. This information is necessary to outline more specific relationships between female control and type of market orientation. Additionally, collecting time series data from the same households would provide more robust future projects, as this study is a snapshot of the present only.

Furthermore, the issue of gender respondent bias raised new questions about how to interpret the female control indicator. While this indicator is useful in measuring the level of equality in a household, it is not a measure of "gender equity"—defined here as what is considered "fair" in a household based on localized gender and societal norms. Indeed, while income plays an important role for changing women's position within households (Bradshaw, 2013), other studies have problematized the treatment of economic growth and gender equality as mutually supportive goals (Bayissa et al., 2018). The premise that women and men make decisions individually ignores the areas of negotiation and joint-ness in households, and the notion of complementary household responsibilities between spouses (Dolan, 2010; Johnson et al., 2016; Doss, 2018). In other words, "the values based on what people do, and how they do it, may be more important than the actual value of the income they make" (Bradshaw, 2013, p. 92).

For example, recent research (Orr et al., 2016) suggests that farmer perceptions of commercialization trends can hinge on the "conjugal contract" within households. In their study among smallholder farmers in Zambia, Orr et al. (2016) found that women's perception of level of control did not change with level of commercialization. This dynamic is indicative of how gender relations and the notion of intrahousehold gender equity are negotiated at the household level (and should not be assumed as a zero-sum game). So although commercialization may decrease women's operational/financial control, it could also open up new opportunities to negotiate shared control over a bigger cash income—a price, some women may be willing to pay (Orr et al., 2016). In sum, while this study points to important regional trends in female control, commercialization, and productive diversity indicators, future qualitative research is needed to address the meanings behind these dynamics.

## CONCLUSION

This study has presented new evidence that on-farm strategies to adapt to and mitigate climate change have gendered trade-offs and are associated with different patterns of female control. Our analyses revealed these patterns and relationships differ depending on the gender-respondent-household type surveyed in the Rural Multiple Indicator Household Survey (RHoMIS). Our results indicate that while market commercialization in the East African region tends to weaken women's control by focusing on sales rather than consumption decisions, diversification may allow women to have greater control through the inclusion of more "marginal" crops (vegetables, legumes) and livestock (chickens, eggs) in the farming system, thus creating a "social safeguard" against the potentially marginalizing effects of commercialization. These findings illustrate the need for climate change mitigation and adaptation interventions and policies to conduct gender-differentiated analysis of trade-offs and risks to mitigate the potential negative consequences shown in this study. In Ethiopia, Kenya, and Tanzania, the national policies promoting intensification of agricultural production that are currently in place must thoughtfully engage with these analyses in creating gender-responsive programming and interventions. Otherwise, large-scale climate adaptation and mitigation strategies focused solely on escalating market orientation may inadvertently intensify gender inequality among crop and livestock farmers.

To maximize data validity and tests of robustness across indicators, this study highlighted the importance of disaggregating gender data by respondent's gender and household type as opposed to homogenizing "women" as an analytic category. This method of gender analysis ensures that crucial gendered trends and/or differences in reporting are not eclipsed or obfuscated by simplified metrics for comparing gender dynamics. Our study was limited by the bounded, aggregated definition we used to create the female control indicator, lack of market type data, and additional time series data from the same households. Future research would benefit from collecting additional data in these areas, and by continued testing of gender respondent bias across different countries, farming systems, and gender-respondent-household typologies.

## DATA AVAILABILITY

The raw data supporting the conclusions of this manuscript will be made available by the authors, without undue reservation, to any qualified researcher.

## ETHICS STATEMENT

This study conforms with the principles of the 1964 WMA declaration of Helsinki. Ethical approval for this study was obtained by the Internal Review Ethics Committee (IREC) of the International Livestock Research Institute. The implementing partner research organizations Bioversity International, World Agroforestry Centre (ICRAF), and Tree AID did not have internal ethical committees but were approved internally by senior management at each organization after careful evaluation of the content, methodology, and oral informed consent statement built-in to the survey. Survey participants were not particularly vulnerable, data was processed in anonymized form, and survey participants had the possibility to skip questions. Explicit oral informed consent was obtained from all survey participants prior to survey enumeration and documented as the opening question in the RHoMIS survey upon informing survey participants of the study's purpose. If consent was denied, survey enumeration was terminated. Permission for obtaining oral rather than written consent from survey respondents was granted by the Internal Review Ethics Committee (IREC) of the International Livestock Research Institute, implementing research organizations and local agricultural officers, given literacy limitations among the target population.

Additional research permissions were granted in Tanzania through the Tanzania Commission for Science and Technology (COSTECH) and from the District Agricultural, Irrigation and Cooperative Officers (DAICOs) in all administrative districts included in the survey. In Ethiopia, following the ABS proclamation 482–2006 of the Ethiopian government, farmers were interviewed after getting the necessary permission from local agricultural office administrators. In Kenya, research permissions were granted through the County Minister for Agriculture in each site and the local administration (chief, assistant chiefs, and village elders), who approved the survey dates, areas the survey would be implemented, and the methods used.

## AUTHOR CONTRIBUTIONS

KT, JH, NdH, IB, and MvW designed the study. KT, MvW, SF, and JH performed analyses. DB, PC, TS, TR, CL, MN, SC, NN, LM, NT, EK, JvE, and JS contributed data and together with KT, JH, NdH, IB, SF, and MvW contributed to writing the manuscript.

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## REFERENCES

Anderson, D. M., Elliot, H., Kochore, H. H., and Lochery, E. (2012). Camel herders, middlewomen, and urban milk bars: the commodification of camel milk in Kenya. *J. East. Afr. Stud.* 6, 383–404. doi: 10.1080/17531055.2012.696886

Anderson, D. M., Elliott, H., Kochore, H. H., and Lochery, E. (2010). "Camel milk, capital, and gender: the changing dynamics of pastoralist dairy markets in Kenya," in *2011 Camel Conference School of Oriental and African Studies (SOAS)* (London: University of London), 1–34.

Assan, E., Suvedi, M., Schmitt Olabisi, L., and Allen, A. (2018). Coping with and adapting to climate change: a gender perspective from smallholder farming in Ghana. *Environments* 5:86. doi: 10.3390/environments5080086

Bayissa, F. W., Smits, J., and Ruben, R. (2018). The multidimensional nature of women's empowerment: beyond the economic approach. *J. Int. Dev.* 30, 661–690. doi: 10.1002/jid.3268

Bradshaw, B., Dolan, H., and Smit, B. (2004). Farm-level adaptation to climatic variability and change: crop diversification in the Canadian prairies. *Clim. Change* 67, 119–141. doi: 10.1007/s10584-004-0710-z

Bradshaw, S. (2013). Women's decision-making in rural and urban households in Nicaragua: the influence of income and ideology. *Environ. Urban.* 25, 81–94. doi: 10.1177/0956247813477361

Bryan, E., Bernier, Q., and Ringler, C. (2018). *A User Guide to the CCAFS Gender and Climate Change Survey data*. Washington, DC: International Food Policy Research Institute (IFPRI). Available online at: http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/132727

Bryan, E., Ringler, C., Okoba, B., Koo, J., Herrero, M., and Silvestri, S. (2013). Can agriculture support climate change adaptation, greenhouse gas mitigation and rural livelihoods? Insights from Kenya. *Clim. Change* 118, 151–165. doi: 10.1007/s10584-012-0640-0

Buechler, S. (2016). Gendered vulnerabilities and grassroots adaptation initiatives in home gardens and small orchards in Northwest Mexico. *Ambio* 45, 322–334. doi: 10.1007/s13280-016-0832-3

Carr, E. R. (2008). Men's crops and women's crops: the importance of gender to the understanding of agricultural and development outcomes in Ghana's central region. *World Dev.* 36, 900–915. doi: 10.1016/j.worlddev.2007.05.009

Chanamuto, N. J. C., and Hall, S. J. G. (2015). Gender equality, resilience to climate change, and the design of livestock projects for rural livelihoods. *Gend. Dev.* 23, 515–530. doi: 10.1080/13552074.2015.1096041

Cole, S. M., Kantor, P., Sarapura, S., and Rajaratnam, S. (2014). *Gender-Transformative Approaches to Address Inequalities in Food, Nutrition and Economic Outcomes in Aquatic Agricultural System*. CGIAR Research Program on Aquatic Agricultural Systems. Working Paper: AAS-2014–S-2042.

Deere, C. D., Alvarado, G. E., and Twyman, J. (2012). Gender inequality in asset ownership in Latin America: female owners vs. household heads. *Dev. Change* 43, 505–530. doi: 10.1111/j.1467-7660.2012.01764.x

Djoudi, H., Locatelli, B., Vaast, C., Asher, K., Brockhaus, M., and Sijapati Basnett, B. (2017). "Beyond dichotomies: gender and intersecting inequalities in climate change," in *Paper Presented at the Resilience 2017: Resilience Frontiers for Global Sustainability* (Stockholm).

Djurfeldt, A. A., Dzanku, F. M., and Isinika, A. C. (2018). *Agriculture, Diversification, and Gender in Rural Africa: Longitudinal Perspectives from Six Countries.* Oxford: Oxford University Press. doi: 10.1093/oso/9780198799283.001.0001

Dolan, C. (2010). The 'Good Wife': struggles over resources in the Kenyan horticultural sector. *J. Dev. Stud.* 37, 39–70. doi: 10.1080/00220380412331321961

Doss, C. (2018). Women and agricultural productivity: reframing the issues. *Dev. Policy Rev.* 36, 35–50. doi: 10.1111/dpr.12243

Edmunds, D., Sasser, J., and Wollenberg, E. (2013). *A Gender Strategy for Pro-Poor Climate Change Mitigation*. CCAFS Working Paper no. 36. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) (Copenhagen). Available online at: www.ccafs.cgiar.org

Farnworth, C. R. (2015). *Recommendations for a Gender Dairy NAMA in Kenya Prepared for Lead and Implementing Partners to the Kenyan Dairy NAMA*. CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), 1–35.

Farnworth, C. R., and Colverson, K. E. (2015). Building a gender-transformative extension and advisory facilitation system in sub-saharan Africa. *J. Gender Agric. Food Secur.* 1, 20–39. doi: 10.19268/JGAFS.112015.2

Farnworth, C. R., Hà, T. T., Sander, B. O., Wollenberg, E., de Haan, N. C., and McGuire, S. (2017). Incorporating gender into low-emission development: a case study from Vietnam. *Gend. Technol. Dev.* 21, 5–30. doi: 10.1080/09718524.2017.1385314

Fehr, R., and Moseley, W. G. (2017). Gardening matters: a political ecology of female horticulturists, commercialization, water access, and food security in Botswana. *Afr. Geogr. Rev.* doi: 10.1080/19376812.2017.1286247. [Epub ahead of print].

Fischer, E., and Qaim, M. (2012). Gender, agricultural commercialization, and collective action in Kenya. *Food Secur.* 4, 441–453. doi: 10.1007/s12571-012-0199-7

Fisher, M., Reimer, J. J., and Carr, E. R. (2010). Who should be interviewed in surveys of household income? *World Dev.* 38, 966–973. doi: 10.1016/j.worlddev.2009.11.024

Forsythe, L., Posthumus, H., and Martin, A. (2016). A crop of one's own? Women's experiences of cassava commercialization in Nigeria and Malawi. *J. Gender Agric. Food Secur.* 1, 110–128. doi: 10.19268/JGAFS.122016.6

Fraval, S., Hammond, J., Lannerstad, M., Oosting, S. J., Sayula, G., Teufel, N., et al. (2018). Livelihoods and food security in an urban linked, high potential region of Tanzania: changes over a three year period. *Agric. Syst.* 160, 87–95. doi: 10.1016/j.agsy.2017.10.013

Frelat, R., Lopez-Ridaura, S., Giller, K. E., Herrero, M., Douxchamps, S., Djurfeldt, A., et al. (2016). Drivers of household food availability in sub-Saharan Africa based on big data from small farms. *Proc. Natl. Acad. Sci. U.S.A.* 113, 458–463. doi: 10.1073/pnas.1518384112

Galiè, A., Teufel, N., Korir, L., Baltenweck, I., Webb Girard, A., Dominguez-Salas, P., et al. (2018). The women's empowerment in livestock index. *Soc. Indic. Res.* doi: 10.1007/s11205-018-1934-z. [Epub ahead of print].

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., et al. (2013). *Tackling Climate Change Through Livestock: A Global Assessment of Emissions And Mitigation Opportunities*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Hakizimana, C., Goldsmith, P., Nunow, A. A., Roba, A. W., and Biashara, J. K. (2017). Land and agricultural commercialisation in Meru County, Kenya: evidence from three models. *J.Peasant Stud.* 44, 555–573. doi: 10.1080/03066150.2016.1260555

Hammond, J., Fraval, S., van Etten, J., Suchini, J. G., Mercado, L., Pagella, T., et al. (2017). The Rural household multi-indicator survey (RHoMIS) for rapid characterisation of households to inform climate smart agriculture interventions: description and applications in East Africa and Central America. *Agric. Syst.* 151, 225–233. doi: 10.1016/j.agsy.2016.05.003

Harvey, C. A., Chacón, M., Donatti, C. I., Garen, E., Hannah, L., Andrade, A., et al. (2014). Climate-smart landscapes: opportunities and challenges for integrating adaptation and mitigation in tropical agriculture. *Conserv. Lett.* 7, 77–90. doi: 10.1111/conl.12066

Herrero, M., Thornton, P. K., Bernués, A., Baltenweck, I., Vervoort, J., van de Steeg, J., et al. (2014). Exploring future changes in smallholder farming systems by linking socio-economic scenarios with regional and household models. *Global Environ. Change* 24, 165–182. doi: 10.1016/j.gloenvcha.2013.12.008

Hovorka, A. J. (2012). Women/chickens vs. men/cattle: insights on gender–species intersectionality. *Geoforum* 43, 875–884. doi: 10.1016/j.geoforum.2012.02.005

Howden, S. M., Soussana, J.-F., Tubiello, F. N., Chhetri, N., Dunlop, M., and Meinke, H. (2007). Adapting agriculture to climate change. *Proc. Natl. Acad. Sci. U.S.A.* 104, 19691–19696. doi: 10.1073/pnas.0701890104

Johnson, N. L., Kovarik, C., Meinzen-Dick, R., Njuki, J., and Quisumbing, A. (2016). Gender, assets, and agricultural development: lessons from eight projects. *World Dev.* 83, 295–311. doi: 10.1016/j.worlddev.2016.01.009

Jost, C., Ferdous, N., and Spicer, T. D. (2014). *Gender and Inclusion Toolbox: Participatory Research in Climate Change and Agriculture*. CGIAR Research Program on Climate Change,Agriculture and Food Security (CCAFS), CARE International and the World Agroforestry Centre (ICRAF), Copenhagen. Available online at: www.ccafs.cgiar.org

KIT, Agri-ProFocus, and IIRR (2012). *Challenging Chains to Change: Gender Equity in Agricultural Value Chain Development*. Amsterdam: KIT Publishers; Royal Tropical Institute.

Klapwijk, C., van Wijk, M. T., Rosenstock, T., Van Asten, P., Thornton, P. K., and Giller, K. E. (2014). Analysis of trade-offs in agricultural systems: current status and way forward. *Curr. Opin. Environ. Sustain.* 6, 110–115. doi: 10.1016/j.cosust.2013.11.012

Kriel, A., Randall, S., Coast, E., and De Clercq, B. (2014). From design to practice: how can household surveys represent the complexity of the social units under investigation? *Afr. Popul. Stud.* 28, 1309–1323. doi: 10.11564/0-0-618

Kriel, A., and Risenga, A. (2014). Breaking the silence: listening to interviewers when considering sources of non-sampling errors in household survey research in South Africa. *South Afr. Rev. Sociol.* 45, 117–136. doi: 10.1080/21528586.2014.917892

Kristjanson, P., Bryan, E., Bernier, Q., Twyman, J., Meinzen-Dick, R., Kieran, C., et al. (2017). Addressing gender in agricultural research for development in the face of a changing climate: where are we and where should we be going? *Int. J. Agric. Sustain.* 15, 482–500. doi: 10.1080/14735903.2017.1336411

Malapit, H., Kovarik, C., Sproule, K., Meinzen-Dick, R., and Quisumbing, A. (2015). *Instructional Guide on the Abbreviated Women's Empowerment in Agriculture Index* (A-WEAI). International Food Policy Research Institute.

Mason, R., Ndlovu, P., Parkins, J. R., and Luckert, M. K. (2014). Determinants of food security in Tanzania: gendered dimensions of household headship and control of resources. *Agric. Human Values* 32, 539–549. doi: 10.1007/s10460-014-9568-5

Matheson, J., and McIntyre, L. (2014). Women respondents report higher household food insecurity than do men in similar Canadian households. *Public Health Nutr.* 17, 40–48. doi: 10.1017/S136898001300116X

Michael, S., Stapleton, J., and Shapiro, B. I. (2017). *Tanzania Livestock Master Plan: Key Findings.* ILRI Internal Report, Brief 1 October 2017, Nairobi, 1–4.

Mohapatra, S., Orakhenshivili, A., Adger, N., Brooks, N., Adger, W., et al. (2018). "Options for support to agriculture and food security under climate change," in *Climate Change, New Security Challenges and the United Nations,* Vol. 90. ed. S. Mohapatra (Oxford: Oxford University Press), 277–309.

Nightingale, A. J. (2011). Bounding difference: intersectionality and the material production of gender, caste, class and environment in Nepal. *Geoforum* 42, 153–162. doi: 10.1016/j.geoforum.2010.03.004

Njuki, J., and Sanginga, P. (eds.). (2013). *Women, Livestock Ownership, and Markets: Bridging the Gender Gap in Eastern and Southern Africa*. London: Routledge.

Office of the President GoK (2018). *Flagship Programmes*. Available online at: https://www.delivery.go.ke/flagship

Orr, A., Tsusaka, T., Kee-Tui, S. H., and Msere, H. (2016). What do we mean by 'women's crops'? Commercialisation, gender and the power to name. *J. Int. Dev.* 28, 919–937. doi: 10.1002/jid.3224

Perez, C., Jones, E. M., Kristjanson, P., Cramer, L., Thornton, P. K., Förch, W., et al. (2015). How resilient are farming households and communities to a changing climate in Africa? A gender-based perspective. *Global Environ. Change* 34, 95–107. doi: 10.1016/j.gloenvcha.2015.06.003

Quisumbing, A., Rubin, D., Manfre, C., Waithanji, E., van den Bold, M., Olney, D., et al. (2015). Gender, assets, and market-oriented agriculture: learning from high-value crop and livestock projects in Africa and Asia. *Agric. Hum. Values* 32, 705–725. doi: 10.1007/s10460-015-9587-x

Rao, S. (2016). *Indicators of Gendered Control Over Agricultural Resources: A Guide for Agricultural Policy and Research*. Working Paper No. 1. CGIAR Gender and Agriculture Research Network. CGIAR Consortium Office and International Center for Tropical Agriculture (CIAT), Cali.

Ravera, F., Martín-López, B., Pascual, U., and Drucker, A. (2016). The diversity of gendered adaptation strategies to climate change of Indian farmers: a feminist intersectional approach. *Ambio* 45, 335–351. doi: 10.1007/s13280-016-0833-2

Ritzema, R. S., Frelat, R., Douxchamps, S., Silvestri, S., Rufino, M. C., Herrero, M., et al. (2017). A simple food availability analysis across smallholder farming systems from East and West Africa: is production intensification likely to make farm households food-adequate? *Food Secur.* 9, 115–131. doi: 10.1007/s12571-016-0638-y

Salmon, G., Teufel, N., Baltenweck, I., van Wijk, M., Claessens, L., and Marshall, K. (2018). Trade-offs in livestock development at farm level: different actors with different objectives. *Global Food Secur.* 17, 103–112. doi: 10.1016/j.gfs.2018.04.002

Shapiro, B., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G., et al. (2015). *Ethiopia Livestock Master Plan*. ILRI Project Report. International Livestock Research Institute (ILRI), Nairobi.

Silvestri, S., Sabine, D., Patti, K., Wiebke, F., Maren, R., Ianetta, M., et al. (2015). Households and food security: lessons from food secure households in East Africa. *Agric. Food Secur.* 4, 1–23. doi: 10.1186/s40066-015-0042-4

Tall, A., Kristjanson, P., Chaudhury, M., McKune, S., and Zougmore, R. (2014). *Who Gets the Information? Gender, Power, and Equity Considerations in the Design of Climate Services for Farmers*. CCAFS Working Paper No. 89. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), 1–77.

Tavenner, K., and Crane, T. A. (2018a). Gender power in Kenyan dairy: cows, commodities, and commercialization. *Agric. Hum. Values* 35, 701–715. doi: 10.1007/s10460-018-9867-3

Tavenner, K., and Crane, T. A. (2018b). Do direct payments to women incentivize participation in low emissions dairy development interventions? Evidence from Kenya. *ILRI Policy Brief* 26, 1–4. doi: 10.13140/RG.2.2.17202.66246

Tavenner, K., Fraval, S., Omondi, I., and Crane, T. A. (2018). Gendered reporting of household dynamics in the Kenyan dairy sector: trends and implications for low emissions dairy development. *Gend. Technol. Dev.* 22, 1–19. doi: 10.1080/09718524.2018.1449488

Thornton, P. K., Kristjanson, P., Förch, W., Barahona, C., Cramer, L., and Pradhan, S. (2018). Is agricultural adaptation to global change in lower-income countries on track to meet the future food production challenge? *Global Environ. Change* 52, 37–48. doi: 10.1016/j.gloenvcha.2018.06.003

Tibesigwa, B., and Visser, M. (2016). Assessing gender inequality in food security among small-holder farm households in urban and rural South Africa. *World Dev.* 88, 33–49. doi: 10.1016/j.worlddev.2016.07.008

Totin, E., Segnon, A., Schut, M., Affognon, H., Zougmoré, R. B., Rosenstock, T., et al. (2018). Institutional perspectives of climate-smart agriculture: a systematic literature review. *Sustainability (TSI)* 10:1990. doi: 10.3390/su1006199

Twyman, J., Green, M., Bernier, Q., Kristjanson, P., Russo, S., Tall, A., et al. (2014). *Gender and Climate Change Perceptions, Adaptation Strategies, and Information Needs Preliminary Results from four sites in Africa*. CCAFS Working Paper no. 83. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen. Available online at: www.ccafs.cgiar.org

Twyman, J., Useche, P., and Deere, C. D. (2015). Gendered perceptions of land ownership and agricultural decision-making in Ecuador: who are the farm managers? *Land Econ.* 91, 479–500. doi: 10.3368/le.91.3.479

van Wijk, M., Hammond, J., Fraval, S., Ritzema, R. S., Bolliger, A. M., and Long, C. (2016). "Including gender equity in a survey tool for rural households," in *A Different Kettle of Fish. Gender Integration in Livestock and Fish Research*, ed R. Pyburn (Amsterdam: LM Publishers), 9–17.

Waha, K., van Wijk, M. T., Fritz, S., See, L., Thornton, P. K., Wichern, J., et al. (2018). Agricultural diversification as an important strategy for achieving food security in Africa. *Glob. Chang. Biol.* 24, 3390–3400. doi: 10.1111/gcb.14158

Westholm, L., and Arora-Jonsson, S. (2018). What room for politics and change in global climate governance? Addressing gender in co-benefits and safeguards. *Environ. Polit.* 27, 917–938. doi: 10.1080/09644016.2018.1479115

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