Impact of soil conservation adoption on intra-household allocations in Zambia

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**Abstract**
Anecdotal evidence suggests that training in soil conservation techniques may lead to greater female involvement in agricultural production in sub-Saharan Africa, but little is known about the causal relationship. We test this relationship empirically, examining the impact of soil conservation training sessions on female agricultural labor contributions within households in Zambia. Moreover, we explore the short-run effects of increased female agricultural productivity on female empowerment through measurement of changes in gender-specific resource allocations within the household. The extension of funding of conservation farming (CF) training sessions in 2007 in specific districts in Zambia provides variation in CF take-up. We use this variation to implement a difference-in-differences strategy on a number of datasets. Our results suggest that expansion of funding for CF training sessions increased take-up of CF, increased female labor hours, and shifted household expenditures toward goods associated more strongly with female preferences than male preferences. These results show the importance of understanding the impact of development programs, specifically promotion of agricultural technologies, on household gender dynamics.
Agricultural productivity in sub-Saharan African lags behind that of other regions. While other areas have seen crop production per capita as much as double in the last fifty years, production in sub-Saharan Africa has remained virtually unchanged (Food and Agriculture Organization, 2012). One reason for this lack of growth in productivity is soil degradation from intensive tillage agriculture. The Dust Bowl in the United States occurred as a result of similar practices and has since led to a sharp increase in the usage of the alternative, conservation farming (CF) methods. A primary feature of CF methods is minimum tillage, leaving soil intact to preserve nutrients and moisture and prevent erosion. While 25.5 percent of land in the USA was farmed using conservation practices in 2007, less than 1 percent of land in sub-Saharan Africa was farmed with these methods (Derpsch and Friedrich, 2010). In recent years, considerable resources have been devoted to CF training programs in Africa for this reason. While this primary motivation for the promotion of such programs is compelling, little research has been conducted on the household impacts of conservation farming, in particular the impact on the division of labor and gender norms within the household in sub-Saharan Africa. We contribute to studies of the impact of CF training programs by testing whether such training programs can not only improve agricultural productivity, which has already been proven to be the case, but also engage women in labor activities outside the household, thereby empowering them and providing a “win–win” scenario for donors.

The existing literature suggests that traditional agricultural practices associated with the plough, the main method of soil tillage, influenced the historical gender division of labor and the evolution of gender norms. In particular, cultures that used the plough historically have been shown in the present to have lower rates of female participation in the labor market, politics, and entrepreneurial activities (Alesina et al., 2013). The primary explanation for this connection is that men had a comparative advantage when using the plough, due to the upper body strength required in its use, leading to a division of labor along gender lines between agricultural activities and domestic production. The historical alternative to use of the plough, use of CF methods, is associated with relatively higher levels of gender equality. Though the long-run connection between CF methods and gender equality has been studied, to our knowledge, no previous papers have evaluated the ability of development programs focused on CF to improve gender norms in the short run. Moreover, the primary mechanism through which CF impacts gender norms has not been proven. We test whether one possible mechanism could be the increased involvement of women in agricultural activities.1

We specifically contribute to the literature by testing the impact of CF training in Zambia on the gender division of labor at the household level as a primary mechanism through which agricultural methods may impact gender norms. We suggest that CF training causes a shift from usage of a gender-biased agricultural technology to a gender-neutral technology through adoption of CF methods. In order to identify the impact of CF, we use a difference-in-differences strategy exploiting the regional variation in a CF training expansion that took place in Zambia in 2007. We find that CF training increased the take-up of CF within households and also increased the agricultural labor hours of females relative to males. Through our findings we provide valuable information for donors about the often overlooked household impacts of CF development programs. We also fill a gap in the literature regarding the primary mechanism through which CF farming impacts gender norms, providing additional information about the short-run impacts of a shift from use of the plough to CF.
In addition to our main results regarding the increase in female agricultural labor hours, we provide suggestive evidence regarding the likely impact of additional labor hours on gender norms. In this secondary analysis, we study household expenditures and behavioral outcomes. We find that CF training improved child outcomes. Females have been shown to have a greater preference for investments in children, suggesting that females may have more decision-making power due to CF training.\(^2\) We also find that the training shifted household expenditures away from goods associated with male consumption preferences. This suggests that CF training may be not only increasing female labor hours outside the home, but also improving gender norms in the short run.

Zambia is an ideal setting for this study for several reasons. A large amount of funding has been directed toward CF training in Zambia. In 2013, the European Union and the Food and Agriculture Organization of the United Nations (FAO), along with the government of Zambia, began an approximately $13 million program to promote CF.\(^3\) In 2014, the Norwegian Agency for Development Cooperation (Norad) donated $9.5 million to promote CF in Zambia.\(^4\) Another reason why Zambia is a sensible setting for our study is that gender norms are unfavorable for women. Over 70 percent of the nations in the bottom quartile of the 2013 United Nations Gender Inequality Index are African. Zambia itself falls at 135 out of 152 ranked countries. Moreover, the 2007 Zambian Demographic and Health Survey data indicate that 47 percent of all Zambian women have experienced physical violence since the age of 15. Of these cases, 77 percent of the perpetrators were a current or former husband or partner. The hope is that when women are more involved in household agricultural productivity, the gender dynamics within the household will change, resulting in increased gender equality.

Though a vast literature on CF adoption exists, no papers to our knowledge address the short-run impacts of adoption on gender-specific labor hours or gender norms. Voigtländer and Voth (2013) examine the impact of historical labor provision by men and women on gender norms. They find that the movement toward animal husbandry from cereal production due to the Black Death in Britain led to an increase in female labor options and a move to later marriages. The findings in their paper are related to those in this paper, but we focus on short-run gains in gender norms and cannot fully attribute gains to the increase in female labor hours outside the home. Voigtländer and Voth use a two-sector agricultural model, while our conceptual framework focuses on an increase in the substitutability between male and female labor.

Our paper is most related to Alesina et al. (2011, 2013), which examine the long-run impacts of the use of the plough as the main agricultural technology. Exploiting cultural differences in agricultural technology, they are able to show that areas where the plough was used have less equal gender norms compared to areas that used a different agricultural technology. The authors also explore fertility, an important measure of gender roles, and find that areas that historically used the plough actually have lower fertility rates. This is due to the fact that children, like women, are less useful for plough agriculture. These results are long-run gender effects of using plough technology. This paper explores short-run gender effects that drive long-run trends.

The last area of literature relevant to this paper examines differences in female and male consumption goods within the household. Duflo and Udry (2004) test whether gender-specific productivity changes in West African agricultural households cause a shift in resource allocations.\(^5\) Specifically, variation in production of female-controlled and male-controlled cash crops is correlated with changes in expenditures on alcohol, tobacco, and prestige goods. When female income increases relative to male income, expenditures on alcohol decrease. Other papers in the development literature, including Haddad et al. (1997), Haddad (1999), and Quisumbing and Maluccio (2000), have found that the more influence women have over
resource allocations within the household, the higher the share of household income spent on food, health, education, and children’s nutrition. Additionally, Lundberg et al. (1997) use a natural experiment in the United Kingdom that exogenously increased female income, but not male income, within a household to identify the impact on female consumption goods. The authors find that females tend to spend more income on children’s clothing than men. In contrast to the existing literature that finds that changes in female income lead to changes in expenditure types, this paper shows that CF training shifts household expenditures toward categories associated with females.

The rest of the paper is organized as follows. Section 2 explains conservation farming in Zambia, the agricultural technology of interest. We introduce a conceptual framework hypothesizing the impact of CF on labor supply by gender in Section 3. In Sections 4 and 5, respectively, we outline the data and empirical strategy utilized throughout our analyses. In Section 6 we present the results of these analyses. Section 7 concludes with a discussion of our findings and their importance.

2 | CONSERVATION FARMING IN ZAMBIA

The technology we focus on in our analysis is conservation farming in Zambia. The primary feature of CF is that, through minimal disruption of soil between agricultural seasons, soil nutrients and moisture are kept intact, providing greater crop yields in the long run. In particular, the following five key practices may be part of CF: reduced tillage, meaning that farmers do not plough a certain percentage of their land; digging of permanent basins or ripping of soil with as little soil disturbance as possible; use of crop residues as soil cover and no burning of crop residues; crop rotation of cereals and legumes; and dry season land preparation. Because each of these methods is considered to be a CF practice, we categorize a farmer as using CF techniques if one or more of these methods is practiced.

There are several differences in the timeline and labor practices required by CF methods in comparison to traditional tillage methods. In general, CF requires adopters to complete their land preparation well before the first rains. Farmers do not burn crop residues, but rather use them as field cover. Another component of the technology is the use of a chaka hoe, an oversized gardening hoe, to dig basins evenly spread throughout fields, finishing land preparation by July or August, well before the planting season. This allows farmers to plant immediately following the first rains in their basins, where they use fertilizer and lime to regenerate the soil. A small percentage of farmers use a magoye ripper to rip shallow lines through their fields to achieve the same effect as digging basins. Finally, during the growing season, farmers who have adopted soil conservation have an increased amount of weeding activity. The household can use herbicides, but weeding is more commonly accomplished by hand. In comparison, ploughing can only be done following the first rain of the planting season, leading to a smaller land preparation window. Overall, CF allows for a more flexible land preparation timeline than traditional agricultural practices, but also requires more labor hours.

The Zambian government has been working with the Conservation Farming Unit (CFU), a local non-governmental organization, since 1999 to introduce CF techniques in Zambia. Specifically, the CFU has focused on training maize farmers to adopt conservation techniques. While the CFU held training sessions prior to 2007, it greatly expanded its training sessions and also began collecting data on farmers in 2007 due to an influx of funding from Norad. This training expansion serves as a district-level treatment that we explore throughout this paper. We exploit this expansion of CFU
training to additional regions to implement a difference-in-differences identification strategy. Figure 1 shows the growth in CF knowledge in treated districts, those where training sessions were conducted starting in 2007, and control districts, where training did not take place. CF knowledge is determined by whether a respondent has received any advice on practicing minimum tillage. While there is knowledge of CF practices in both treated districts and control districts, the knowledge in only treated districts increases following the expansion of CFU training sessions in 2007. Districts were chosen as treatment districts due to the quantity of maize farming in the district. Potential identification threats due to this selection are addressed in Section 5.

3 | AGRICULTURAL PRODUCTION TECHNOLOGY
CONCEPTUAL FRAMEWORK

In order to clarify the assumptions under which we would expect increased female labor as a result of conservation farming, we introduce here a conceptual framework. Specifically, our assumptions are as follows: CF training sessions lower the information cost and/or stigma cost incurred in the take-up of CF; female labor is cheaper than male labor; and female labor is more substitutable for male labor under CF, a gender-neutral technology, than under traditional tillage farming, a gender-biased technology that is more easily carried out by males. As shown in the framework, under these assumptions, we expect the introduction of training sessions to increase take-up of CF. We also expect that female labor should increase as it becomes more substitutable for male labor.

Consider a farmer faced with a technology adoption decision. The farmer can either continue to use a traditional production technology (ploughing) and produce using the following simplified constant elasticity of substitution agricultural production technology that is a function of male labor $L_M$ and female labor $L_F$ that have prices $w_M$ and $w_F$ respectively and are used to produce an output crop $Q$ (maize) with a price $p=1$:

$$f_0(L_M, L_K) = Q_0 = \left( \frac{L_M}{L_M^{\alpha_0 - 1}} \right)^{\frac{n_0}{\alpha_0}} + \left( \frac{L_F}{L_F^{\alpha_0 - 1}} \right)^{\frac{n_0}{\alpha_0}}. \quad (1)$$

However, the farmer may also adopt a new production technology (conservation farming) that is a constant elasticity of substitution agricultural production technology that is a function of male labor $L_M$ and female labor $L_F$ that are used to produce an output crop $Q$:
Additionally, each household $i$ faces a cost of adoption $c_i > 0$ for the new technology which can be seen as an information cost and/or a stigma cost. Finally, the new technology is more productive than the old one. That is, $\gamma > 1$.

Assuming that households are utility maximizers and there are complete markets, then the separability property between production and utility holds and we can focus solely on the profit-maximizing decision of the household. The only additional assumptions necessary for our model are that male labor and female labor are more substitutable when the new technology is adopted, tasks are less gender-specific, or $\sigma_o > \sigma_n > 0$, and the male wage rate, $w_M$, is higher than the female wage rate, $w_F$. The household either chooses to adopt CF ($\beta = 1$) or chooses not to adopt ($\beta = 0$). Given our assumptions, households will maximize the following unconstrained profit equation:

$$
\max_{\beta, L_M, L_F} \Pi_i(\beta, L_M, L_F) = \beta \left[ f_o(L_M, L_K) - w_M L_M - w_F L_F - c_i \right] + (1 - \beta) \left[ f_o(L_M, L_K) - w_M L_M - w_F L_F \right],
$$

subject to $\beta \in \{0, 1\}, L_M \geq 0, L_F \geq 0$.

where the household chooses the optimal allocations of male labor, $L_M$, and female labor, $L_F$, under both technologies. The household chooses to adopt the technology if $\Pi_i^*(1, L_M^*, L_F^*) \geq \Pi_i^*(0, L_M^*, L_F^*)$ and does not adopt otherwise. If we assume that $c_i$ is normally distributed, we will have a set of households that will always adopt the new technology and a set of households that will never adopt the new technology. Our empirical strategy is centered on the fact that a training intervention significantly lowers $c_i$ for treatment households. In our model this will induce certain households to adopt the new technology that previously did not.\footnote{8}

The profit-maximizing household will choose labor inputs for the old technology accordingly:

$$
L_o^* = \frac{L_F^*}{L_M^*} = \left( \frac{w_M}{w_F} \right)^{\sigma_o}.
$$

Similarly, the household will choose labor inputs for the new technology:

$$
L_n^* = \frac{L_F^*}{L_M^*} = \left( \frac{w_M}{w_F} \right)^{\sigma_n}.
$$

Combining the two ratios of optimal allocations, we can see that

$$
\left( \frac{w_M}{w_F} \right)^{\sigma_n} > \left( \frac{w_M}{w_F} \right)^{\sigma_o}
$$

because $\sigma_n > \sigma_o$ and $w_M > w_F$. This result suggests that adopting households will use relatively more female labor compared to male labor than households that do not adopt the new technology. The framework explicitly tells us that households that adopt will substitute toward the less expensive input, female labor, away from the more expensive input, male labor. We can test this theoretical result empirically by studying whether households in districts that received CF training significantly increased the share of female labor relative to male labor. There is a vast amount of literature that provides the conceptual link through which female household share of
earnings relates to outcomes related to female empowerment and bargaining power (Haddad et al., 1997). Because the increase in female earned income in our analysis is due to an increase in female labor hours, which may have a separate effect on behaviors and expenditures, we believe that in our case the test of the impact of CF training on gender-specific outcomes is strictly empirical.

4 | DATA

In order to estimate the impact of conservation farming training and adoption on labor hours and household resource allocation, we use a number of data sources. First, we use the CFU training dataset, which is a record of whether training in CF techniques was conducted by CFU in a given district post 2007. Figure 2 shows the geographical variation of treatment districts. We then merge the CFU dataset on to a number of other primary source survey datasets in Zambia that were administered both before and after 2007, when the CFU expanded its training sessions. This variation at the district level allows for the implementation of a difference-in-differences strategy to estimate causal effects of CF.

We use the Rural Agricultural Livelihoods Surveys (RALS) to measure the impact of CF training sessions on CF adoption, CF knowledge, household investment in children’s education, women’s fertility decisions, and child illness. The Zambian RALS was conducted in 2001, 2004, and 2008 by the Zambian Central Statistical Office with support from the Zambia Food Security Project and the Agricultural, Food, and Resource Economics Department at Michigan State University. Topics covered by the survey include individual and household characteristics, farming practices, and productivity measures. Summary statistics for the RALS data are shown in Table 1. Throughout our analysis, we define CF as any mention of conservation farming or the use of CF techniques. In addition to respondent reporting of farming techniques that fall under CF, we additionally define a respondent as a user of CF if he or she directly self-reports as a conservation farmer. We find that users often report that they are conservation farmers even if they do not

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**FIGURE 2** Conservation Farming Training Treatment in Zambia, by District

Notes: Treatment districts received training in 2007. Data provided by CFU. [Colour figure can be viewed at wileyonlinelibrary.com]
### TABLE 1  Balance Table of Baseline Demographic Variables by Treated and Control Districts: Rural Agricultural Livelihoods Survey

|                  | (1) Treatment districts | (2) Control districts | (3) Treated − Control |
|------------------|-------------------------|-----------------------|-----------------------|
| Age              | 34.96                   | 34.63                 | 0.33                  |
|                  |                         |                       | (0.315)               |
| Female           | 0.52                    | 0.51                  | 0.01                  |
|                  |                         |                       | (0.006)               |
| Married          | 0.59                    | 0.58                  | 0.01                  |
|                  |                         |                       | (0.017)               |
| Sick             | 0.01                    | 0.01                  | 0.00                  |
|                  |                         |                       | (0.001)               |
| Education (all)  | 5.50                    | 5.52                  | −0.02                 |
|                  |                         |                       | (0.336)               |
| Education (females only) | 4.72              | 4.63                  | 0.08                  |
|                  |                         |                       | (0.077)               |
| Household size   | 5.27                    | 4.46                  | 0.81***               |
|                  |                         |                       | (0.256)               |

**Data source:** Zambia 2004 Rural Agricultural Livelihoods Surveys.

**Notes:** Education is defined as number of years of formal education. Sick is an indicator for whether the household head is ill. *p < 0.10, **p < 0.05, ***p < 0.01.

### TABLE 2  Balance Table of Baseline Demographic Variables by Treated and Control Districts: Labor Force Survey

|                  | (1) Treatment districts | (2) Control districts | (3) Treated − Control |
|------------------|-------------------------|-----------------------|-----------------------|
| Age              | 35.15                   | 35.46                 | −0.31                 |
|                  |                         |                       | (0.995)               |
| Female           | 0.49                    | 0.48                  | 0.01                  |
|                  |                         |                       | (0.005)               |
| Married          | 0.64                    | 0.63                  | 0.01                  |
|                  |                         |                       | (0.033)               |
| Literate         | 0.74                    | 0.74                  | 0.00                  |
|                  |                         |                       | (0.061)               |
| Education (all)  | 5.45                    | 5.75                  | −0.30                 |
|                  |                         |                       | (0.323)               |
| Education (females only) | 5.66              | 6.15                  | −0.49                 |
|                  |                         |                       | (0.366)               |
| Household size   | 5.87                    | 5.85                  | 0.02                  |
|                  |                         |                       | (0.229)               |

**Data source:** Zambia 2005 Labor Force Survey.

**Notes:** Education is defined as highest grade completed.
report usage of CF techniques. We assume in our analysis that farmers truthfully report their usage of farming techniques to the best of their knowledge.

Additionally, in order to study the impact of CF on household labor allocation, we use the Zambian Labor Force Surveys (LFS) that were conducted in 2000, 2005, and 2008 by the Zambian Central Statistical Office and Ministry of Labour and Social Security with support from the International Labour Organization (ILO). The surveys are cross-sectional and geographically comprehensive data collected during the months of November and December. Topics covered by the survey include individual and household characteristics, labor force participation, and time use. Summary statistics for the LFS are shown in Table 2.

Finally, we use the Zambian Living Conditions and Monitoring Surveys (LCMS) to measure household consumption and expenditures. The LCMS datasets were administered in 2004 and 2010 and contain household characteristics, as well as detailed information on household consumption and expenditures, including items such as clothing, education and alcohol. Summary statistics for the LCMS are shown in Table 3.9

### TABLE 3 Balance Table of Baseline Demographic Variables by Treated and Control Districts: Living Conditions Monitoring Survey

|                | (1) Treatment districts | (2) Control districts | (3) Treated – Control |
|----------------|-------------------------|-----------------------|----------------------|
| Age            | 34.58                   | 35.27                 | −0.69                |
|                |                         |                       | (0.646)              |
| Female         | 0.50                    | 0.51                  | −0.01                |
|                |                         |                       | (0.005)              |
| Married        | 0.50                    | 0.50                  | 0.00                 |
|                |                         |                       | (0.030)              |
| Disabled       | 0.01                    | 0.01                  | 0.00                 |
|                |                         |                       | (0.001)              |
| Poor           | 0.63                    | 0.56                  | 0.07                 |
|                |                         |                       | (0.067)              |
| Education (all)| 7.55                    | 7.25                  | 0.30                 |
|                |                         |                       | (0.640)              |
| Education (females only) | 7.75 | 7.57 | 0.19 |
|                |                         |                       | (0.050)              |
| Household size | 6.64                    | 6.26                  | 0.38                 |
|                |                         |                       | (0.303)              |

Data source: Zambia 2004 Living Conditions Monitoring Survey.

Notes: Education is defined as number of years of formal education. Poor is a self-reported indicator variable denoting perceived poverty. Disabled is an indicator for whether the household head is disabled.

5 | **EMPIRICAL ANALYSIS**

All of the primary survey data sources mentioned above, as well as the CFU geographic and training data, allow for the use of a difference-in-differences estimation of the causal effect of soil
conservation training on household resource allocations. Assigning households to treatment based on whether they are in a district where the CFU held training sessions in the period of interest, the following equation can be estimated to identify how the training and adoption of CF impacts household allocations:

\[
Y_{idt} = \beta_0 + \beta_1 S_t + \beta_2 T_d + \beta_3 S_t \cdot T_d + X_{idt}' \gamma + \epsilon_{idt},
\]

where \(Y_{idt}\) is an outcome of interest at the household level, \(S_t\) is an indicator for year (pre-treatment or post-treatment), \(T_d\) is an indicator for whether a farm is in a treated district, \(X_{idt}\) is a vector of household characteristics, and \(\epsilon_{idt}\) is an error term clustered at the district level. The empirical analysis is applied to three main sets of outcomes. These include the impact of CF training on CF adoption, female labor supply relative to male labor supply, and a variety of household behavior and resource allocation measures.

**TABLE 4** Impact of CF Training on Percentage of Fields Dedicated to Maize

|                | (1)     | (2)     | (3)     |
|----------------|---------|---------|---------|
| Treated*Post 2007 | −0.0260 | −0.0259 | −0.0276 |
|                 | (0.0180)| (0.0180)| (0.0166)|
| Post 2007       | 0.0715***| 0.0712***| 0.0725***|
|                 | (0.0136)| (0.0135)| (0.0117)|
| Treated district| 0.157***| 0.157***| 0.0704**|
|                 | (0.0376)| (0.0375)| (0.0305)|
| Province fixed effects | No | No | Yes |
| Controls        | No | Yes | Yes |
| Observations    | 12,215 | 12,209 | 12,209 |

*Data sources:* Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys.
*Notes:* Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, total land under cultivation, and age. *\(p < 0.10\), **\(p < 0.05\), ***\(p < 0.01\).

**TABLE 5** Impact of CF Training on Receipt of Other Aid Programs

|                | (1)     | (2)     | (3)     |
|----------------|---------|---------|---------|
| Treated*Post 2007 | −0.0426 | −0.0392 | −0.0408 |
|                 | (0.0519)| (0.0518)| (0.0520)|
| Post 2007       | 0.0905***| 0.0857***| 0.0864***|
|                 | (0.0320)| (0.0313)| (0.0316)|
| Treated district| −0.0450 | −0.00927| −0.00607|
|                 | (0.0356)| (0.0340)| (0.0344)|
| Province fixed effects | No | No | Yes |
| Controls        | No | Yes | Yes |
| Observations    | 10,682 | 10,682 | 10,682 |

*Data Sources:* Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys.
*Notes:* Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, and age. *\(p < 0.10\), **\(p < 0.05\), ***\(p < 0.01\).
Identification hinges on the assumption that prior to treatment, treatment and control districts followed parallel trends. To examine the validity of the difference-in-differences identification strategy, we can use the RALS dataset to test the pre-trends assumption for the take-up of CF. Additionally, we control for key demographic variables in our empirical analysis, accounting for demographic changes within districts during the period of interest. Finally, we examine relevant time-varying characteristics in treatment and control districts to ensure that they do not differentially change in treatment and control districts, which would be a threat to the parallel trends assumption. Because differences exist in crop production in treatment and control districts by the nature of the district treatment selection process, we ensure in Table 4 that these differences do not lead to differential time-varying changes in production between treatment and control districts. In this table, we show a difference-in-differences estimation of the percentage of fields at the household level dedicated to maize and find that the changes in maize farming prevalence in treatment and control districts were the same. In Table 5 we also test whether treated districts, in addition to receiving CF training beginning in 2007, received other sources of aid during this time that could pose a threat to identification. The results suggest that there was not an increase in access to other aid for treated districts that corresponded with the CF training. Other aid is a simple indicator variable for whether a household received any goods or aid from non-household members or organizations. Due to data limitations, we cannot test pre-trends for outcomes in the LFS and LCMS datasets, but we feel these additional tests provide support for the parallel trends assumption.

6 | RESULTS

There are several main findings. First, CF prevalence increased as a result of CF trainings. Second, female labor supply increased as a result of exposure to CF training, which is linked to higher levels of CF adoption. Finally, a variety of household resource allocation measures suggest that women may have increased decision-making power within the household.

6.1 | Conservation Farming Adoption

We first test the impact of CF training on adoption of CF methods. In order to ensure that districts treated with CF training are not different from control districts prior to treatment, we test whether districts are different across a set of key demographic observables in the 2004 RALS data. The results in Table 1 show that the only characteristic for which there is a difference is household size. However, it is not clear why larger households would face different trends in CF adoption. Moreover, we also can test for pre-trends in our CF prevalence analysis.

The difference-in-differences regression results in Table 6 show that training increases the likelihood of adoption by 12–13 percentage points. This equates to a 109–113% increase in CF. The result is robust to the addition of household controls. While previous studies, such as Arslan et al. (2014), have shown lower levels of adoption, as mentioned in Section 4, we use a broader definition of conservation farming than such studies. Our adoption results are similar to those observed by the CFU.

In addition to the regression analysis, the RALS data from 2001 allow for a direct test of the pre-trends assumption on CF between treatment and control districts prior to treatment. Figure 3 shows that the pre-trends are fairly flat. The differences in means in 2001 and 2004 are not statistically significant across groups. This result provides evidence that our difference-in-differences estimate of CF adoption is causal. Even though treatment districts were chosen by the CFU in order
to reach as many maize farmers as possible, in the sample of only farmers planting maize, the treatment and control groups look fairly similar in terms of demographics and tillage techniques prior to treatment.

6.2 | Female labor supply

We next explore the impact of CF training on labor hours by gender within the household. In order to ensure that districts treated with CF training are not different from control districts prior to treatment, we test whether districts are different across a set of observable characteristics in the 2005 LFS. The results in Table 2 show that there are no significant differences in the treatment and control households across these demographics.

### Table 6 Impact of CF Training on CF Prevalence

|                                | (1) Probability of Conservation Farming | (2) Probability of Conservation Farming |
|--------------------------------|----------------------------------------|----------------------------------------|
| Treated*Post 2007              | 0.130***                               | 0.126***                               |
|                                | (0.0279)                               | (0.0281)                               |
| Post 2007                      | 0.0203                                 | 0.0214                                 |
|                                | (0.0213)                               | (0.0215)                               |
| Treated district               | −0.0260                                | −0.0271                                |
|                                | (0.0171)                               | (0.0174)                               |
| Mean dependent variable        | 0.1150                                 | 0.1150                                 |
| Percent effect                 | 113.04%                                | 109.57%                                |
| Controls                       | No                                     | Yes                                    |
| Observations                   | 7,979                                  | 7,979                                  |

Data sources: Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys.

Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, and age. *p < 0.10, **p < 0.05, ***p < 0.01.

![Figure 3: Trends in Conservation Farming Adoption](image)

Note: Trends calculated using Zambia 2001, 2004, and 2008 Rural Agricultural Livelihoods Surveys. [Colour figure can be viewed at wileyonlinelibrary.com]
The results of the difference-in-differences regression analysis are displayed in Table 7. The first two columns are from a difference-in-differences estimation with the outcome $Y_i$ defined as number of hours worked daily by females in the household. The pre-treatment year is 2005 and the post-treatment year is 2008. The number of hours worked prior to treatment is not significantly different across treatment and control districts. However, in the post-treatment period, females in both treatment and control districts worked significantly less. This could be due to the change in the timing of the survey collection. The difference-in-differences estimate of the effect of CF training on female labor supply supports our earlier hypothesis, as females in treated districts are working significantly more in the post-treatment period compared to females in control districts. Females are specifically working about 1 more hour per day, or 16–19% more hours, as a result of the CF training. Additionally, the estimates are robust to the inclusion of additional control variables and province fixed effects.

The conceptual framework suggests that treated households with lower costs of adoption $c_i$ will increase their adoption probability and also increase female labor hours relative to male labor hours. We can test this by estimating a difference-in-differences regression on the share of the labor supply that is provided by females. The results are shown in columns (3) and (4) of Table 7. Again, we can see that the female share of labor supply in treatment districts is significantly higher compared to control districts. The results suggest that, relative to men in their household, women are working significantly more in treatment districts. This result supports the prediction from the theoretical framework that training and increased adoption lead to increased female labor supply relative to male labor supply.

Moreover, we can test the assumptions in the conceptual framework that total off-farm wages for males and females do not change due to training. To do this, we estimate a difference-in-differences regression on total wages earned by household members in the RALS dataset. The results in Table 8 show that households in treated districts were not bringing in higher off-farm wages after treatment when compared to control districts. This result, which holds when broken down by

### Table 7: Impact of CF Training on Labor Supply

|                | Female Labor Supply |                           | Female Labor Share |                           |
|----------------|---------------------|---------------------------|--------------------|---------------------------|
| **Treated*Post 2007** |                     |                           |                    |                           |
|                 | 0.901**             | 1.105***                  | 0.0323*            | 0.0307*                  |
|                 | (0.392)             | (0.386)                   | (0.0171)           | (0.0172)                 |
| **Post 2007**   |                     |                           |                    |                           |
|                 | −0.491**            | 0.0476                    | −0.0204*           | 0.0173                   |
|                 | (0.188)             | (0.226)                   | (0.0109)           | (0.0139)                 |
| **Treated district** |                   |                           |                    |                           |
|                 | −0.233              | −0.430                    | −0.0155            | −0.0170                  |
|                 | (0.382)             | (0.399)                   | (0.0113)           | (0.0122)                 |
| **Mean dependent variable** |     |                           |                    |                           |
|                 | 5.7267              | 5.7267                    | 0.4956             | 0.4956                   |
| **Percent effect** |                     |                           |                    |                           |
|                 | 5.73%               | 19.30%                    | 6.52%              | 6.19%                    |
| **Province fixed effects** |             |                           |                    |                           |
|                 | No                  | Yes                       | No                 | Yes                       |
| **Controls**    | Yes                  | Yes                       | Yes                | Yes                       |
| **Observations** | 5,336               | 5,336                     | 7,947              | 7,947                     |

*Data sources: Zambia 2005 and 2008 Labor Force Surveys.*

*Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, and age. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.***
gender, suggests that training did not impact off-farm wages in treated districts, thus supporting the assumptions of the theoretical framework.

### 6.3 | Household female empowerment

We next test the impact of CF take-up on household female empowerment. To do so, we examine the impact of CF training on fertility in the RALS data. The existing literature suggests that women in Zambia prefer to have fewer children than do men, thus we would expect an increase in female decision-making power to decrease fertility (Salem, 2004). However, Alesina et al. (2011) found that the use of the plough resulted in lower fertility levels in the long run. Therefore, the short-run empirical prediction of CF adoption on fertility is ambiguous. Table 9 suggests that there is indeed a decrease in fertility when defined as having an infant present in the household. While this result could be considered an increase in empowerment, we cannot rule out the possibility that the decrease is caused by an increase in female labor.\(^\text{12}\)

### 6.4 | Household child investment

Table 10 examines the impacts of CF training on household child investment. The existing literature suggests that women favor expenditures on children, so we expect an increase in women’s decision-making power to increase school attendance and improve child health.\(^\text{13}\) We are able to test household child investment outcomes in the RALS data. The results of the difference-in-differences regressions testing changes in household child investment as measured in the RALS data are in Table 10. The outcome variables are percentage of household children currently in school, the highest level of education obtained by children in the household, and whether a child is chronically ill. CF training led to a significant increase in school attendance by children. This means treatment households increased their investment in children’s human capital, which is often preferred by females more than males. The average level of education and the probability of a child being sick are not significantly changed by the training in treatment districts, but do have the correct sign. The latter two null results may be explained by the fact that the outcomes are cumulative and unlikely to be impacted during such a short period.

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**TABLE 8** Impact of CF Training on Off-Farm Wages (ZMK)

|                      | (1)         | (2)         | (3)         |
|----------------------|-------------|-------------|-------------|
| Treated*Post 2007    | −3,449      | −14,837     | −16,639     |
|                      | (33,112)    | (39,183)    | (37,761)    |
| Post 2007            | 88,919***   | 77,605***   | 76,692***   |
|                      | (15,866)    | (17,710)    | (17,314)    |
| Treated district     | 3,452       | 28,553      | 17,820      |
|                      | (25,022)    | (22,723)    | (36,649)    |
| Province fixed effects| No         | No          | Yes         |
| Controls             | No          | Yes         | Yes         |
| Observations         | 63,520      | 57,308      | 57,308      |

*Data sources: Zambia 2004 and 2008 Rural Agricultural Livelihoods Surveys.*

*Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, and age. \(*p < 0.10, **p < 0.05, ***p < 0.01.*\)
6.5 | Household expenditures

Finally, we use the LCMS data to explore household expenditures. Table 3 suggests that there is balance in demographic characteristics between treatment and control districts in this survey. Tables 11 and 12 show the results of difference-in-differences analysis estimating the impact of CF training on household consumption of a male-preferred good, alcohol, and a female-preferred good.
good, clothing. In Table 11, for a variety of specifications, we find that CF training led to a decrease in expenditure on alcohol as a share of total household expenditures by about 0.55–0.58 percentage points, or about 39–40%. Table 12 suggests that CF training led to an increase in expenditure on clothing as a share of total household expenditures by about 1.5 percentage points, or 17–18%. In both sets of regressions, we control for overall expenditures, so that the likely explanation for changes in the share of expenditures is a shift in household decision-making power. In addition to controlling for overall household expenditure in Tables 11 and 12, we show in Table 13 that there is no impact of the CF training treatment on total household expenditure.

7 | CONCLUSION

Low and unsustainable agriculture productivity in Africa is an important issue for the development of the economy. Soil conservation technologies are a viable way to increase sustainable productivity, especially in the face of climate change. However, nongovernmental organizations, aid agencies, and other players in the development field need to understand the role of gender and gender norms when attempting to implement soil conservation technologies. This paper has shown that soil conservation adoption can lead to changes in household allocations in the short run. Combined with the long-run results estimated by Alesina et al. (2011, 2013), we are confident that soil conservation training programs have significant impacts on gender norms. These benefits should be accounted for when evaluating such programs.

Specifically, we find a number of results. First, we use the RALS data to show that there was a significant increase in both knowledge and adoption rates of conservation farming practices. Second, we use the LFS to show that in areas that received CF training female labor hours increased relative to male labor hours. Finally, we use the RALS and LCMS data to explore household

| TABLE 11 | Impact of CF Training on Alcohol Expenditure as a Share of Total Household Expenditure |
|----------|-------------------------------------------------|
| **Household Alcohol Expenditure Share** |
| Treated*Post 2007 | (1) | (2) | (3) |
| −0.00552** | −0.00576** | −0.00556** |
| (0.00252) | (0.00250) | (0.00255) |
| Post 2007 | (1) | (2) | (3) |
| −0.000163 | −0.000713 | −0.000644 |
| (0.00171) | (0.00174) | (0.00174) |
| Treated district | (1) | (2) | (3) |
| 0.00223 | 0.00219 | 0.00155 |
| (0.00237) | (0.00217) | (0.00251) |
| Mean dependent variable | (1) | (2) | (3) |
| 0.0140 | 0.0140 | 0.0140 |
| Percent effect | (1) | (2) | (3) |
| −39.30% | −41.01% | −39.58% |
| Province fixed effects | No | No | Yes |
| Controls | No | Yes | Yes |
| Observations | 20,036 | 19,990 | 19,990 |

Data sources: Zambia 2004 and 2010 Living Conditions and Monitoring Surveys.
Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, total expenditures, and age. *p < 0.10, **p < 0.05, ***p < 0.01.
allocations for which we find increases in school attendance and clothing expenditure and decreases in fertility and alcohol expenditure.

These overall results suggest that there are positive gender equality spillovers associated with CF training programs. However, these gender-specific impacts may also be a barrier to adoption in

| TABLE 12 | Impact of CF Training on Clothing Expenditure as a Share of Total Household Expenditure |
|----------|--------------------------------------------------------------------------------------|
|          | (1) | (2) | (3) |
|          | Household Clothing Expenditure Share | | |
| Treated*Post 2007 | 0.0154* | 0.0158* | 0.0166* |
| | (0.00830) | (0.00830) | (0.00837) |
| Post 2007 | −0.00813* | −0.00998** | −0.0105** |
| | (0.00428) | (0.00430) | (0.00426) |
| Treated district | −0.0150** | −0.0162*** | −0.0126* |
| | (0.00709) | (0.00608) | (0.00715) |
| Mean dependent variable | 0.0907 | 0.0907 | 0.0907 |
| Percent Effect | 16.98% | 17.42% | 18.30% |
| Province fixed effects | No | No | Yes |
| Controls | No | Yes | Yes |
| Observations | 19,990 | 19,990 | 19,990 |

Data sources: Zambia 2004 and 2010 Living Conditions and Monitoring Surveys.
Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, total expenditures, and age. *p < 0.10, **p < 0.05, ***p < 0.01.

| TABLE 13 | Impact of CF Training on Total Household Expenditure |
|----------|---------------------------------------------------|
|          | (1) | (2) | (3) |
|          | Total Household Expenditure | | |
| Treated*Post 2007 | 73,577 | 78,173 | 88,029 |
| | (178,792) | (186,762) | (182,304) |
| Post 2007 | 658,619*** | 578,664*** | 583,833*** |
| | (77,785) | (78,861) | (78,944) |
| Treated district | 128,564 | 99,470** | 8,363 |
| | (107,485) | (41,310) | (105,716) |
| Mean dependent variable | 1,032,004 | 1,032,004 | 1,032,004 |
| Percent effect | 0.07% | 0.08% | 0.09% |
| Province fixed effects | No | No | Yes |
| Controls | No | Yes | Yes |
| Observations | 19,990 | 19,990 | 19,990 |

Data sources: Zambia 2004 and 2010 Living Conditions and Monitoring Surveys.
Notes: Robust standard errors are clustered at the district level. Regressions include controls for education, household size, an indicator for female-headed household, total expenditures, and age. *p < 0.10, **p < 0.05, ***p < 0.01.
these traditional household settings. A man in a traditional household may be unwilling to give up bargaining power to the female in the household, resulting in low initial levels of adoption and/or high rates of eventual abandonment. Moreover, weather fluctuations are important inputs that are not accounted for in the theoretical models or empirical analysis of this paper. Understanding how weather shocks impact adoption decisions is imperative to understanding the true gender effects of CF adoption.

Ideally, this study would benefit from additional survey data with questions aimed at understanding take-up of CF, as well as time and expenditure allocations by gender. A randomized controlled trial or an additional natural experiment or quasi-experiment could offer more insights into the mechanisms through which CF impacts gender-related outcomes. Our results provide a launch pad for research measuring the gender impacts of similar agricultural technologies and the promotion of these technologies throughout the developing world.

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NOTES

1 Teklewold et al. (2013) find anecdotal evidence that females do increase their workload more than males after take-up of CF in Ethiopia, though no causal evidence has been documented to our knowledge.

2 Many papers (such as Lundberg et al., 1997; Haddad et al., 1997; Haddad, 1999; Quisumbing and Maluccio, 2000) show that females have a stronger preference for investment in children than males.

3 See the FAO news article at http://www.fao.org/news/story/en/item/178349/icode/.

4 See Norad’s summary of projects in and donations to Zambia at https://www.norad.no/en/front/countries/africa/zambia/.

5 This result builds on Udry (1996), who showed that agricultural households are not always unitary.

6 Haggblade and Tembo (2003) examined the benefits of CF in Zambia for small-scale cotton farmers. They found that yields significantly increase when conservation techniques are used compared to traditional tilling methods, but that adoption is costly in the first few years, specifically because of the increased amount of labor needed for weeding.

7 https://conservationagriculture.org/uploads/pdf/MT-CT-CF-CA- DEFINITIONS-CFU-ZAMBIA.pdf.

8 The cost distribution need not be normal for an increase in CF farming to occur due to the training program. It must only be true that a single household exists for which the reduction in \( c_i \) due to the training intervention would induce the household to choose adoption, \( b=1 \), over non-adoption, \( b=0 \).

9 Any differences between the values in summary statistic tables are due to the fact that they rely on three different datasets. Differences in survey measurement techniques, variable definitions, and sample choices explain differences in variable means.

10 We are unable to estimate household fixed effects models because our data are repeated cross-sections. We do include province fixed effects in some specifications. There are 10 provinces in Zambia, containing 72 districts in total.

11 Percent effect calculated as coefficient/mean dependent variable.

12 Additionally, we examine the impact of CF training on the election of female parliament members. A similar outcome was used by Alesina et al. (2013) to measure female empowerment. We use a unique dataset with the gender of each district-level parliament member to examine the impact of CF training on the election of female
delegates. Table 9 shows the results of the difference-in-differences regression. While the results are positive, they are not significant, which suggests that the long-run outcomes examined in other papers may not be impacted in the short run.

13 See O’Sullivan et al. (2014) for a list of studies that link women’s preferences to child health and education outcomes.

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