The Effect of Weather Shocks on Women's Labor Supply and the Income of Women-Headed Households in Lesotho

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Abstract
This study examines the effect of weather shocks on labour-supply decisions and income for rural farming households in Lesotho. We examine how these shocks affect women and households headed by women relative to men. We use the Lesotho Agricultural Survey data, merged with the Standardized Precipitation Evapotranspiration Index (SPEI) data. We then employ a multinomial logit model of labour supply choice as well as the Heckman selection models to study the income effects of these shocks. Our identification relies on the fact that weather shocks are plausibly exogenous once we control for time and community fixed effects. We find that women are more vulnerable to weather shocks and have limited coping strategies than their male counterparts. However, men have an option to intensify their participation in relatively shock-resistant farming activities as a coping strategy in the presence of the weather shock. Drought increases the probability of men to choose farming, but it does not affect labour-supply choices for women. Therefore, more opportunities for women in rural non-farming sectors–tourism, for example-as well as increased access and ownership of productive assets, such as land, would mitigate weather shocks as well as the additional effects of the pandemic.

Key words: Climate shocks, Off-farm, rural farming households, agricultural production

JEL Classification: Q12; Q13; etc.

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1 Introduction

Climate change is a growing global concern. The increase in global temperatures since the early 20th century has resulted in an increased risk of weather shocks such as floods, drought and heat waves. The effects of these shocks may be especially severe in low-income countries, despite their minimal contribution to climate change (International Monetary Fund, 2017, Taraz, 2018). This has led to a considerable decline in economic output, partly due to the fall in agricultural output and a drop in labour productivity (Burket et al., 2015). Following a climate shock event, individuals may or may not be able to cope with the effects associated to the shock. Various coping mechanisms have been studied by the literature, like migration towards internal or international unaffected zones (Cattaneo et al., 2020), assets and livestock sales (Kazianga and Udry, 2006), access to credit markets (Skoufias et al., 2016) and adoption to drought-resilient seeds (Cacho et al., 2020). Another mitigation strategy is represented by labor supply adjustments, by increasing the total number of working hours or moving to off-farm activities (Branco and Feres, 2020). However, not all socio-demographic groups have the same chances to adapt. In particular, women because of cultural norms favoring men or economic constraints, may be unable to adjust their labor supply, thereby making them more vulnerable to weather shocks. Yet, little evidence exists about the gender-based resilience capacity to the adverse effects of climate shocks on income-generating activities. Developing policies to cope with these weather shocks requires a better understanding of how rural farming individuals and households cope in the face of these shocks.

This paper investigates the role of labour supply options as a possible adaptation strategy to weather shocks in rural Lesotho. This strategy has been cited as particularly critical for rural communities in developing countries where insurance options for poor households are very limited (Branco and Feres, 2020). We argue that substitution between on-farm and off-farm activities can be adopted to mitigate the negative effects of weather shocks. For example, Amare and Shiferaw (2017) show that participation in alternative labour supply options, such as non-farming activities, can provide the necessary insurance against weather shocks. Demeke and Zeller (2012), Mathenge and Tschirley (2015) argue that weather shocks affect off-farm employment, resulting in increased off-farm labour

participation. These studies, however, do not analyse the consequent effect of those labour supply choices on household income.

It is important, therefore, to understand how available labour supply options are effective in alleviating economic losses due to weather shocks (Burke and Emerick, 2016; Taraz, 2017, 2018). This is important for effective implementation of labour market and agricultural policies targeted to vulnerable households in developing countries where the role of agriculture is significant (Branco and Feres, 2020). Further, we evaluate the effects of weather shocks on household labor income. Some studies examine how weather shocks influence households' welfare in terms of income sources, whether from on-farm and/or off-farm employment (for example, Chuang, 2019) and consumption dynamics (for example, Asfaw and Maggio, 2018).

Most importantly the study extends the existing literature by introducing gender dynamics. We unpack the differential effects of weather shocks on men and women. We also provide insights into how the mitigation strategies available in terms of resilience affect men and women when they are faced with weather shocks. Studies that explore the gendered effects of weather shocks (for example, Asfaw and Maggio, 2018; Flato, Muttarak and Pelser, 2017) show that female-headed households are adversely affected by weather shocks. Yet these studies do not examine the effects of weather shocks on individual labour supply choices. By and large, little is known about coping strategies involving the adjustment of labor supply by men and women when faced with weather shocks and how these strategies differ. Developing adaptation strategies and well-targeted social safety nets requires this knowledge.

Specifically, the paper aims to answer the following questions: What is the effect of weather shocks on labour supply decisions of women and men? What is the effect of weather shocks on income of female- and male-headed households? Through what channels are these gendered effects of weather shocks, if any, are transmitted?

To answer these questions, we use household level data from the 2015/2016, 2016/2017, 2017/2018 and 2018/2019 Agricultural Production Surveys from the Lesotho Bureau of Statistics. We use GPS coordinates to merge this data with the Standardized Precipitation

Evapotranspiration Index (SPEI), a multi-scalar drought index that was first introduced by Vicente-Serrano et al. (2010) to measure spatial and temporal weather patterns.

In our empirical strategy, we first apply a multinomial logit model to analyse the effects of weather shocks on male- and female-individuals' labour supply options – whether they choose the off-farm sector, the on-farm sector, home production (homemakers and housewives), to be unemployed, or to be outside the labour market. Our identification strategy relies on the assumption that, once we control for time and community council fixed effects, weather shocks are plausibly exogenous. Second, we assess the effect of weather shocks on female- and male-headed households' income. We first use the simple fixed effects model, accounting for unobserved heterogeneity across councils and time. Since individuals within a household may self-select into specific sectors, we next account for this potential endogeneity by employing the Heckman selection approach and estimates the decision to participate in various labour supply options and the likely income gaps between those labour supply regimes.

We find significant gender differences in the effects of weather shocks on labour supply choices. Weather shocks have no influence on women labour supply options, while drought increases men's participation in farming activities, likely in the livestock sector (a male predominant activity). We also find that floods have a significant negative impact on income of female-headed households and that their participation in non-farming activities offers no security against weather shocks. Conversely, drought has no significant effect on income of male-headed households in farming only and those doing farming and non-farming activities but significantly reduce income of male-headed households doing both farming and non-farming activities.

Exploring the potential mechanisms, we find that these results are likely due to the fact that women engage in climate vulnerable farm and off-farm activities such as selling grains and food compared to men who sell livestock and livestock products. Further, drought significantly increases the risk of adolescent girls (12-16 year olds) in female-headed households to be home-makers or housewives. We also show, using the Lesotho Demographic Health Survey data, that drought actually reduces the risk of getting

married young. We, therefore, argue that the weather effects on income of female-headed households cannot be explained by child marriage phenomenon. In an alternative strategy, we argue that young girls' labour can substitute that of their mothers and other female adults within the household as they intensify their search for employment and reduce their time doing household chores. Overall, the results suggest that weather shock has a very significant effect on rural labour markets and households' income in Lesotho. Women and adolescent girls are most vulnerable to these shocks in terms of income and labour supply decisions.

The rest of the paper is organized as follows. Section 2 discusses the context; section 3 discusses the data and measurement of key variables, and presents some descriptive analysis. Section 4 outlines the methodology; section 5 discusses the empirical results while section 6 concludes the paper and provides policy implications.

2 Context

Over the past three decades, the overall structure of the economy has significantly changed, from where agriculture was the dominant sector to where manufacturing, retail and services became the dominant sectors in terms of their contribution to GDP and to employment. Between 2009 and 2019, the share of agriculture to GDP declined from 6.04 percent to 4.53 percent while that of manufacturing increased to over 16 percent during the same period (World Development Indicators, 2020). During the same period, the share of employment in agriculture to total employment was around 10 percent while that of manufacturing was above 40 percent. However, agriculture remains important for rural livelihoods in Lesotho. More than half of Lesotho's population (58 percent) is concentrated in rural areas where more than 70 percent of households are dependent on subsistence farming for survival (SDP II, 2019/2020-2022/23).

Lesotho's agriculture landscape comprises primarily of rain-fed cereal production and livestock farming. Only 10 percent of the total land in Lesotho is arable. The majority of smallholder farmers cultivate an average of 1.5 hectares of land. The main crops grown in Lesotho include maize, wheat, sorghum, which occupy 60 percent, 20 percent and 10 percent of agricultural land. Summer crops (maize and sorghum) are mostly grown

between August and January while wheat is mostly grown in the mountainous areas, between July and February.

Livestock farming dominates the agricultural sector, accounting for 62 percent of the total agricultural output. The sub-sector is male-dominated and consists of extensive animal grazing, wool and mohair production as well as aquaculture. The Household Budget Survey (2017), from the Bureau of Statistics (BOS), shows that around 56 percent of men (compared to 44% of women) obtain off-farm income from selling livestock.

The agricultural sector is also characterized by large fluctuations in productivity and production in recent years mainly due to severe climatic conditions including recurrent droughts, heavy rains, floods, hail, strong winds and progressive environmental degradation (Government of Lesotho, NSDP II 2019/2020-2022/23). For example, during the El Nino drought of 2015/2016 agricultural year, the arable land allocated for maize crop within the four districts of Lesotho (Leribe, Berea, Maseru and Mafeteng) declined to between 4,000 and 13, 000 hectares in 2015/2016 from between 13,000 and 22,000 hectares in the previous agricultural year 2014/2015 (BOS Lesotho Population Census, 2016). Farmers experienced a huge drop in grain harvest, which led to early shortage of food stocks for farming households and increased food prices, leaving many households food insecure.

However, during the 2016/2017 agricultural year, there were heavy rains (La Nina) throughout the country and, as a result, the area planted increased to between 21 000 and over 30 000 hectares (BOS 2017/2018 Crop Forecasting Report). The harvest also increased by 173.8 percent. This was mainly due to adoption of various flood resilient methods during that year by majority of farming households. These included use of hybrid seeds, implementation of conservation agriculture to prevent soil erosion and creating terraces that draw water out during floods. The proportion of households that used hybrid seeds increased by 53.6 percent in 2016/2017.

The uncertainty in agricultural production and productivity brought by changing weather conditions has also affected migration patterns in Lesotho. In recent years, there has been an increase in rural-urban migration, created by occupational choice as the garment and

textile industry began to improve, creating more job opportunities, particularly for women. The 2016 population census indicates that over 90 percent of the population has moved from their districts of birth, of which 62 percent has been absorbed by the private sector and private households. The census also shows that 8.9 percent of Basotho (179,579) have migrated outside the country. The Republic of South Africa is the major destination for rural men and women, accounting for 78 percent of the total out-migrants. The changing patterns of migration also led to an increase in the number of women migrating from rural Lesotho to South Africa to work in the factories, farms and do domestic work (BOS, 2016). The remaining 22.5 percent is absorbed by the rest of Africa and the United Kingdom.

Traditionally, women have been mostly engaged in homemaking activities (home gardens, childcare, homecare) while men are engaged in farming and non-farming activities (BOS Labour Force Survey, 2008). The custom of bride price is universally practiced in Lesotho, presented to the family of the bride, to show appreciation by the family of the groom to bride's family and to strengthen the union between two families (Boshego, 2006). Being a patriarchal society, Lesotho determines its lineage along the male line (NSDP II, 2019/2020-2022/23). This influences important decisions on the way of life of Basotho, including succession, property rights and land allocation among others; it has also likely significant pro-men (and male-headed households) effects on productivity and copying mechanisms.

Lesotho also practices dual legal system, consisting of the customary law and the common law. Although there is progress in the review and implementation of legal reforms, the constitution still undermines gender and social equality due to its explicit recognition of the customary law (NSDP II, 2019/2020-2022/2023). The customary practices often deny women access to productive assets, such as land, while compromising their economic independence. Women may participate in agricultural activities but their access to resources associated to agricultural land (e.g fields, farming equipment, livestock) is generally through men. This suggests that female participation in key decision-making roles in socio-economic activities is still deficient in Lesotho. Again, such norms would favor men and would provide them with more copying options.

3 Data and Descriptive Statistics

3.1 Household Income and Labour Supply data

Our main source of data is the Agricultural Production Survey (APS), collected by the Lesotho Bureau of Statistics (BOS) on annual basis. The APS is a nationally representative survey, covering both crop and livestock farmers in the parts of Lesotho. Households are selected using the two-stage sampling, whereby the first stage involves selection of Primary Sampling Units (PSUs) and the second stage involves stratification of households by farming activities. A sample of households from each farming category – crop farming and livestock farming - is selected. This sample varies depending on the number of farming households available in the PSU. These households are followed throughout the agricultural year to collect information on individual, household, location and community characteristics.

The APS collects household characteristics such as household size, number of adults, number of children and infants, savings status, access to credit, land holding and use, sources of household income and marital status of household head. The survey also collects socio-economic information of all household members such as age, gender, education level, employment status, participation in off-farm activities and income earned. Finally, the survey has GPS coordinates indicating the location (or community council) where households and the agricultural plots are located. For purposes of this study, we use the 2015/2016, 2016/2017, 2017/2018 and 2018/2019 surveys.[1]

3.2 Weather Data

We follow the existing literature (e.g., Harari and La Ferrara, 2018; Vicente-Serrano et al., 2010) and measure drought using the Standardized Precipitation Evapotranspiration Index (SPEI). SPEI is a multi-scalar drought index that was first introduced by Vicente-Serrano et al. (2010) as an improved measure of the Standardized Precipitation Index

[1] We do not include the 2014/2015 survey because there were no climate shocks and, more importantly, it was a year of heightened political instability, which could influence our results.

(SPI). The SPEI index takes into account the climatic water balance (the monthly or weekly) difference between precipitation and potential evapotranspiration (PET)) to determine the severity of drought. Unlike drought indicators based on precipitation only, the SPEI accounts also for the extent to which the soil retains water, and combines the joint effects of precipitation, potential evaporation, and temperature. Given our focus on agriculture and rural areas, our drought variable is defined based on the average SPEI index observed for the years 2015 to 2018 between November (of the previous year) and April, which corresponds to the rainy season and the onset of the cropping season in rural Lesotho.

We merged the household survey (or the APS) data with the (SPEI) dataset using the GPS coordinates of the closest geographic units, which were recovered for both datasets (the grid and council level, respectively). For the household survey, the councils where the plots are situated were used.

3.3 Defining Outcomes and construction of weather shocks

The main outcome variables in this study are labour supply (i.e. labour market participation) and household income. We assume that individuals within a household can choose to be in any of the five labour supply regimes: (1) farm labour (2) non-farm labour (3) look for job (i.e. be unemployed), (4) housewife/homemaker, and (5) be outside the labour market. Based on labour supply decisions of individual household members, we classify the household into three labour supply regimes: (1) farming, (2) nonfarming, and (3) both farming and nonfarming. For instance, we classify a household as a farming household if at least one household member participates in farming activities and no member is working in the off-farm sector. Household income is constructed by summing up income of individual household members. In our empirical analysis below, we just use farming regime and farming-and-nonfarming regime because we mainly focus on rural areas and there are few observations in the off-farm only regime to perform meaningful regression analysis.

The main treatment variable is weather shocks (or drought) and is measured using SPEI.[2] Conceptually, drought is defined as "a protracted period of deficient precipitation resulting in extensive damage to crops, and a consequential loss of yield".[3] The severity of drought can be categorized using the SPEI variable, where SPEI≤-2 indicates dry seasons and SPEI≥2 indicates wet seasons. Table A1 presents a detailed categorization. In this study, we define weather shocks as drought (i.e. SPEI<-1, which indicates moderately dry climate) and flood (i.e. SPEI>1.5, which indicates a very wet climate).

3.4 Summary Statistics

Table 1 presents individual and household characteristics by gender of household head. The sample consists of 4131 individuals in female-headed households and 8953 in male-headed households. Looking at the demographic composition of female- and male-headed households, we observe that male-headed households are larger, have more infants and fewer elderly people compared to female-headed households. The average age of individuals in male-headed household is 35 years while in female-headed households is 34 years. But the average education in female-headed households in slightly higher (at 6.8 years) compared to that in male-headed households (at 6.6 years). Also, female household heads are more educated than male household heads. Both female- and male-headed households have experienced almost the same normal weather conditions, with SPEI of -1.1.

In terms of labour market participation, fewer individuals (38 percent) in female-headed households participate in farm-labour activities compared to 46 percent for those in male-headed households. Therefore, 73 percent of male-headed households are classified as farming households compared to 54 percent of female-headed households. However, participation in non-farming activities in female-headed households is higher than in male-headed households. Finally, individuals in female-headed households are more likely to be housewives/homemakers, unemployed, and outside the labour force.

These differences in labour market participation could therefore explain the relatively

[2] A detailed variable description is provided in Table A2.
[3] https://drought.unl.edu/Education/DroughtIn-depth/WhatisDrought.aspx

high (individual and household level) income in male-headed households than in female-headed households. Average (real) household income is M21,168 and M31,597 in female-headed households and male-headed households, respectively. Similarly, average household farming income is M10,939 in female-headed households versus M16,496 in male-headed households. However, household farming income is calculated using a relatively small sample size compared to total household income possibly because a number of households are not engaged in farming and some farming households do not sell their farm produce. Despite this, the distributions of total and farming household income are very similar, as shown in figure 1, except that agricultural income has many zeros. Given this similarity in distributions, therefore, we use total household income in our analysis since it has a larger sample size.

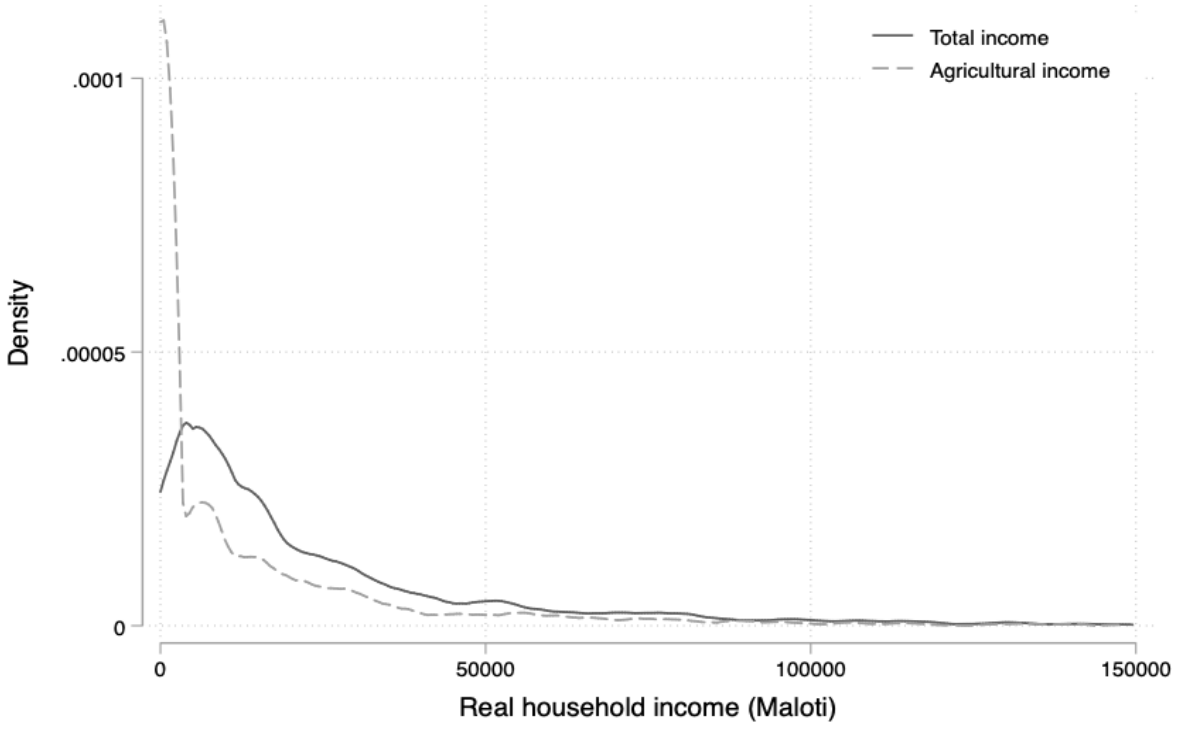


Figure 1: Total household income versus Household agricultural income
Notes: Household agricultural income is the sum of income from subsistence farming, cash crops, livestock, and livestock products.

Table 1: Summary statistics by gender of the household head

	Female					Male				
Variable	**N**	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**
Individual-level variables						*Individual-level variables*				
Age	4131	34.54	16.61	15	70	8953	35.20	15.74	15	70
Years of education	4080	6.775	3.173	0	17	8782	6.558	3.450	0	18
Farm-employed	4131	0.380	0.485	0	1	8953	0.458	0.498	0	1
Nonfarm employed	4131	0.109	0.311	0	1	8953	0.086	0.280	0	1
Housewife/Homemaker	4131	0.278	0.448	0	1	8953	0.256	0.437	0	1
Unemployed	4131	0.063	0.243	0	1	8953	0.044	0.204	0	1
Outside labour force	4131	0.170	0.376	0	1	8953	0.156	0.363	0	1
Individual income (M)	4130	6070	34072	0	1480000	8943	7944	23572	0	693000
Household-level variables						*Household-level variables*				
Household Size	990	4.863	2.777	1	24	2247	5.066	2.768	1	24
Infants (0-5 years)	990	0.542	0.872	0	6	2247	0.597	0.862	0	6
Children (6-9 years)	990	0.443	0.721	0	4	2247	0.456	0.726	0	7
School children (6-18 years)	990	1.708	1.623	0	10	2247	1.635	1.641	0	12
The elderly (65+ years)	990	0.279	0.559	0	4	2247	0.194	0.537	0	6
HH Head's Education	990	5.900	3.016	0	17	2247	4.693	3.789	0	18
HH Head's Age	990	54.21	12.45	15	70	2247	46.94	13.37	15	70
Education of males in HH	990	4.057	4.093	0	16	2247	5.104	3.480	0	16
Education of females in HH	990	6.453	2.885	0	17	2247	6.167	3.726	0	17
Age of males in HH	990	17.61	15.76	0	95	2247	40.44	12.56	0	82
Age of female in HH	990	48.84	12.85	0	90	2247	31.16	18.13	0	90
Workers per household	990	1.635	1.375	0	12	2247	1.941	1.301	0	12
Farming HH	990	0.551	0.498	0	1	2247	0.739	0.439	0	1
Non-farming HH	990	0.103	0.304	0	1	2247	0.066	0.248	0	1
Farming/Non-farming HH	990	0.116	0.320	0	1	2247	0.131	0.337	0	1
HH Income (M)	990	21702	76945	0	1820000	2247	30339	55743	0	955000
HH Farming Income (M)	657	13569	76676	0	1650000	1512	15324	34858	0	472000
SPEI	990	-1.132	1.830	-3.254	2.774	2247	-1.140	1.849	-3.254	2.774

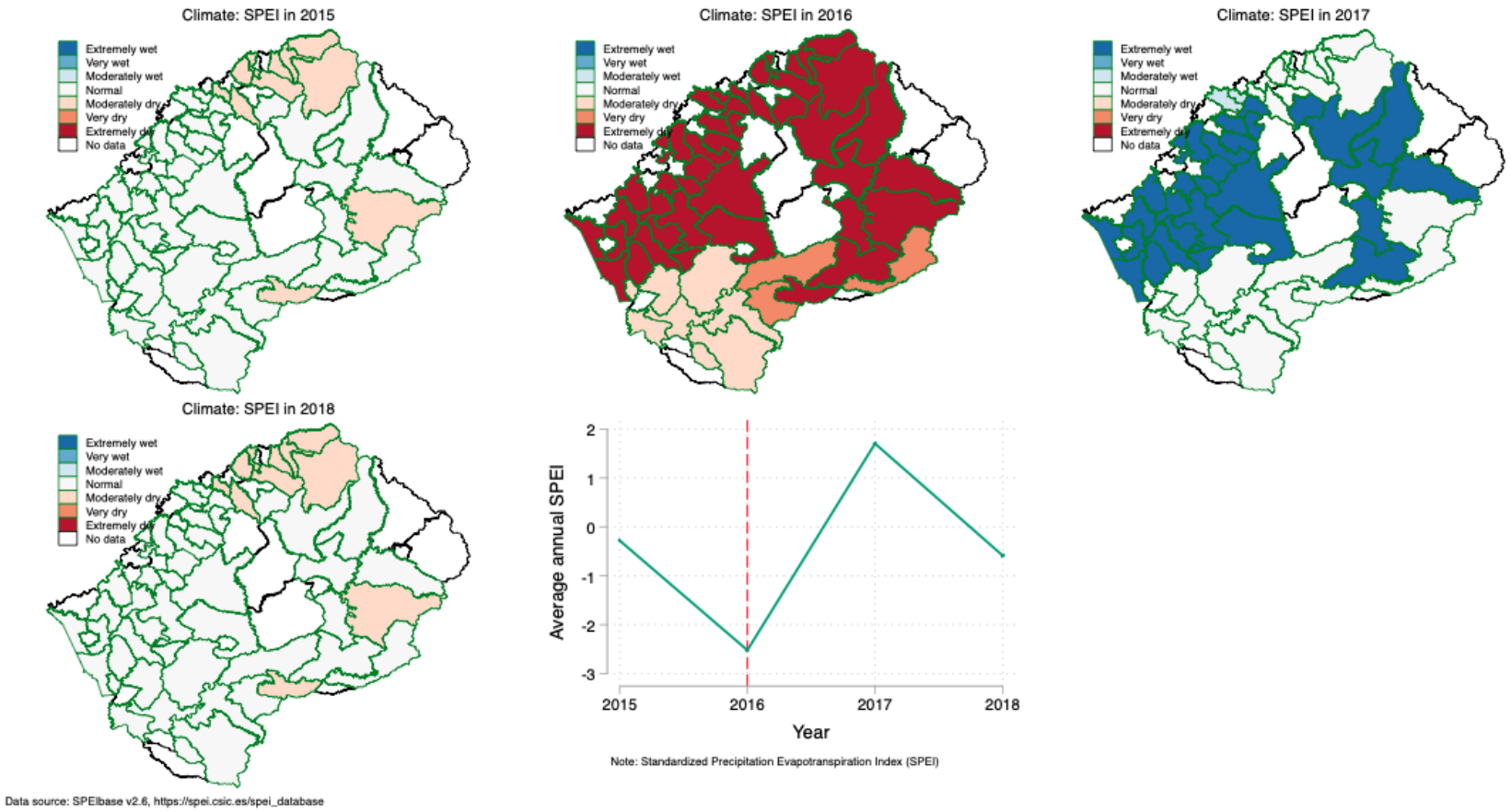
Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics. *Notes:* Sample is all those aged 15-70 years from 64 rural community councils. All monetary variables adjusted for inflation. HH stands for household.

3.5 Descriptive Analysis

We now provide an analysis of spatial and temporal changes in weather, household income and labour supply. We begin with spatial and temporal weather changes presented in figure 2. As we can see from the diagram, there is a significant variation in weather patterns across space and time. During the agricultural years 2014/2015 and 2017/2018, the weather conditions were largely normal, with few community councils (about 11) experiencing moderately dry weather conditions (i.e. with SPEI ranging between -1.5 and -1) in 2014/2015 and 2017/2018 planting seasons. During the 2015/2016 El Nino, all but a few councils in the southern region of the country were very dry or extremely dry. Therefore, the entire country experienced drought (i.e. SPEI less than -1) in 2015/2016 agricultural year.

In 2016/2017 agricultural year, the weather changed from one extreme end to another. Most the community councils that were extremely dry in 2015/2016 season became extremely wet (i.e. experience floods) in 2016/2017. The weather pattern only normalized during the 2017/2018 season. The last graph in figure 1 shows this extreme volatility in annual weather conditions over time. The data shows a significant variation in weather patterns between 2015 and 2018, with the biggest, country-wide, shocks happening in 2015/2016 and 2016/2017 planting seasons.

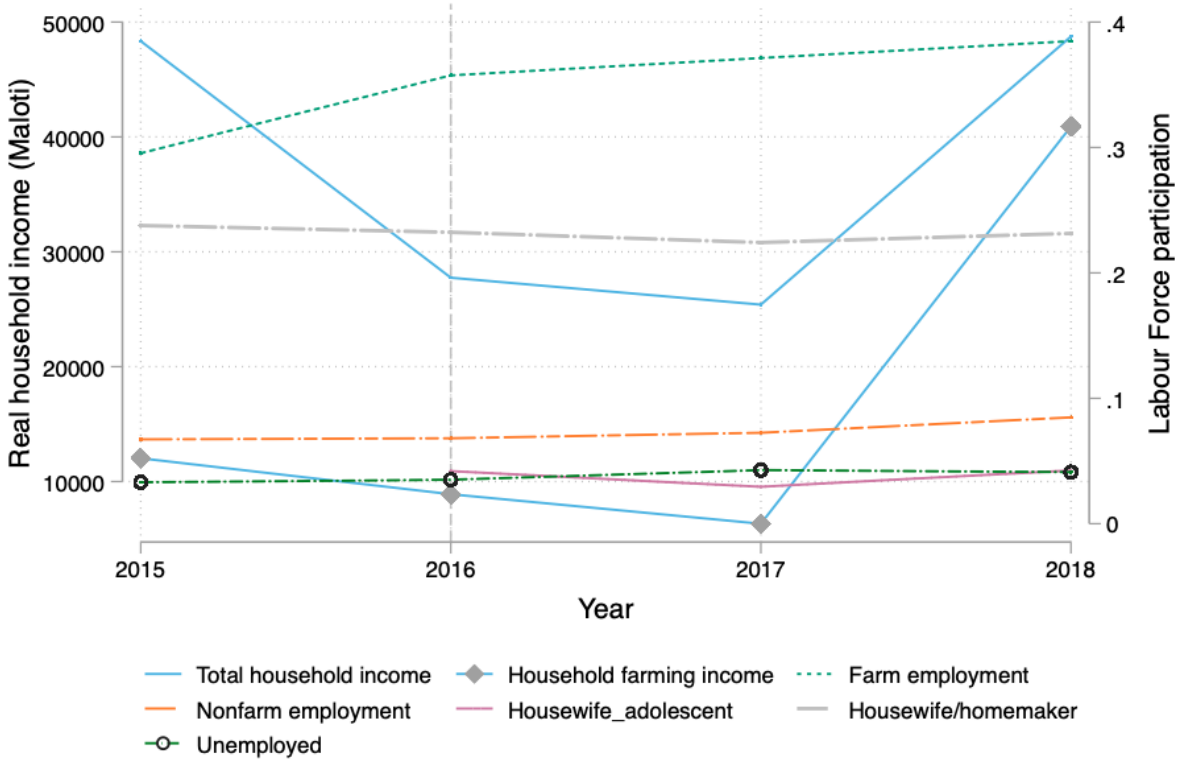
These changes in weather conditions likely caused a decline in incomes of farming household, potentially forcing them to seek employment in the off-farm sector or to intensify their labour supply in farming activities, making them less vulnerable, at least in the immediate term, to shocks. Further, these weather effects are likely gendered, with females affected differently from males. We next explore these effects.



Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics. *Notes*: Showing weather patterns for 64 rural councils.

Figure 2: Spatial and temporal changes in weather

Figure 3 illustrates trends in household income and labour supply over the period 2015-2018. The data shows a significant variation in real household income over the period of study. In particular, there was a steep decrease in 2016, potentially associated with the extremely dry weather conditions experienced during the 2015/2016 planting season. Household income further declined between 2016 and 2017, potentially due to floods, but it began to increase in 2017. Similarly, household agricultural income significantly declined between 2015 and 2017, after which it sharply increased. This synched movement between total household income and household farm income shows that movements in total household income closely reflect those in farm income.



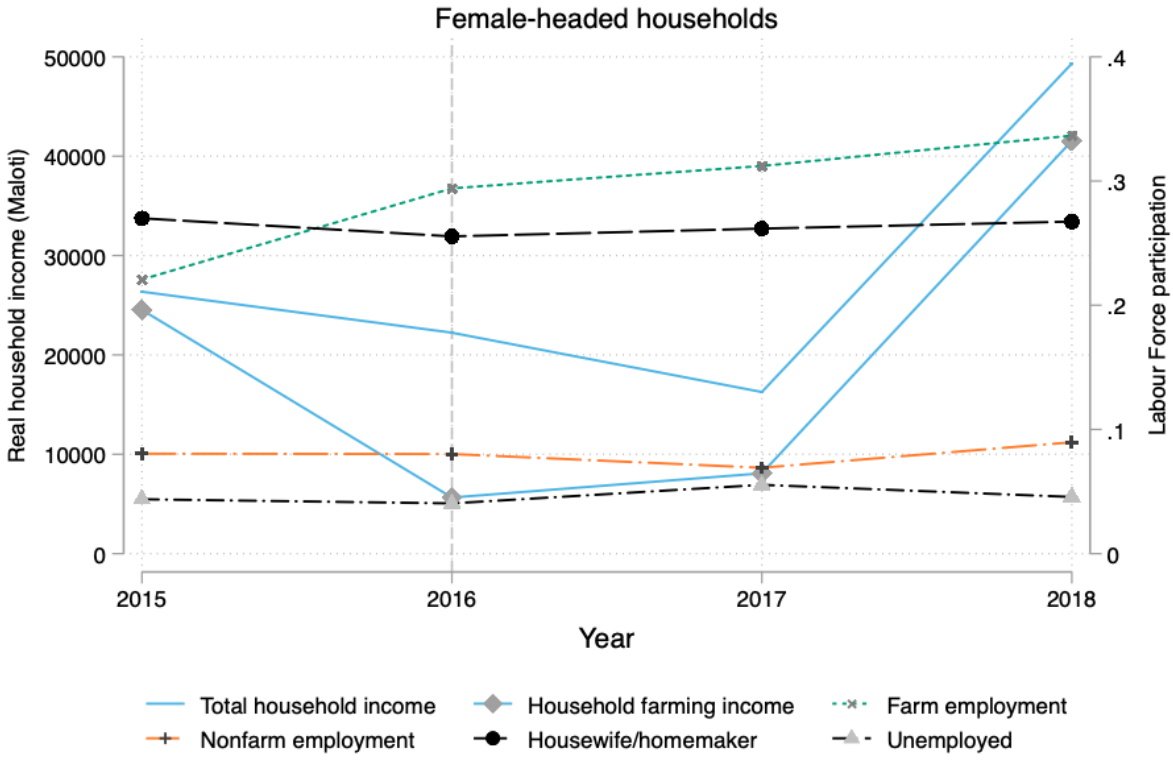
Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics.

Figure 3: Changes in household income and labour supply overtime

Labour force participation is significantly higher in the farm sector and lower in the non-farm sector. But the growth in farm employment slowed from 2016. This is potentially due to the 2015/2016 drought, which negatively affected crop production. Drought leads

to reduced pasture and this increases the farmers' need for hay, which in turn is likely to cause an increase in hay prices. The combination of reduced household income and increased hay prices may force farmers, mostly men and young boys, to herd their animals for longer hours in search of pastures. We can further see from the figure that, while the proportion of those who are housewives and/or homemakers declined between 2015 and 2016 for overall sample, it increased for adolescents (i.e., 12-16-year-olds).

A further disaggregation of the sample by gender (see figures 4a and 4b) reveals that the participation rate in farming sector is higher for male-headed households than for female-headed households. However, participation in non-farming sector is higher for female-headed households compared to their male counterparts.

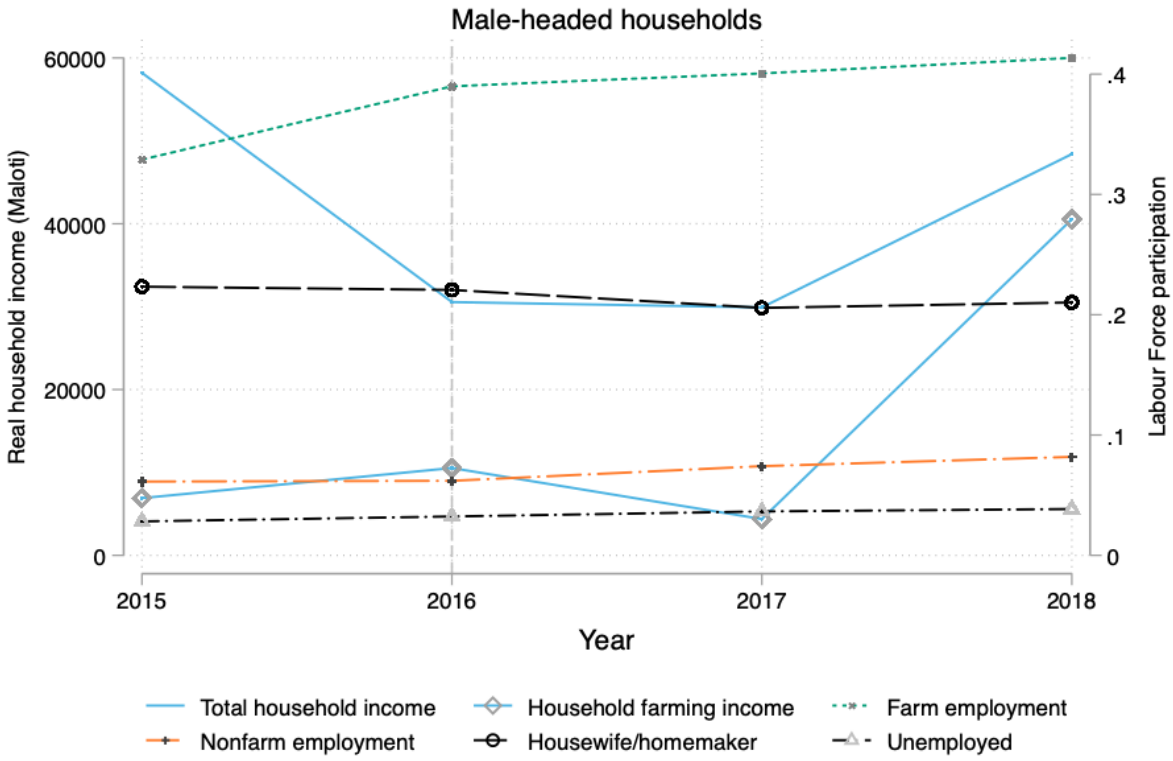


Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics.

Figure 4a: Changes in household income and labour supply for female-headed households

There are considerable differences between male headed-households and female-headed households. For female-headed households, farming income displays a similar trend to

that of total household income. However, for male-headed household, farming income moves in sync with total household income particularly from 2016/2017 agricultural year, which was also a drought year. Further, the increase (decrease) in household income between 2015/2016 and 2016/2017 agricultural years for male-headed (female-headed) households suggests that these households intensified (decreased) their participation in farming activities as a form of insurance against the weather shock. Notably, in both scenarios, although farming income has fewer observations, its trend moves systematically with that of total household income throughout the sample period. This underscores the use of total household income in our analysis.

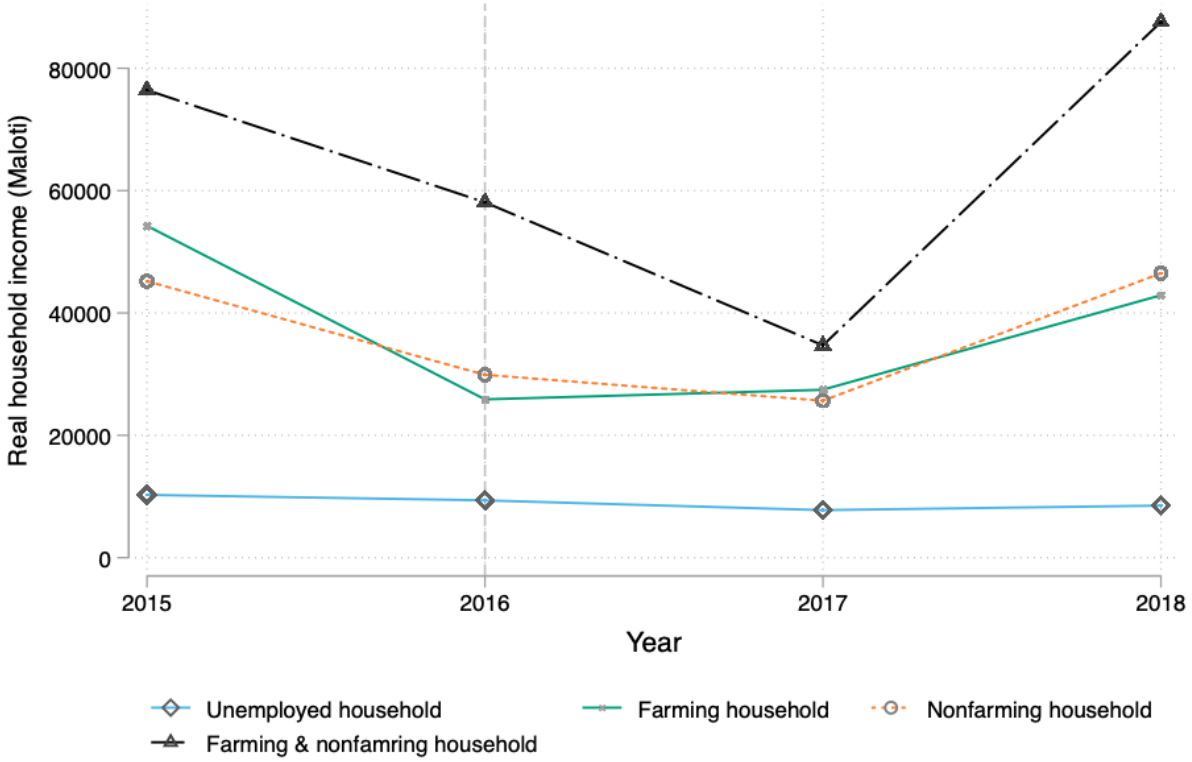


Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics.

Figure 4b: Changes in household income and labour supply for male-headed households

We present household income for various labour regimes in figure 5. Mostly, the trends in income move in sync with each other over the period 2015/2016-2018/2019, except for the unemployed whose income trends remained flat throughout the period. The largest source of income was obtained from participating in both farming and non-farming.

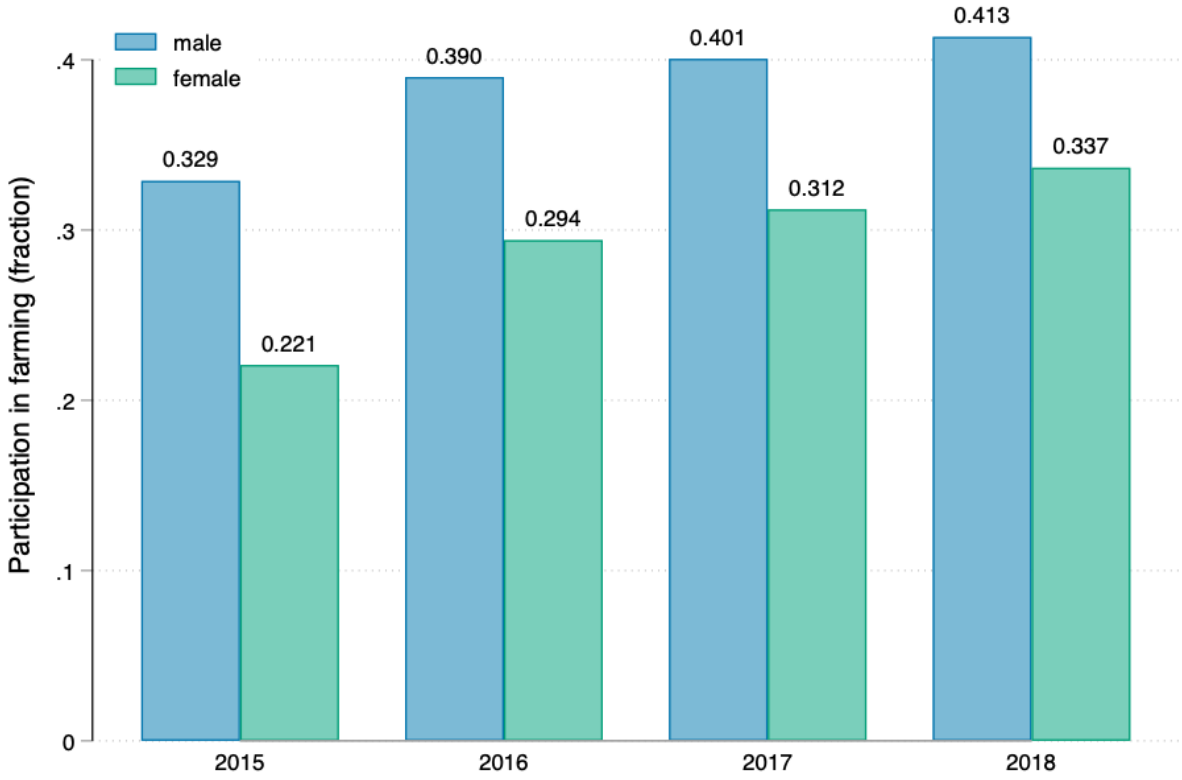
Trends in income of households that participate in farming activities only or in non-farming activities only track each other closely. While drought seems to have decreased income from all sources between 2015 and 2016, only farming households' income increased between 2016 and 2017, following the 2016/2017 floods.



Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics.
Figure 5: Household income by household labour regime

Figure 6 shows on-farm participation rates by gender over time. Generally, men have a higher participation rate in on-farm activities than women. Between 2015 and 2018, men's participation in farming activities increased from 33 percent to 41 percent, while that of women increased from 22 percent to 34 percent. Therefore, despite the drought incidence during the 2015/2016 planting season, both men and women increased their participation in farming activities between 2015 and 2016. The increase in farm labour participation tapered off following the 2017 floods. For example, men's participation in farming increased by 1 percentage point between 2016 and 2017 compared to 5

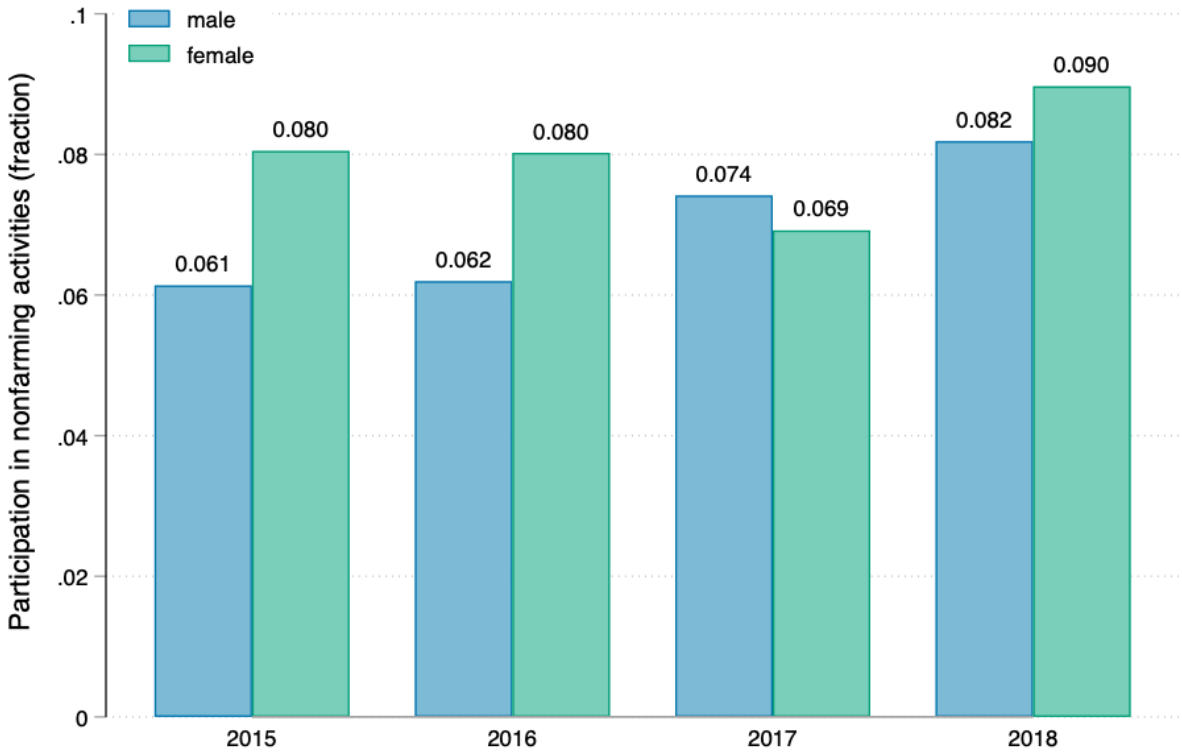
percentage points between 2015 and 2016.



Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics.
Figure 6 Participation in farming activities by gender overtime

Looking at figure 7, we can see that off-farm labour participation rates are far less than farm labour participation rates. Further, unlike farm labour participation, off-farm labour participation is largely dominated by females. But, as we have seen in table 1 above, there are more male-headed than female-headed households in the farm and off-farm labour force participation regime. Between 2015 and 2018, off-farm labour participation increased from a paltry 6.1 percent and 8 percent to 8.2 percent and 9 percent for men and women, respectively. Further, off-farm labour participation of men has been increasing throughout the period. But that of women dropped by 1.1 percent between 2016 and 2017, potentially due to floods of the 2016/2017 planting season. The largest increase in off-farm labour participation happened between 2017 and 2018 where females increased their participation by 2.1 percentage points, 1.3 percentage points higher than the increase by males during that period. And, in spite of the 2015/2016 drought, off-farm

labour participation continued to increase between 2015 and 2016, albeit at a much slower pace.



Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics.
Figure 7: Participation in non-farming activities by gender overtime

There are three important take-aways from figures 6 and 7. First, participation in farm and non-farm labour is increasing over time. Second, drought and floods do not deter farm labour participation, despite potentially reduced returns from farming. Third, floods discourage women, not men, from participating in off-farm labour activities. This implies that weather shocks (floods and drought) encourage men to intensify their participation in both farming and non-farming labour activities. The differential gender effects of floods on off-farm labour participation possibly implies that men and women engage in different off-farm labour activities and that women are engaged in those that are more vulnerable to floods such as sale of grains, vegetables and fruits (Lesotho Household Budget Survey,2017). Since off-farm employment acts as an insurance against adverse weather shocks, the results imply that women, and possibly women-headed households, cannot insure themselves against floods, and this could lead to a decrease in their

incomes. Next, we specify an econometric model that we use to test this hypothesis.

4 Empirical Framework

4.1 Estimation Strategy

Here we specify a model of how weather shocks influence individuals' labour supply options and then how they affect household income. We first specify the multinomial logit labour supply choice model, where we assume that each individual in the household chooses one of M mutually exclusive labour supply options to cope with climate shocks. Second, we estimate the effect of climate shocks on household income. To do so, we estimate two variants of a linear model, i.e., one which does not control for possible non-random selection into working and another one which accounts for potential selection. In all the models, we control for councils and year fixed effects.

The Individual Labour Supply Choice model

Recall that individuals within a household can choose to be in any of the five labour supply regimes: (1) farm labour (2) non-farm labour (3) look for job (i.e. be unemployed), (4) housewife/homemaker, and (5) be outside the labour market. Let Y^*_{ictj} be the latent expected income of individual i living in community council c at time t from choosing labour supply option j ($j = 1, \ldots, M$). The model is specified as

$$Y^*_{ictj} = \sum_{l=0}^{1} \gamma_{lj} Drought_{ct-l} + \sum_{l=0}^{1} \theta_{lj} Flood_{ct-l} + \boldsymbol{Z}_{ict}\psi_j + \lambda_t + \delta_c + \eta_{ictj} \qquad (1)$$

where $Drought_{ct-l}$ and $Flood_{ct-l}$ are dummies for contemporaneous ($l = 0$) and previous ($l = 1$) council/region-specific weather shocks, $\boldsymbol{Z}_{ict}$ is a vector of other covariates for individual i living in community council c at time t that influence the probability of choosing labour supply option j, such as education, age, gender, region of residence, household composition, λ_t and are, respectively, time and council fixed effects and η_{ictj} is an idiosyncratic unobserved error term. The parameters of interest are γ_{lj} and θ_{lj}.

In response to weather shocks, individual i in community council c at time t chooses labour supply option j over other alternatives $k \neq j$ whenever j is expected to yield higher income than k.

Weather Shocks and Household Income Model

Depending on what individual household members choose, a household is classified into three labour supply regimes: (1) farming, (2) nonfarming, and (3) both farming and nonfarming. The fourth option is being outside the labour force. The household income model for each possible labour supply regime is defined as

$$Y_{ictr} = \sum_{l=0}^{1} \gamma_{l1} Drought_{ct-l} + \sum_{l=0}^{1} \theta_{l1} Flood_{ct-l} + \boldsymbol{X}_{ict}\boldsymbol{\beta}_1 + \lambda_t + \delta_c + u_{ictr} (3)$$

where Y_{ictr} is income of household i in community council c and year t from labour supply regime r, $(r = 1, \dots, 3)$, and $\boldsymbol{X}_{ict}$ is a vector of covariates that influence household income (labour market returns) such as the difference in mean-age of men and mean-age of women within the household, difference mean-education of men and mean-education of women within the household, household size, etc., u_{ictr} is the stochastic error.

In this study, we are only interested in two labour regimes – farming activities only, and both farming and off-farm activities – for two reasons. First, there are few rural households doing only off-farm activities. Second, the farming and non-farming activities labour regime choice is a diversification option, which enables us to examine how whether this sort of income diversification can mitigate against effects of agricultural weather shocks. Therefore, we estimate equation (3) using linear fixed effects model to account for unobserved heterogeneity across the councils and time, separately for each labour regime and by gender of the household head.

It is likely that the probability that a household participates in either farm activities only or in both farm and off-farm activities is correlated with the level of expected earnings from either labour regime. That is, if the labour supply regime selection model (1) errors (η_{ictj}) are correlated with the income model errors (u_{ictj}), that is, if $\rho_j = E(\eta_{ictj}, u_{ictj}) \neq$

0, then estimating the household income model (3) by linear fixed effects model yields inconsistent parameter estimates.

To address this problem, we employ the Heckman Two-step selection model (Heckman, 1979). In the first stage, we model the household's decision to participate in farming alone or in farming and off-farm activities simultaneously, as two separate decision-making processes, using a probit model.

$$Y_{ictj} = \begin{cases} 1 & if \;\; Y^*_{ictj} > 0 \\ 0 & if \;\; Y^*_{ictj} \leq 0 \end{cases}$$

where Y^*_{ictj} is the latent income from labour supply regime $j = \{farm\ only,\ farm\ and\ off-farm\}$, and is specified as in equation (1).

In the second stage, we estimate the household income equations, separately for those in farming only and those in both farming and off-farm activities, by Ordinary Least Squares. For each labour supply regime j, the selection bias-corrected household income equation is given as

$$Y_{ictj} = \sum_{l=0}^{1} \gamma_{lj} Drought_{ct-l} + \sum_{l=0}^{1} \theta_{lj} Flood_{ct-l} + \boldsymbol{X}_{ict}\boldsymbol{\beta}_j + \sigma\left[\boldsymbol{Z}_{ict}\widehat{\psi_J}\right] + \lambda_t + \delta_c + v_{ictj} \quad (4)$$

where σ is the inverse Mills ratio (Heckman, 1979).

4.2 Identification strategy

In order to identify the effect of weather shocks on household income from labour supply regime j, γ_j, we need some exclusion restrictions or selection instruments. That is, we need variables that influence selection of labour supply regime but not the household income. In this study, we use as instruments the number of children aged under 10 years old (0-9 year olds) and that of the elderly (65+ year olds) in the household. These are valid instruments for the following reasons. First, schooling reduces the household's farm labour and this may influence labour supply options by household members. However,

the number of children aged under 10 years old do not directly affect household income. Second, the elderly, just like schooling children, are dependents and do not contribute to household income. Therefore, the number of elderly persons within the household may influence the labour supply options by household members but not household income.

Upon the control for time and council fixed effects, and given the plausibly exogenous temporal and spatial variation in weather shocks, gamma (γ_{lj}) and theta (θ_{lj}) coefficients identify the causal effects of weather shocks (drought and floods, respectively) on individuals or household labour supply decisions and on household income. The standard errors are clustered at the council level to account for the potential serial correlation of the shock episodes within the same community council.

5 Results

In this section, we present evidence on the impact weather on individuals' labour supply decisions, and on household income. We specifically look at how weather changes influence labour supply decisions of females versus males, and how the weather affects income of female-headed households versus male-headed households.

5.1 Effect of weather shocks on individual's labour supply

Table 3 presents the results for the effect of weather shocks on individual labour supply. Column (1) shows the results for the male sample, while column (2) shows those for the female sample. Looking at column (1), we can see that drought increases the probability of men being in farming by 20 percentage points, and decreases the probability of being a non-farm labourer by 11 percentage points relative to being outside the labour market. Similarly, if there was drought in the previous year, men are 16 percentage points more likely to be in farming than being outside the labour market. The increased likelihood of being a farm labourer during drought could imply that individuals in rural areas have no other coping strategies other than to intensify their participation in farming activities even when the potential returns from farming are low. Men potentially intensify the participation in the more shock-resistant (at least in the short-run) livestock farming during droughts.

Table 3: Marginal Effects of Weather shocks on labour supply decisions

	(1) Men	(2) Women
Drought		
1. Farm labour	0.196***	0.0989
	(0.0634)	(0.0687)
2. Non-farm labour	-0.108***	-0.0958*
	(0.0350)	(0.0538)
3. Unemployed or Looking of job	0.00302	0.0709**
	(0.0372)	(0.0290)
4. Housewife/Homemaker	-0.0881	-0.0248
	(0.0555)	(0.0818)
Lag drought		
1. Farm labour	0.161***	0.0769
	(0.0620)	(0.0579)
2. Non-farm labour	-0.0160	-0.00308
	(0.0446)	(0.0419)
3. Unemployed or Looking of job	-0.0245	0.0413
	(0.0318)	(0.0388)
4. Housewife/Homemaker	-0.0959*	-0.0534
	(0.0495)	(0.0590)
Flood		
1. Farm labour	-0.131**	-0.0589
	(0.0547)	(0.0577)
2. Non-farm labour	0.0370	0.00553
	(0.0344)	(0.0359)
3. Unemployed or Looking of job	0.0267	0.0160
	(0.0269)	(0.0168)
4.Housewife/Homemaker	0.0612	-0.0255
	(0.0461)	(0.0608)
Lag flood		
1. Farm labour	-0.00747	0.00849
	(0.0493)	(0.0489)
2. Non-farm labour	-0.00287	-0.00649
	(0.0329)	(0.0317)
3. Unemployed or Looking of job	0.0133	0.0254
	(0.0307)	(0.0304)
4. Housewife/Homemaker	0.0151	-0.0575
	(0.0286)	(0.0647)
N	6967	5324

Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics.
Notes: Standard errors, in parentheses, are clustered at the council level. For the male (female) model, the sample is all 18-70 (18-60) year olds, in rural councils observed for at least three years. "Farm labour", "Non-farm labour", "Unemployed or Looking of job", and "Housewife/Homemaker" are labour supply

options. The base category is "Not being in the labour force". All models control for numbers of infants (0-5 year olds), 6-9 year olds, school-age children (6-18 year olds), and the elderly (65+ year olds) in the household, and council and year fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

On the contrary, during floods, men are 13 percentage points less likely to engage in farming activities. This is in line with expectations that since floods are destructive, farming then become not a profitable activity. Previous floods do not affect individuals' labour choices.

In column (2), we can see that contemporaneous drought reduces women's participation in non-farm activities by 9.6 percentage points, and increases the likelihood of being unemployed by 7 percentage points. All other weather shocks – previous drought and contemporaneous and previous floods – have no significant effect on labour supply choices of women. However, the the signs of the coefficients are largely consistent with those of the men's sample. This implies that, in the face of adverse weather conditions, women are indifferent between getting out of the labour force and being in any other labour supply option, potentially because none of the available labour supply options offers better security during weather shocks. This indicates that women and women-headed households are more vulnerable than men during adverse weather conditions. Women also have fewer coping strategies against weather shocks.

5.2 Differential effect of weather shocks on household income by gender

Next, we explore the effect of weather shocks on household income by gender of the household. The results are presented in table 4. Columns (1) to (4) show the linear FE model results and columns (5) to (8) show the Heckman selection model results. The odd-numbered columns present the effects for female-headed households and the even-numbered columns present those for male-headed households.

Generally, the linear FE model results are similar to the Heckman selection model results. We can see from columns (1), (2), (5) and (6) of the table that contemporaneous and previous drought have no significant influence on income of female- and male-headed households engaged in farming activities. On the other hand, contemporaneous drought reduces income of female-headed households who are simultaneously engaged in farming

and off-farm activities by 128 percent (see columns (3) and (7) of the table). However, the same weather shock has no statistically significant effect on income of male-headed households doing the same labour activities (see columns (4) and (8)).

Further, contemporaneous floods, and not previous floods, have a significant negative effect on incomes of farming female-headed households, and on incomes of those – female-headed households – doing both farming and non-farming activities (see columns (3) (5), and (7)). For instance, during floods, income of farming female-headed households drops by up to 62 percent and that of farming and non-farming female-headed households declines by about 77 percent. Previous floods reduce income of male-headed households who participate in both and farm and off-farm activities by 63 percent (see columns (4) and (8)). Conversely, both current and previous floods have no influence on income of male-headed farming. This implies that contemporaneous floods represent a huge income shock to female-headed households, and being in off-farm employment provides no security against this shock but rather intensifies the income loss.

These results are largely consistent with what we have observed in figures 3 and 4 above, and the evidence that women engage in off-farm activities that are more susceptible to weather shocks than men. We know that during the La-Nina period, there was an increase in agricultural produce in Lesotho (2017/2018 Crop Forecasting Report). The negative effect of floods on female-headed households' income is potentially due to suppressed prices of agricultural produce (e.g. vegetables and grains).

By and large, the results in table 4 indicate that women are more vulnerable to weather shocks than men. More importantly, we can see that the effect of previous floods is twice as high on income of female-headed households than male-headed ones. In the next section, we explore potential mechanisms for these differential effects.

Table 4: Effect of weather shocks on female- and male-headed households' income

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Linear Fixed Effects model				Heckman Selection model			
	Female-Farmers	Male-Farmers	Female-Farmer & Nonfarmer	Male-Farmer & Nonfarmer	Female-Farmers	Male-Farmers	Female-Farmer & Nonfarmer	Male-Farmer & Nonfarmer
Drought	0.0864	0.352	-1.278*	-0.230	0.273	0.414	-1.254**	0.171
	(0.332)	(0.270)	(0.706)	(0.540)	(0.319)	(0.275)	(0.581)	(0.573)
Lag drought	0.169	0.181	-0.820	0.251	0.170	0.213	-0.844	0.134
	(0.310)	(0.229)	(0.717)	(0.429)	(0.303)	(0.229)	(0.581)	(0.475)
Flood	-0.578**	-0.258	-0.775	-0.392	-0.622**	-0.276	-0.770*	-0.303
	(0.290)	(0.224)	(0.493)	(0.364)	(0.274)	(0.224)	(0.393)	(0.382)
Lag flood	0.145	0.0487	-0.319	-0.627**	0.195	0.0536	-0.325	-0.582*
	(0.277)	(0.185)	(0.384)	(0.280)	(0.265)	(0.183)	(0.308)	(0.353)
N	808	2021	164	379	1461	2637	1026	2539

Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics. *Notes*: Robust standard errors in parentheses. Sample is all female-headed households in rural councils observed for at least three years. In all regressions, the dependent variable is log of household income. The reference labour option is being unemployed. Control variables are council and year fixed effects, household size, and average education and average age of female and male individuals in the household. Selection instruments in the Heckman selection model are the number of children under 10 year olds and number of the elderly (65+ year olds) in the household. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.3 Potential mechanisms

What could possibly explain the differences in labour supply choice between men and women, and hence differences in male- and female-headed households' incomes in response to weather shocks? Some of the possible explanations are that: (1) male- and female-headed households engage in different off-farm activities that differentially cushion their incomes during weather shocks; (2) male- and female-headed households possibly engage in different (short-term resilient) farming activities such as livestock; (3) female-headed households are likely to substitute young girls to do household chores to enable their mothers or other adult females in the household to engage in income generating activities and (4) male-headed households possibly marry off their young girls and receive the bride price as a form of insurance against weather shocks (see Corno, Hildebrandt, and Voena, 2020).

We initially look at the first two potential explanations that the differences in labour supply and household income effects on weather shocks are likely due to the different farm and off-farm activities that men and women participate in. Unfortunately, we do not have enough data to provide causal effect evidence, but we are only able to provide some descriptive evidence. According to Lesotho Household Budget Survey (HBS) of 2017 (see table 5), women's farm and off-farm activities mostly include sell grains (sorghum, maize, etc.), firewood, traditional herbs, home-brewed beer, food, while men mostly sell livestock, animal products and are involved in construction (building houses). Therefore, farm and off-farm activities by women are more susceptible to weather shocks than those that men are involved in. For example, during droughts, selling of cattle and animal products may increase because there is less use of cattle for ploughing, while selling grains will likely decline because of lack of grain supply.

Next, we explore the second mechanism to explain the negative drought and previous drought effects on female-headed (and not male-headed) households' income for those engaged in farm and off-farm activities simultaneously. According to Yaya, Odusina, and Bishwajit (2019), there is a higher incidence of child marriages in male-headed households relative to female-headed ones in sub-Saharan Africa, and this may explain

the negative effect of contemporaneous and previous drought on income of female-headed households in farm and off-farm activities. The bride price from marrying young daughters during droughts may offset the negative effects of weather shocks in male-headed households.

Table 5: What farm and off-farm activities did individuals do in the past 12 months?

	Female (%)	Male (%)	Total
Sell livestock			
No	50.60	49.40	100.00
Yes	43.83	56.17	100.00
Total	50.56	49.44	100.00
Sell grains			
No	50.56	49.44	100.00
Yes	57.26	42.74	100.00
Total	50.56	49.44	100.00
Sell/gather firewood			
No	50.56	49.44	100.00
Yes	50.52	49.48	100.00
Total	50.56	49.44	100.00
Sell traditional herbs			
No	50.52	49.48	100.00
Yes	59.85	40.15	100.00
Total	50.56	49.44	100.00
Sell animal products			
No	50.57	49.43	100.00
Yes	25.37	74.63	100.00
Total	50.54	49.46	100.00
Sell home-brewed beer			
No	50.32	49.68	100.00
Yes	55.87	44.13	100.00
Total	50.56	49.44	100.00
Sell food			
No	50.36	49.64	100.00
Yes	60.98	39.02	100.00
Total	50.56	49.44	100.00
House building (Construction sector)			
No	50.64	49.36	100.00
Yes	42.95	57.05	100.00
Total	50.55	49.45	100.00

Source: Authors' computations from the Lesotho Household Budget Survey of 2017, Bureau of Statistics.

The APS data has information on whether individuals are home-makers and/or housewives. We argue that adolescent girls replace their older female household members

in the household chores to allow older female members to increase their labor supply into farming or to look for job (consistent with the labor supply model – female-headed households). Since we cannot separate these two categories, we first use this information to investigate the child-marriage transmission channel and within household labour substitution channel. Table 6 presents results of the impact of drought on the likelihood of an adolescent (12-16-year-old) being a home-maker or housewife.

Table 6: Marginal effect of drought on the probability of an adolescent being a home-maker or a housewife.

	(1) Men	(2) Women
Drought	-0.0829	0.176*
	(0.106)	(0.0968)
Lag drought	-0.0769	0.0799
	(0.0632)	(0.0684)
Flood	-0.0488	-0.0112
	(0.0671)	(0.0523)
Lag flood	-0.0965	0.0649
	(0.106)	(0.0466)
N	478	952

Source: Lesotho Agriculture Production Surveys 2015/16 - 2018/19, Lesotho Bureau of Statistics. *Notes*: Standard errors, in parentheses, are clustered at the council level. The sample is all 12-16 year olds, in rural councils observed for at least three years. All models control for numbers of infants (0-5 year olds), 6-9 year olds, school-age children (6-18 year olds), and the elderly (65+ year olds) in the household, and council and year fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

While weather shocks reduce off-farm employment and increase unemployment of adult females who are in the labour force, they significantly increase labour supply of adolescent girls (12-16 year olds). From table 6, we can see that drought increases the likelihood of an adolescent girl being a homemaker or a housewife by 18 percentage points relative to non-adolescents. That is, during drought, young girls likely to drop out of school and get married and/or do household chores to enable their mothers or adult females in the household to engage in income generating activities.

If female-headed households were marrying off their young daughters as a form of insurance against drought-induced weather shocks, we would expect the bride-price, which is paid to the family of the girls, to offset the negative effect of drought. It is, therefore, unlikely that this result is explained by child-marriage channel. We, in fact, show in table 7 that drought reduces (rather than increase) the hazard of young girls being

married. These results are based on the replication of Corno, Hildebrandt, and Voena (2020) for Lesotho.

Table 7: Effect of drought on timing of marriage

VARIABLES	(1) Timing of marriage
Drought	-0.00460***
	(0.00141)
Observations	98,945
Adjusted R-squared	0.064

Source: Authors' replication of Corno, Hildebrandt, and Voena (2020)' s results for Lesotho using the 2004, 2008, and 2014 Demographic Health Survey data. *Notes*: OLS regression (with grid cell fixed effects) results on a sample of women aged 25 or older at the time of interview. Observations are at the level of person × age (from 12 to 24 or age of first marriage). The dependent variable is a binary variable for marriage, coded to 1 if the woman married at the age corresponding to the observation. Standard errors (in parentheses) are clustered at the grid cell level. A drought is defined as an annual rainfall realization below the 15th percentile of the local rainfall distribution. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Taken together, tables 6 and 7 results imply that, during and following droughts, adult women lose their off-farm jobs. As they intensify their search for employment, they reduce their time doing household chores and younger daughters are used are substitutes within the household. This strategy, however, is not successful in mitigating the negative effects of climate shock as these families still see a significant decline in their incomes. Adopting this strategy may actually have negative longer-term effects in terms of investment of women's human capital, by making women even more vulnerable to future shocks.

6 Conclusions and policy implications

This study examines the effect of weather shocks, drought and floods, on labour supply decisions and income for rural farming households in Lesotho. The study also explores the extent to which women are affected by these shocks relative to their male counterparts. We use the Lesotho Agricultural Survey data, merged with climatic conditions data, the Standardized Precipitation Evapotranspiration Index (SPEI). We then employ a simple multinomial logit model to examine labour choice effects of weather shocks. To study the household income effects of these shocks, we use the linear Fixed Effects model and Heckman Selection model.

The results show that women are more vulnerable to weather shocks and have limited coping strategies than their male counterparts. While men have an option to intensify their participation in farming activities as a coping strategy in the presence of the weather shock, women have no such options. Contemporaneous and previous droughts lead to an increased participation in farming activities for men but not for women while contemporaneous floods negatively affect farm labour supply decisions of men but not women.

We also analyse the gender-differentiated effects of weather shocks on household income. The results reveal that floods reduce income for farming female-headed households by up to 62 percent, and that contemporaneous drought reduces income of female-headed households that engage in farming and in farming and non-farming activities by up to 128 percent, while both contemporaneous and previous floods have no significant impact on the income of their counterpart households headed by men.

Finally, we explore two potential mechanisms that may generate these differentiated effects of weather shocks: first, that female- and male-headed households engage in different off-farm activities that may dampen or not the effects of weather shocks; and second, that male-headed households may be complementing their income with bride-price money from marrying their young daughters given the high incidence of child marriages and child labour in such households.

Our evidence shows that females and men engage in different off-farm activities, and that females do those off-farm activities that more susceptible to weather shocks relative to those men engage in. Further, we find that drought increase the probability of an adolescent girl living in a female-headed household being a homemaker or housewife by about 18 percent. Two possible explanations underpin this result. Firstly, young girls are prone to early marriages in exchange for bride price, which could become a cushion against weather shocks. Secondly, girls could become homemakers as their mothers or adult females within household seek for income generating activities to cushion themselves against the weather shock.

We show that the child marriage channel cannot explain our results for two reasons. First,

since only adolescent girls in female-headed households are likely to be homemakers/housewives, we would expect this to dampen the negative effect of drought in these households, especially those engaged in farm and off-farm activities. Second, and more importantly, we use the Demographic Health Survey data for Lesotho to show that drought reduces the risk of getting married young in Lesotho. Therefore, the more plausible mechanism for these results is that young girls in female-headed households substitute adult females in doing household chores as those increase their search for employment.

Taken together, the results suggest that climate change has a very significant effect on rural labour markets and households' welfare in Lesotho. Women and adolescent girls are most vulnerable to these shocks in terms of income and labour supply decisions. The prevailing COVID-19 pandemic amplifies the gendered effects as women become even more vulnerable to the shocks. Men on the other hand, are less affected by climate shocks. Therefore, extensive use of climate-smart agricultural technologies and inputs, such as use of hybrid seeds, by rural households would provide the necessary self-insurance against weather shocks for rural farming households. Further, more opportunities for women in rural non-farming sector as well as increased access and ownership of productive assets, such as land, for women would provide mitigating effects of weather shocks. Lastly, increase in female-dominated non-farm activities such as rural-based tourism-related industries could serve as a cushion against weather related shocks as well as the likely effects from the pandemic.

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Appendices
Appendix A

Table A1: Categorization of dry and wet grade according to the SPEI

Categorization	SPEI
Extremely dry	Less than -2
Severely dry	-2 to -1.5
Moderately dry	-1.5 to -1
Normal	-1 to 1
Moderately wet	1 to 1.5
Severely wet	1.5 to 2
Extremely wet	Greater than 2

Table A2: Variable description

Variable	Definition	Source
Individual-level variables		
Age	Variable that identifies the year of age of members of the household	Agricultural Production Survey (APS)
Years of education	Measures levels of education attained by household head	Agricultural Production Survey (APS)
Farm-employed	Binary variable that takes the value 1 if the individual is employed on farm and 0 otherwise	Agricultural Production Survey (APS)
Nonfarm employed	Binary variable that takes the value 1 if the individual is employed on non-farm and 0 otherwise	Agricultural Production Survey (APS)
Housewife/Homemaker	Binary variable that takes the value 1 if an individual is housewife/homemaker and 0 otherwise	Agricultural Production Survey (APS)
Unemployed	Binary variable that takes the value 1 if an individual is unemployed and 0 otherwise	Agricultural Production Survey (APS)
Outside labour force	Binary variable that takes the value 1 if an individual is outside labour force and 0 otherwise	Agricultural Production Survey (APS)
Individual income (M)	Consists of receipts in cash and in kind income by individuals within the household	Agricultural Production Survey (APS)
Household-level variables		
Household Size	Total number of persons living permanently within the household	Agricultural Production Survey (APS)
Infants (0-5 years)	Number of infants aged 0 to 5 years within the household	Agricultural Production Survey (APS)
Children (6-9 years)	Number of children aged 6 to 9 years within the household	Agricultural Production Survey (APS)
School children (6-18 years)	Number of school children aged 6 to 18 years in the household	Agricultural Production Survey (APS)
The elderly (65+ years)	Number of elderly individuals aged 65+ years within the household	Agricultural Production Survey (APS)
HH Head's Education	Measures level of education attained by household head	Agricultural Production Survey (APS)

HH Head's Age	Identifies the year of age of the household head	Agricultural Production Survey (APS)
Education of males in HH	Measures level of education attained by males in the household	Agricultural Production Survey (APS)
Education of females in HH	Measures level of education attained by females in the household	Agricultural Production Survey (APS)
Age of males in HH	Identifies the year of age of the males in the household head	Agricultural Production Survey (APS)
Age of female in HH	Identifies the year of age of the females in the household head	Agricultural Production Survey (APS)
Workers per household	Number of hired individuals (workers) within the household	Agricultural Production Survey (APS)
Farming HH	Dummy variable that takes the value 1 if the household participates in farm employment and 0 otherwise	Agricultural Production Survey (APS)
Non-farming HH	Dummy variable that takes the value 1 if the household participates in non-farm employment and 0 otherwise	Agricultural Production Survey (APS)
Farming/Non-farming HH	Dummy variable that takes the value 1 if the household participates in both on-farm and non-farm employment and 0 otherwise	Agricultural Production Survey (APS)
HH Income (M)	Sum of agricultural income, non-farm wage income, self-employment or entrepreneurial income, property income, transfers income and any other income by the individuals in Maluti	Agricultural Production Survey (APS)
HH Farming Income (M)	Income that is generated from agricultural sector in Maluti	Agricultural Production Survey (APS)
SPEI	Index that takes into account the climatic water balance difference between precipitation and potential evapotranspiration (PET)) to determine the severity of drought	SPEI database