The Journal of Development Studies

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/fjds20

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To cite this article: T.I. Bouwman , J.A. Andersson & K.E. Giller (2020): Herbicide Induced Hunger? Conservation Agriculture, *Ganyu* Labour and Rural Poverty in Central Malawi, The Journal of Development Studies, DOI: 10.1080/00220388.2020.1786062

To link to this article: https://doi.org/10.1080/00220388.2020.1786062

Published online: 12 Jul 2020.

The Journal of Development Studies, 2020
https://doi.org/10.1080/00220388.2020.1786062

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Herbicide Induced Hunger? Conservation Agriculture, *Ganyu* Labour and Rural Poverty in Central Malawi

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(Original version submitted February 2020; final version accepted June 2020)

ABSTRACT *Herbicide use is increasing in sub-Saharan Africa. While herbicides promise improved weed-control, labour savings and even reduced land degradation – they are promoted to enable Conservation Agriculture (CA) adoption – there are concerns about their health and environmental risks. Yet, their socio-economic implications have been largely ignored. We investigated the effects of herbicide use on casual labour relations (ganyu) in Central Malawi using a survey of 275 households. In rural Malawi doing ganyu is the main coping strategy during the hunger season/growing season. We find that where CA promotion incentivised herbicide use, herbicides became common and substituted much in-season ganyu hiring. Consequently, many households were unable to find work and ended up hungry. While herbicides mainly benefited the better-off who could afford them, these benefits occurred at the expense of the poor and food insecure. Agricultural development initiatives should be aware that herbicides are likely to reduce agricultural labour opportunities and rural wages. Where alternative labour opportunities are limited, this may contribute to social differentiation, hunger and the individualisation of poverty. Our study demonstrates the potential hazards of neglecting the social equity implications of technology promotion – a lesson pertinent to the sustainable intensification agenda, including the promotion of CA.*

1. Introduction

Green revolutions have helped to alleviate hunger and poverty in Asia and Latin America (Pingali, 2012). Meanwhile, in sub-Saharan Africa (SSA) agricultural productivity remains low and one-in-five still faces hunger (FAO, IFAD, WFP, & WHO, 2019; Van Ittersum et al., 2016). As it is often smallholder farmers who experience hunger, it is no surprise that many development interventions promote yield-improving agricultural technologies that do harm the environment, that is, through sustainable intensification (Pretty & Bharucha, 2014; Tilman, Balzer, Hill, & Befort, 2011). Common examples of the technologies promoted in SSA include fertilisers, higher yielding varieties, soil and water-conserving practices and irrigation (Pretty, Toulmin, & Williams, 2011).

In this paper, we investigate socio-economic consequences of technology adoption – something which both green revolutions and the sustainable intensification of agriculture (SI) agenda have been criticised for overlooking (Loos et al., 2014; Mahon, Crute, Simmons, & Islam, 2017). Our focus is on a technology – chemical herbicides – that can improve yields and save labour. Herbicides are argued to be a major underexploited means of increasing yields in SSA since they can lessen the

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substantial yield losses caused by weeds (Gianessi & Williams, 2011). Herbicides are often promoted to enable conservation agriculture (CA) adoption in Africa (Chavula & Makwiza, 2012; Giller et al., 2015; Lotter, 2015). CA aims to reduce land degradation and to increase yields, and is defined as based on three principles: no-tillage, crop residue retention, and crop rotation/intercropping (Hobbs, Sayre, & Gupta, 2008; Kassam, Friedrich, Shaxson, & Pretty, 2009), but often requires herbicides because abandoning tillage typically results in substantially higher weed pressure (Gianessi, 2009; Haggblade, Smale, Kergna, Theriault, & Assima, 2017b). More broadly, herbicides promise reduced labour burdens, including for women and children since they often do the weeding, a reduced demand for labour during peak periods in the agricultural season, as well as the potential to free up agricultural labour for other activities (Gianessi, 2009; Haggblade et al., 2017b). Use of herbicides has recently increased in some countries; estimates place herbicide use as a percent of households at 27% in Ethiopia, 22% in Nigeria, 55% in Ghana but only 1% in Niger and Malawi (Gianessi, 2009; Haggblade et al., 2017b). When considering the risks of herbicide use, studies of herbicide adoption in SSA, as well as public perception more broadly, mainly focus on health and environmental implications (for example, water quality, weed resistance) rather than their social implications. Some socio-economic observations have, however, been made. Grabowski and Jayne (2016) note that it is mainly the better-off, more commercially oriented farmers that use herbicides. Haggblade et al. (2017b), Tamru, Minten, Alemu, and Bachewe (2017) and Grabowski and Jayne (2016), provide mixed results on the relationship between wages and herbicide adoption; while Haggblade, Minten, Pray, Reardon, and Zilberman (2017a) mention that herbicides may present a problem for employment in Africa but emphasise the free choice of farmers to use herbicides or find other work. Overall, however, the socio-economic risks that herbicides pose in Africa have not been explored.

We investigated the effects of herbicides on the coping strategies of the poor during times of hunger in Malawi. Building on a hypothesis of Andersson and D'Souza (2014), we examine whether better-off farmers substitute hired labour from poorer farmers who rely on *casual off-own-farm labour* to cope with hunger. Herbicides have been promoted in many CA projects in Malawi (Chavula & Makwiza, 2012; Mloza-Banda & Nanthambwe, 2010) – including in numerous partnerships between non-governmental organisations (NGO) and the herbicide company Monsanto (Ito, Matsumoto, & Quinones, 2007; Mloza-Banda & Nanthambwe, 2010). It was in the context of CA promotion – as part of a larger investigation into CA adoption and its impacts – that this study of the social implications of herbicides was performed.

In Malawi, casual off-own-farm labour is very common and is called *ganyu*. Common *ganyu* tasks include ridging – land preparation done before the growing season – and weeding – which is done during the growing season. *Ganyu* is done by men, women and children, frequently for relatives and neighbours, but also for other farmers (smallholders or estate) nearby or further afield (Whiteside, 2000). *Ganyu* is usually done as piecework (for example, paid per weeded plot), lasts for days or weeks and is paid in cash or in kind (for example, as food) (Whiteside, 2000). *Ganyu* has several important features: (1) after, own-farm production *ganyu* constitutes the most important livelihood strategy of rural households (Coulibaly, Gbetibouo, Kundhlande, Sileshi, & Beedy, 2015; Whiteside, 2000). It is especially important for households with smaller land holdings who cannot meet their consumption needs through own-farm production (Holden, 2014; Mtika, 2001). (2) Since *ganyu* is usually done by households experiencing a food shortage, it is also a coping strategy and an indicator of vulnerability (Cole & Hoon, 2013; Coulibaly et al., 2015; Ellis, Kutengule, & Nyasulu, 2003). (3) As a result, those who do *ganyu* are prone to exploitation (Bezner Kerr, 2005; Bryceson, 2006; Whiteside, 2000). (4) Further, since producing one's own food is highly valued in rural Malawi (Van Donge, 2005), being forced to do *ganyu* can be accompanied by shame and stigma (Whiteside, 2000). (5) Households doing *ganyu* may not be able to adequately tend their own plots, which may lead to delays in the execution of key activities such as planting and weeding, and consequently, lower yields. Doing *ganyu*, thus, has the potential to act as a poverty trap (Orr, Mwale, & Saiti-Chitsonga, 2009; Van Donge, 2005). (6) *Ganyu* can function as an insurance mechanism and a safety net. Households may offer help when they are not in need in order to ensure the availability of *ganyu* when they are food insecure; while other households may hire *ganyu* out of kindness to households in need (Michaelowa, Dimova, & Weber, 2010; Whiteside, 2000).

Half to three-quarters of rural households in Malawi suffer from inadequate food each year (MNSO, 2005, 2012, 2017). Hunger occurs mainly during the growing season, when households' food stocks are depleted, and crops in the field still months from harvest. At this time of food scarcity, weeding is the main labour activity (Carr, Kool, & Giller, 2017; Kamanga, Waddington, Whitbread, Almekinders, & Giller, 2014; Wodon & Beegle, 2006). And herein lies the rub. Where herbicides are used, they may replace *ganyu* labour hiring at the exact time this coping strategy is most needed by the food insecure. Thus, herbicide use may contribute to the hunger of the food insecure while benefiting the better-off who can afford them.

To test whether herbicides contribute to hunger and inequality in rural Malawi, we surveyed 275 households in areas of CA promotion in Central Malawi. In the survey we investigated the following five questions: (1) Did herbicides reduce labour hiring? (2) Were herbicide users the better-off and households involved in piecework the worse-off? (3) Was (weeding related) piecework a vital coping strategy? (4) Did failing to find piecework result in hunger? (5) Were perceived changes in piecework availability and food security related to herbicide use? We also consulted village leaders to understand their views of the impacts of herbicides in their villages.

2. Methods

2.1. Study area

2.1.1. Study locations. We focused on three Extension Planning Areas (EPAs) in which Conservation Agriculture had been promoted through on-farm trials/demonstrations[1] and in which CIMMYT was a partner. The locations were Zidyana and Mwansambo EPAs in Nkhotakota district and in Tembwe EPA in Salima district (Figure 1(a)). CA promotion began in 1996/97 in all three EPAs while the on-farm demonstrations began in 2004/2005 in the Mwansambo and Zidyana EPAs and in 2010 in the Salima site. Within the three EPAs, 10 areas of approximately 15 km^2 with many CA plots were delimited using satellite images captured by the Worldview 3 satellite in 2013 and 2014 (available on Google Earth). CA plots were identifiable in these images as they were covered with crop residues at the end of the dry season when the images were captured. The areas were also selected to include land near to the on-farm CA demonstrations and were made with a view to ensuring different topographies (hilly or flat, along riversides or not), soil types, and population densities were represented. Seven of the 10 polygons were visited and included in a survey (see white polygons Figure 1(c–e)). The remaining three polygons were not included due to logistical reasons.

2.1.2. A description of the study area. Rain-fed maize is the predominant crop across the study area which lies at 500–750 m above sea level. Rain falls during a five-month growing season that begins in November and ends in April (see Figure 3). In Tembwe the study area covered topographically flat land, approximately 5 km north of the large town of Salima (see Figure 1(c)) and had a higher population density with smaller farm sizes but more work opportunities (for example, a nearby large 500 ha seed farm, bicycle taxiing in Salima township and paved road access to the fishing town of Senga Bay). In Mwansambo and Zidyana EPAs, households were surveyed between approximately 1 km and 8 km from the small towns (trading centres) of Mwansambo and Mkaika, respectively (see Figure 1(c,d)). The Zidyana EPA site is crossed by the Lifuliza River where irrigation and rice cultivation are possible. It is also closer to Lake Malawi which offers some opportunity for fishing. The Mwansambo site is most remote on undulating to hilly land, about 20 km from the nearest paved road and from Lake Malawi. In this area, alternatives to obtain off-farm work are least available (see Table 1 for a summary).

CA promotion began in 1996/1997 in each EPA with a government-led minimum-tillage project that ran into the early 2000s (Mloza-Banda & Nanthambwe, 2010; Nkunkia, 2003). Since, then the

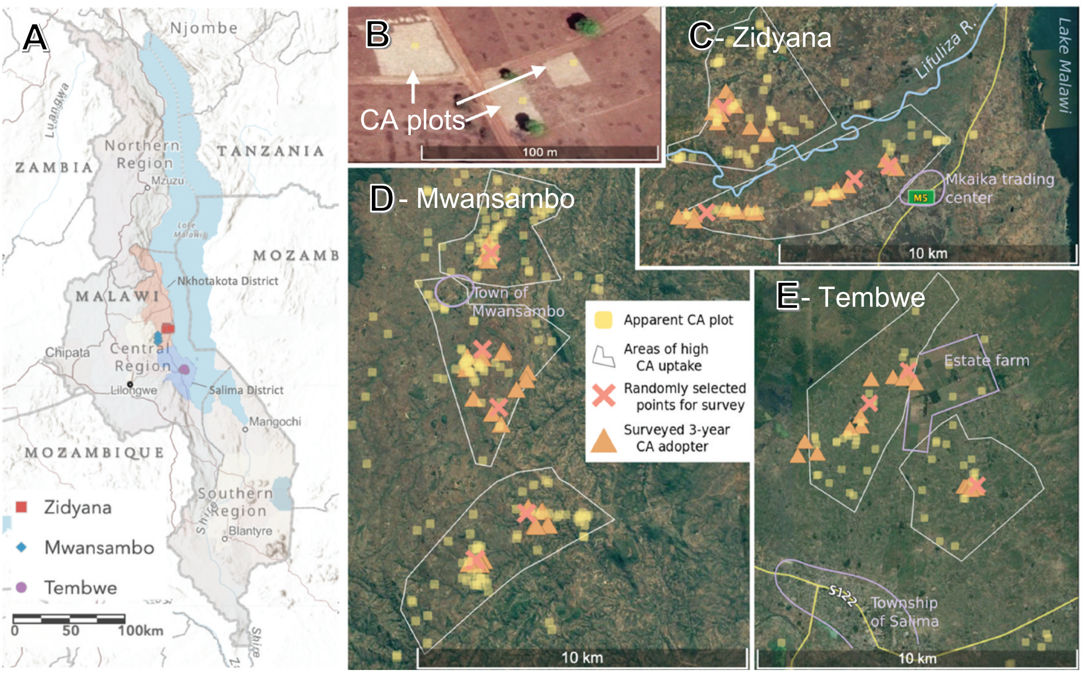

Figure 1. The location and selection of the study areas. Part A shows the location of the three study sites within Malawi in the Nkhotakota and Salima districts. Part B shows CA plots are identifiable from satellite images. Part C-E shows, for each EPA, the delimited areas of high CA uptake (based on apparent CA plots), the locations of the randomly selected points within the delimited areas used to ensure the randomness of the CA adopter group and the locations of the surveyed 3-year CA adopting households.

non-governmental organisation (NGO) Total Land Care (TLC) has promoted CA in Mwansambo and Zidyana in collaboration with CIMMYT and the Malawi Government (MG) extension services. During most of this time TLC, in collaboration with Monsanto, as well as other NGOs such as Concern Worldwide, have promoted CA with herbicides using demonstration plots, lead farmers, farmer fields schools. Some programmes also provided free inputs and loans for inputs. TLC was the most significant promoting organisation. With its USAID guaranteed revolving loan fund, it offered loans for herbicides to households who followed recommended agricultural practices such as CA. The loans required a 25%–40% down payment. TLC also provided free application equipment to lead farmers. In 2014 these loans were turned over to a bank which significantly reduced the availability of loans for herbicides. In Tembwe EPA, CIMMYT and the Malawian government extension services have promoted CA for about 6 years. Other organisations also promoted CA for some years in the study area including Concern Worldwide in Zidyana and Mwansambo and Malawi Lake Basin (since 2010), Assembly of God, Adventist Development and Relief Agency, and Land O'Lakes International Development in Tembwe.

In all three locations, herbicides were also available for purchase from agro-dealers in trading centres. Glyphosate, Bullet® (atrazine and alachlor) and Harness® (acetochlor) had all been promoted in the study area – especially in the TLC/CIMMYT demonstration plots, though Glyphosate and Harness® were the main herbicides in use. Glyphosate is a broad-spectrum weed killer applied before planting (smallholders did not grow glyphosate-resistant maize). Bullet® and Harness® are residual herbicides that prevent the emergence of weeds long after application; they are usually applied several days after planting. Manual weeding techniques in the study area were those typical of ridge-furrow cultivation (most crops in Malawi are grown on ridges). Weeding usually involves hoeing weeds and laying them down between the ridges (first weeding) and later, moving soil from the furrow to build up the sides of the ridges and bury weeds (second weeding) (Orr, Mwale, & Saiti, 2002). This latter process, which also helps prevent lodging, is called *banking*.

2.2. The household survey

A household survey (n = 275) was conducted during a three-week period in late June and July 2016. The survey was conducted by four experienced enumerators who had been trained to administer the questionnaire using tablets equipped with Open Data Kit. Household heads or their spouses (or in rare cases another adult in the household) were asked questions about the household's socioeconomic and demographic characteristics, cropping system, maize yields for maize CA plots and comparison plots, wealth, food security, labour relations, and herbicide use. The location of the household and the corner points of a selection of plots (up to two maize CA plots and one non-CA plot per farm) were also recorded.

Two kinds of households were selected for the survey – *CA adopters* and *comparison households. CA adopters* were defined as having farmed for three or more years without ridging and with some (that is 30% or more) ground cover at planting time. The *CA adopters* were selected by: (1) Selecting one to three points (depending on the size and the spread of *CA adopters*) randomly on a map in each of the seven 15 km^2 areas, (2) Locating these points on the ground using a GPS device, and (3) Identifying the nearest six or 12 (depending on logistics) *CA adopters* with the help of local extension officers or lead farmers. *Comparison households* were selected as the third and sixth nearest homestead to that of the *CA adopters*. Thus, the number of *comparison households* was twice the number of *CA adopters*. The *comparison household* group included farmers practicing only ridge-furrow cultivation and farmers who practiced one or more of the CA principles. The group is approximately representative of households in the communities in which CA was promoted. Occasionally, no one in the third or sixth nearest homestead was available for interviewing and the next nearest neighbour was selected. In total, 286 households were surveyed. Of these 11 interviews were excluded due to inconsistent responses on important topics (such as whether or not the household had practiced CA in a given year).

The final number of households interviewed was 99, 101 and 75 in Mwansambo, Zidyana, and Tembwe EPAs, respectively. The survey data were supplemented with aerial photography captured with an unmanned aerial vehicle (an eBee designed by SenseFly). These were captured prior to the implementation of the survey, at a resolution of 5–10 cm per pixel, and were used to verify the area (using GPS collected corner points) of a selection of maize focus plots.

The terms 'piecework', '*ganyu',* and 'hired labour' are used interchangeably in this paper. This is done to allow for the use of the original phrasings in the survey (which was created in English and translated into Chewa by the enumerators) and still allows us to talk of *ganyu* as a concept that does not easily translate into English.

2.3. Interviews with traditional authorities

In addition to the survey, semi-structured interviews were held with 13 village leaders concerning herbicide use in their villages. These leaders are village chiefs, who play an important role in the distribution of collective goods (including fertiliser subsidies), in the arbitration of disputes and in village external relations (including with NGOs and government) (Swidler, 2013). They were selected as key informants because they are intimately familiar with village life and are recognised and respected representatives of a village (Ellis et al., 2003; Logan, 2013).

The interview locations were selected randomly within the surveyed areas of each EPA. Handwritten notes of the interviews where typed out by the translator and indexed by topic by the first author. Table 1 presents the key features of each EPA and the descriptive statistics of the survey respondents.

Table 1. Description of EPAs, number of village leader interviews and descriptive statistics of survey respondents

	Location (EPA)			
	Mwansambo	Zidyana	Tembwe	Overall
Description of EPA	Long distances to alternative forms of work	Near to Lake Malawiand busy trading centre	Near to Salima town and large seed farm (*employment, trading*)	
	Isolated from paved roads	Close to main lakeside road	Near to Salima town and major crossroads	
	Lower population density (larger farm sizes)		Higher population density (smaller farm sizes)	
Village leaders interviewed	4	5	4	13
Households surveyed	99 (36%)	101 (37%)	75 (27%)	275 (100%)
CA adopters	33 (12%)	33 (12%)	23 (8%)	89 (32%)
Comparison households	66 (24%)	68 (25%)	52 (19%)	186 (68%)
Households using herbicides	53 (19%)	43 (16%)	15 (5%)	111 (40%)
CA adopters that used herbicides [a]	20 (7%)	15 (5%)	9 (3%)	44 (16%)
Comparison households that used herbicides	33 (12%)	28 (10%)	6 (2%)	67 (24%)
All households hiring-out *ganyu* [b]	39 (14%)	42 (15%)	38 (14%)	119 (43%)
All households hiring-in *ganyu* [c]	24 (9%)	35 (13%)	25 (9%)	84 (31%)
All herbicide using households that hired-in *ganyu* [c]	17 (6%)	25 (9%)	7 (3%)	49 (18%)

[a]Reported using herbicides in 2015/16.
[b]Excluding those that also hired-in ganyu. Fifteen of 275 households (5%) reported both hiring-in and hiring-out *ganyu*.
[c]Including those that also hired-out ganyu.

2.4. Statistical analysis

Data analysis was carried out in R version 3.6.1 (R Core Team, 2019). Households that to use herbicides in 2015/16 but did not report herbicide use in any of the plots they farmed in 2015/16 or vice versa, were excluded where herbicide adoption is reported (up to nine households, relevant to Figure 2(a) and Table 2). Linear-mixed models were used to compare households that used herbicides in 2015/2016 with those that did not and to compare households that hired-out piecework with those that did not. The models included location (EPA) as a random effect and predicted various household characteristics – most of which were wealth indicators. The tests were performed separately for each household characteristic and were thus not adjusted for *p-value* inflation. Counted household characteristics were compared using Generalised Linear Mixed Models with the response modelled as a Poisson distribution. Binary household characteristics were compared using Generalised Linear Mixed Models with the response modelled as a binomial distribution. Continuous household characteristics were compared using Linear Mixed Models. To improve the fit of the Linear Mixed Models comparing the household characteristics of *farm size* and *household income*, these variables were square root transformed and log-transformed, respectively. For the same variables, outliers 3.5 standard deviations from the transformed means were excluded (one household was removed from the *farm size* variable and three from the *household income*). The statistical significance ($p < 0.05$) of the model outcomes were robust to both transformation and outlier removal. Model estimates of the main effect (hiring out piecework or herbicide use) and their 95% confidence intervals, as well as the *p-values* of pairwise comparisons were obtained using *emmeans* (Russell, 2019).

3. Results

3.1. Did herbicides reduce labour hiring?

Herbicide use had increased substantially in the decade preceding to the survey. Disregarding purposely selected CA adopters – which would unduly influence uptake figures – we found that among *comparison households*, only 2% reported using herbicides in 2005/06, compared with 36%[2] by 2015/16 (n = 185) (Figure 2). In the two northern sites, where the TLC/CIMMYT/MG CA demonstrations were located, herbicide adoption rates were highest – measured at 52% of *comparison households* in Mwansambo (n = 62) and 39% in Zidyana (n = 64). By contrast, only 12% of *comparison households* had adopted herbicides in Tembwe. These high rates of herbicide adoption

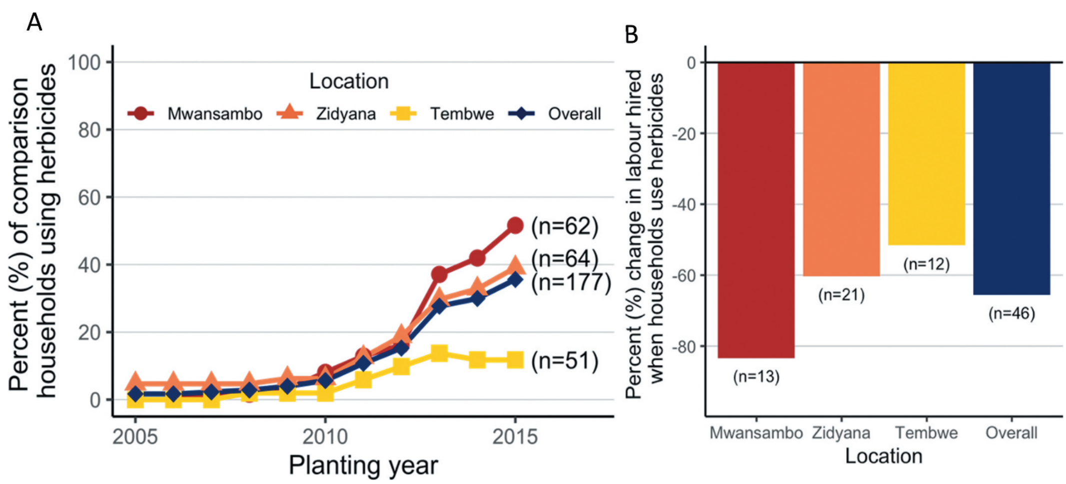

Figure 2. Herbicide use and its impact on labour hiring. (a) The proportion of comparison households reporting herbicide use in each site from 2005/06 to 2015/16. (b) The difference (in %) between the amount of labour households hired before herbicides were used and the labour hired when herbicides were used.

Table 2. Comparisons of 2015/16 herbicide users (n = 62) with non-users (n = 114) and of households hiring-out piecework (n = 101) with households not hiring-out piecework (n = 84). Only comparison group households were included. Estimates of the means or proportions (reported in percent) are outcomes of mixed models which predicted the household characteristics with location as a random effect

	2015/16 Herbicide user			Hires out piecework		
	Yes (n=62)	No (n=114)		Yes (n=101)	No (n=84)	
	Mean or percent		Difference	Mean or percent		Difference
Household income (x100,000 MK)	1.98	1.03	0.95***	0.90	1.90	-1.00***
Livestock owned	4.1	1.3	2.8***	0.91	3.76	-2.85***
Farm size (Ha)	1.44	0.90	0.54***	0.96	1.25	-0.28**
Bicycles owned	1.07	0.53	0.54***	0.45	1.01	-0.56***
Months struggled to find food (of past 12 months)	1.11	2.69	-1.58***	2.89	1.36	1.53***
Education of household head (scored 0-5) †	1.95	1.35	0.6**	1.38	1.70	-0.32
Homestead has iron roof	30%	8%	22%***	6%	27%	-21%***
Received herbicides on loan	18%	3%	15%**	2%	12%	-10***
Practiced no-tillage in 2015/16	59%	31%	27%**	37%	46%	-9%
Struggles to find food in a normal year	37%	54%	-17%*	50%	45%	5%
Hires in piecework	37%	25%	13%	13%	48%	-35%***
Hires out piecework	35%	63%	-28%***			
Used herbicides in 2015/16				22%	44%	-21%**

*p < 0.05. **p < 0.01. ***p < 0.001.
† 0: no school, 1: incomplete primary, 2: completed primary, 3: incomplete secondary, 4: completed secondary and 5: O-level or higher education.

are far above the national average which estimate their use at 1% (Grabowski & Jayne, 2016) and indicate their successful introduction by CA promotion programmes. The greater frequency of herbicide use in Mwansambo and Zidyana correlate with the length and intensity of herbicide promotion in these locations. To illustrate, in Mwansambo (n = 99) and Zidyana (n = 101), 17% and 13% of all surveyed households reported having received herbicides on loans, while in Tembwe (n = 75) no households reported having received them. Larger farm sizes and an orientation towards cash crops (that is groundnuts) in Mwansambo and Zidyana also played a role in the rapid rise of herbicide use in these locations. In these locations farm incomes from crop sales were almost double those in Tembwe.

When households used herbicides, they hired substantially less labour than before. They were asked to indicate whether the labour they hired for weeding and for banking ridges (which is also a weed management strategy) changed when they used herbicides. Forty-six of 56 herbicide-using labour-hiring households provided answers, and all of these said they reduced this labour hiring. The median (and interquartile range) reported labour they hired *before* they used herbicides was 72 (34–137) labour days; while the reported labour hired *when* they used herbicides was 27 (3–47) labour days. Altogether, these households hired 65% less labour for weeding and banking when they used herbicides (n = 46). Tamru et al. (2017) and Haggblade et al. (2017b) report similar reductions (50% and 70–80%) in labour demand in Ethiopia and Mali. Among the three sites of the present study, the reduction in labour use was largest in Mwansambo (83% decrease, n = 13) and smallest in Tembwe (52% decrease, n = 21) (Figure 2(b)). Since 73% of the labour-hiring households used herbicides (n = 77), the total change in labour hired in the surveyed areas was substantial. A 65% reduction among 73% of labour-hiring households resulted in a 48% reduction in total labour hiring. When disaggregated by location, the reductions in labour hiring for Mwansambo, Zidyana, and Tembwe were 73%, 48% and 25%, respectively. A rapid expansion of herbicide use beyond CA or no-till goes a long way in explaining the impact of herbicide use on labour hiring in the study sites. Forty-nine percent of the pre-selected *CA adopting* households (n = 90) reported using herbicides in

2015/16 while 23% of households that farmed only with the commonly practised ridge-furrow system used herbicides. Consequently, 72% of the land on which herbicides were reported to have been applied was ridged – that is neither CA nor no-till.

3.2. Were herbicide users the better-off and piece-working households the worse-off?

Households that used herbicides in 2015/2016 were significantly better-off than those that did not. Table 2). *Comparison households* using herbicides (n = 62) had significantly more assets – they were more likely to have a house with an iron roof, had more livestock (sheep, goats, pigs, and cattle) and owned more bicycles than non-users (n = 114). They also had higher incomes, larger farms, were more food secure, both in the year preceding the survey and in normal years and were less likely to have hired-out ganyu. In addition, they were more likely to have received herbicides on loan and to have adopted no-tillage. Their household heads were also better educated on average. The households did not differ significantly in terms of demographic indicators of household size and age and gender of household head (data not shown). That herbicide users were better-off echoes results of Grabowski and Jayne (2016) and is hardly surprising. The cost of applying glyphosate and Harness® to one hectare (the average land area on which herbicides were applied) was approximately 25,000 MK. This was equivalent to 25% of the median reported income of households that did piecework.

In contrast, those who supplied labour for piecework – that is *ganyu* workers – were worse-off. As Table 2 shows, comparison group households that hired-out labour (n = 101) had fewer assets (iron-roofed houses, bicycles, and livestock), had lower incomes and smaller farms, and were less food secure in the past year than the rest of the surveyed households (n = 84). The land size they reported to have owned was not significantly different, though the farm size data better fit the assumptions of normality in the model. Piecework supplying households were also less likely to have experienced the benefits of herbicide use (they were about half as likely to have used them) and were less likely to have received loan support for herbicides. The relationship between doing piecework and female household headship was not significant (data not shown); though the literature on Malawi presents mixed results on this relationship (Cole & Hoon, 2013; Marsland, Long, & Sutherland, 1999; Michaelowa et al., 2010).

Among *comparison households*, 55% hired out their labour during the growing season (n = 185)[3] and 29% of *comparison households* hired in labour[4]; only 7% reported both hiring in and hiring out labour. These findings closely resemble nationally representative data from 2004, reported by Michaelowa et al. (2010). They reported that 68% of households participated in *ganyu* labour exchanges across the year, with 53% supplying *ganyu* and 25% hiring in *ganyu.*

3.3. Was (weeding related) piecework a vital coping strategy?

Hunger was not uncommon in the study area. In total 69% of *comparison households* reported having struggled to find food in the year preceding the survey. This figure is comparable to estimates provided by national surveys in 2005, 2011, and 2017, where respectively, 52%, 58%, and 79% of rural Malawians reported not having enough food during the preceding year (MNSO, 2005, 2012, 2017). However, hunger is seasonal – it follows the rains, peaking in January and February (Figure 3). At this time the previous season's food stocks are depleted, and the now verdant countryside remains unfruitful.

It is also during these months of acute hunger that households, now without food, turn to weeding in the fields of others to earn enough to survive. As Figure 4(a) shows, 70% of *comparison households* that struggled to find food in at least 1 month (n = 108) turned to piecework once they ran out of food. Meanwhile, 87% of households that hired out labour during the growing season reported the main tasks they did was weed control related (that is weeding or banking ridges) (Figure 4(b)). These are the main

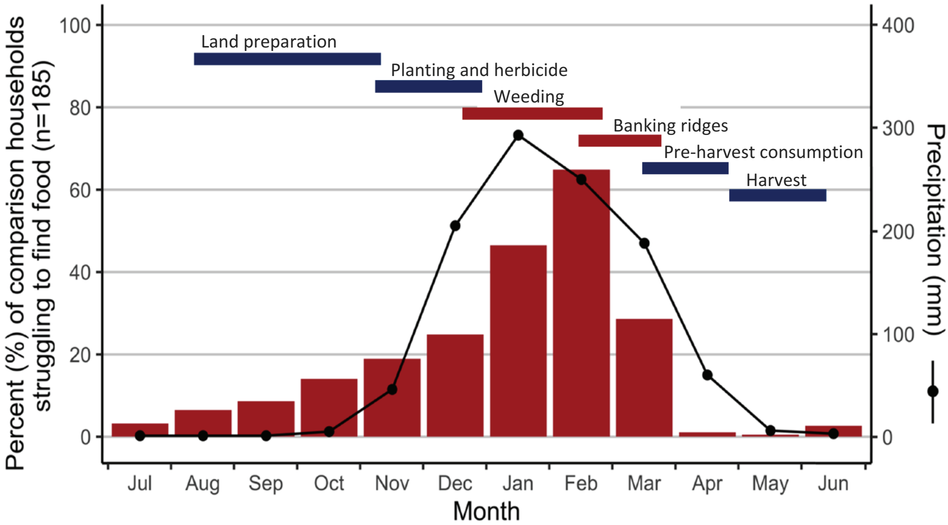

Figure 3. Seasonality of the food insecurity, rainfall, and farming activities in Malawi. The plot shows the percentage of comparison households that indicated they struggled to find food in each month of the year preceding the survey (vertical bars), the average monthly rainfall (line and point), and the main farming activities (horizontal bars). Precipitation data are for Salima township, based on the period 1982 to 2012 (Climate-Data.org, 2019). Note: Banking ridges is a method of weed control.

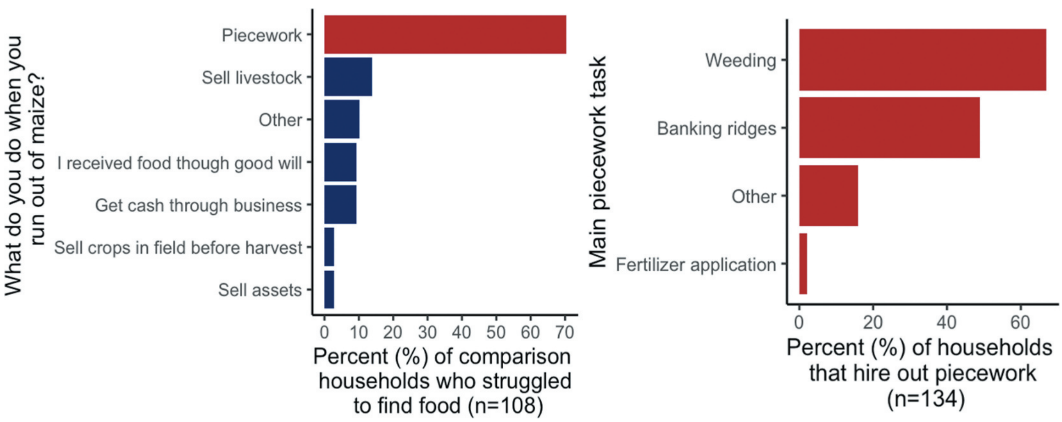

Figure 4. Coping strategies in the context of food shortage. A: Reactions to running out of maize (the staple food) among those who indicated they struggled to find food during at least one of the past 12 months. B: Main piecework tasks among respondents who reported hiring out labour during the growing season. Except for 29 respondents replying to the question of Plot A, respondents could indicate multiple responses. These 29 households were excluded from Plot A (though the frequencies are almost identical, with 71% reporting piecework, when these households are included).

agricultural activities during the growing season (Figure 3) and the same activities that herbicides had replaced (Figure 2).

3.4. Did failing to find piecework result in hunger?

Most households that sought piecework experienced occasions when they were unable to find work. In total, 70% of *comparison households* that said they hire out piecework (n = 101) reported having experienced at least one occasion during the previous growing season in which they were unable to find piecework. Moreover, many of these households failed to find piecework on multiple occasions: 72% reported they failed to find piecework on one to three occasions and 28% reported that they failed between four and ten times (*n* = 71). At the same time, only 11% of households that hired labour reported difficulties in finding pieceworkers. Together these data indicate that the supply of piecework had far outstripped the demand.

The consequence of failing to find piecework was usually hunger (Figure 5). In total, 57% of all respondents that were unable to find piecework indicated that they went hungry as a result (*n* = 92). Only 4% of these households reported that they were able to find other activities to get food or money (Figure 5). Overall, 35% of households that did piecework (*n* = 134) reported failing to find piecework and experiencing hunger as a consequence, while 19% (*n* = 184) of all *comparison households* that reported they do piecework, were unable to find piecework and consequently experienced hunger.

It should be noted that not all piecework was done to avoid hunger and not all food-insecure households did piecework. For instance, 32% of households (*n* = 127) who struggled to find food during the growing season (November–March) did not hire out their labour during the growing season (though perhaps some of these looked for piecework and were unable to find it). Similarly, a sizeable proportion (24%, *n* = 58) of households that did not report struggling to find food during growing season had hired out their labour. Orr et al. (2009) and Michaelowa et al. (2010) also report that *ganyu* is not only done to avoid hunger. Nevertheless, most *ganyu* seeking was related to hunger: the vast majority of households that were unsuccessful in finding piecework (85%), said they searched for piecework to find food (n = 90) (data not shown). Similarly, Cole and Hoon (2013) reported 82 per cent (*n* = 34) of ganyu-seeking households sought *ganyu* to obtain food.

3.5. Were changes in piecework availability and food security related to herbicide use?

Survey respondents also perceived that piecework had become less available in the time that herbicides became popular – and many even attributed the change to herbicides. Among households who were unable to find piecework (*n* = 92), 65% reported that it had become harder to find piecework over the past 10 years, while only 15% said it had become easier to find piecework (Figure 6(a)). Correspondingly, 58% of households that hired in piecework (*n* = 84) reported that it had become easier to find pieceworkers, while only 23% said it had become harder to find pieceworkers during the past 10 years (Figure 6(b)).

A simple open-ended question, *'Why?'*, followed the questions these about long-term changes in piecework availability (Figure 6(c,d)). The most frequent explanation for an increase in difficulty of

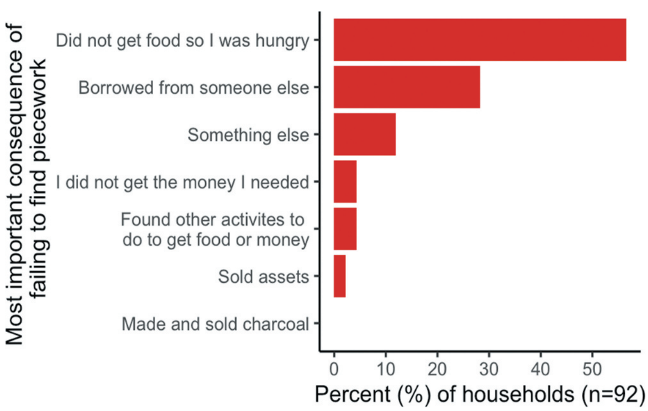

Figure 5. The consequences of failing to find piecework. Respondents who indicated they were unable to find piecework on at least one occasion (n = 92) were asked what the consequence of this failure was.

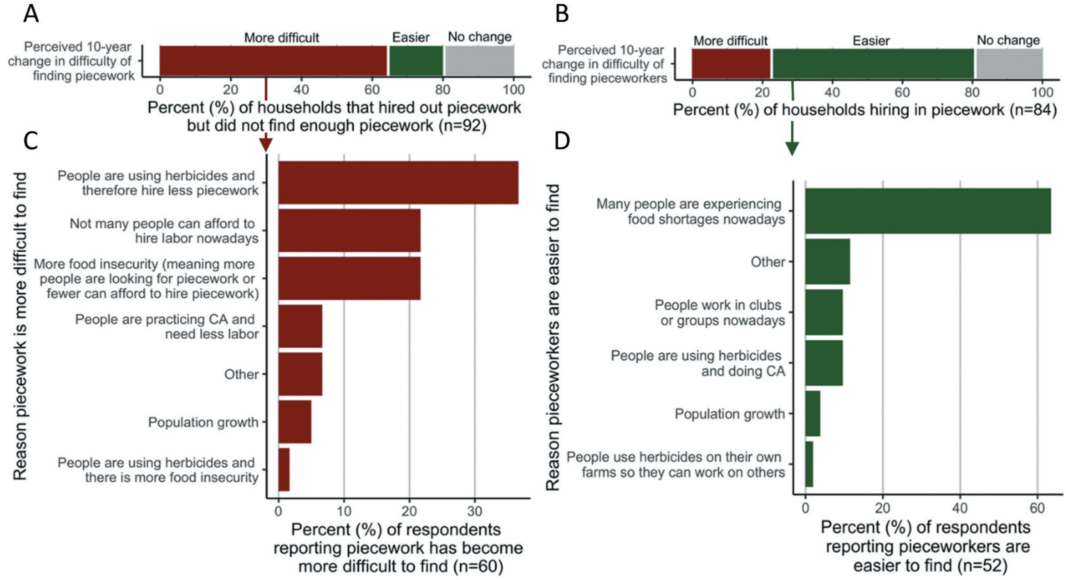

Figure 6. Perceived 10-year change in piecework availability (A) and (B) and explanations offered for the change (C) and (D). (A) and (C) pertain to households that hired out piecework but experienced times in which they were unable to find piecework; (B) and (D) to households that hired in piecework. The explanations offered in (C) and (D) are categorised answers to open-ended question, 'Why?', which followed the questions about perceived changes in piecework availability. The 'Other' category in (C) includes answers indicating women were less likely to be hired than men and the respondent not knowing. The 'Other' category in (D) includes topics such as, more people need piecework, climate change, the respondent not knowing, and the household having permanent workers.

finding piecework was indeed herbicide use (Figure 6(c)). In total, 38% drew a direct connection between reduced piecework availably and herbicides (n = 60). In addition, 7% mentioned CA as a cause. This may be an indirect reference to herbicides as herbicides are associated with CA or a reference to reduced weeding due to CA farmers bringing large quantities of crop residues into CA plots to suppress weeds. Even when households that used herbicides were excluded, 27% of the remaining respondents (n = 41) mentioned herbicide use as an explanation for the increased difficulty in finding piecework. Most of the remaining responses referenced causes that point to increased hardship and poverty – increased food insecurity, for instance from poor harvests, and fewer being able to afford to hire labour, for instance, because of low crop prices and more people relying on the same resources.

Labour-hiring households that reported piecework was easier to find usually pointed to food insecurity among the labour supplying households to explain this change. A number of these respondents mentioned herbicides and CA as reasons that *ganyu* had become easier to find, which may indicate that increased herbicide use also increased the supply of *ganyu* labour. Respondents who indicated that piecework was easier to find or that finding pieceworkers was becoming more difficult, offered varied explanations without a general theme (data not shown).

Hiring out one's labour for piecework was associated with long-term trends in food insecurity. Households indicated whether their food security situation had become *'much worse', 'worse'*, had *'not changed'*, had become *'better'* or *'much better'*, during the previous 10 years. Among households that hired out labour, 63% reported their food security situation had become *worse* or *much worse* (n = 111). Of households that did not hire out labour, 45% (n = 119) reported the same. Meanwhile, herbicide use was associated with the opposite trend. Forty percent of households using herbicides in 2015/2016 who reported a change in their food security situation (n = 94) said it had become *worse* or *much worse*, while 63% of non-users (n = 136) reported the same.

3.6. Village leaders' perceptions of the impact of herbicides

Unlike the survey respondents, village leaders were asked directly whether herbicides are causing a scarcity of *ganyu* and affecting food security in their villages. Not surprisingly, the responses varied with location and social context. In Mwansambo, the site where herbicide use was most prevalent (Figure 2), all four interviewed village leaders confirmed herbicide use had an impact on piecework hiring patterns. For instance, one village leader responded that, '*Herbicides contribute to food insecurity up until the banking period*', suggesting that banking is less impacted by early season herbicide use than weeding (which mostly takes place before banking). However, the survey data indicate that banking was not unaffected by herbicide use: among *comparison households*, 41% of plots were banked when herbicides were applied (n = 70 plots), while 60% were banked when herbicides were not applied (n = 161). In Zidyana, where herbicide use was common, three village leaders indicated that: '*Ganyu is hard to find during the hunger season since more people are using the herbicides and once the gardens are sprayed, the gardens are no longer attended to'*. In two other locations in Zidyana and all four locations in Tembwe, village leaders did not describe herbicides as causing a scarcity of *ganyu*. This was understandable as nearly all of these village leaders also indicated that herbicide adoption in their villages was limited.

In Mwansambo and Zidyana, village leaders reported that the labour saved from herbicides enabled herbicide using farmers to grow other (more labour demanding) crops such as cotton, groundnuts, and rice, to expand their farms onto marginal scrubland or by renting land from other farmers. Labour savings were also reported as having been spent in other people's gardens doing *ganyu* – indicating that herbicides not only reduce demand but also increases supply of *ganyu*. Village leaders did, however, affirm that *ganyu* was only done in case of household emergencies, suggesting that this strategy was not common among the food secure. Village leaders regularly mentioned that plots with herbicides gave improved yields through better weed control.

Most village leaders were aware of the prevailing *ganyu* wage rates. Labour costs for weeding and banking were reported as 37,000 MK per hectare, though figures ranging from 27,000 MK to 50,000 MK were reported. With glyphosate and Harness® costing approximately 25,000 MK herbicides significantly reduced labour costs among households that formerly hired-in labour. The degree of savings is comparable to figures reported by Haggblade et al. (2017b) for Mali and the Tamru et al. (2017) for Ethiopia. Households substituting *ganyu* hiring with herbicides stand to benefit from such savings at the expense of *ganyu* workers who face both reduced *ganyu* demand and prices.

Village leaders frequently pointed out that the scarcity of *ganyu* labour was not only caused by herbicide use. Rather, they emphasised other problems faced by their villagers that they deemed more important. High or increasing input prices or lack of fertiliser was most commonly mentioned – especially in the more remote Mwansambo area. Erratic rainfall and land pressure were also frequently mentioned, as were sickness, exploitative maize pricing, and exploitative borrowing terms – something those who could not find *ganyu* suffered from (Figure 5). Although the views of village leaders were insightful, it is worth noting that they are more likely to be the better-off (and thus to be herbicide users) than to be doing *ganyu*. This may have influenced their views.

4. Discussion

Our findings indicate that herbicides contributed to the seasonal hunger of food insecure households in CA promotional areas in Central Malawi. This occurred because most food insecure households rely on *ganyu* (piecework) (Figure 4(a)) – mostly in the form of weeding (Figure 4(b)) – in order to obtain food during the hunger season. Herbicide use reduces labour needs for weeding, and therefore piecework availability (Figure 2), particularly in this period of acute food shortage (Figure 3). Consequently, use of herbicides by those who could afford them, contributed to hunger among the most food insecure (Figure 5). Households participating in piecework exchanges also noticed piece-work availability had declined and often attributed this to herbicide use (Figure 6); meanwhile village leaders in areas of herbicide adoption agreed that herbicides were affecting *ganyu* hiring. Herbicides were thus contributing to social differentiation; the better-off benefited from labour cost reductions and (possibly) higher yields, at the expense of the poor, whose paid labour opportunities declined, and hunger increased. These are important findings, for they show how the promotion of agricultural technologies (for example, CA and herbicides) – intended to reduce hunger in rural communities – may have the opposite effect: intensifying hunger among the most vulnerable.

In the following sections, we discuss three important implications of our findings: (1) the consequences of labour displacement for hunger and the individualisation of poverty; (2) how impact assessments fail to capture this dimension of technological change, and; (3) the implications for future promotion of CA and labour-saving technologies in Malawi.

4.1. The implications of herbicide use: hunger and the individualisation of poverty

In Malawi, the implications of herbicide use reach further than contributing to social differentiation and the seasonal hunger of the rural poor: herbicide use affects the nature of rural poverty. *Ganyu* is not merely a term to denote an unregulated agricultural labour market; it refers to an informal social institution that simultaneously regulates labour exchange between rural households, redistributes rural wealth, and mitigates food shortages (Whiteside, 2000). Although it can be exploitative, forcing the hungry to work for very little, it is at the same time a social safety-net and an insurance mechanism that provides a source of livelihood for those in acute need (Bezner Kerr, 2005; Michaelowa et al., 2010; Van Donge, 2005; Whiteside, 2000). Households that offer *ganyu* employment may not merely be in need of labour; they may (also) offer *ganyu* out of social obligation or kindness (Englund, 1999; Whiteside, 2000) – as could also be observed in the study area: '*We did not use herbicides so that we could still provide ganyu to some people who need piecework'*. However, herbicides cut the interdependency of the hungry and better-off households, enabling labour hiring households to opt out of this social institution. A remark of a farmer in Tembwe is illustrative: '*My fields are clean so I can tell those who ask for ganyu that I have no work.'* As a consequence, as one village leader put it, *'The starving households are denied the ganyu that they used to do in the past'*. Thus, with better-off households no longer dependant on *ganyu* labour, herbicide use contributes to the individualisation of poverty and hunger in rural Malawi.

4.2. Impact assessments and the problem of rural inequality

Impact assessments of newly introduced technologies in smallholder agriculture typically measure differences between technology adopting households and comparable non-adopting households, while controlling for confounding factors and (self-)selection biases using econometric tools (Amare, Asfaw, & Shiferaw, 2012; Kassie, Teklewold, Marenya, Jaleta, & Erenstein, 2015; Khonje, Manda, Alene, & Kassie, 2015; Mango, Siziba, & Makate, 2017). However, this study reveals a serious limitation of commonly used econometric methods: they disregard the effects of technology adoption on non-adopting households. As a result, impact analyses may wrongly attribute observed differences between adopters and non-adopters to technology adoption, may over- or underestimate them, or even overlook important impacts of adoption. Indeed, where technology adoption harms non-adopters, impact assessments are prone to interpret the harm as a positive effect of technology adoption. The present study illustrated this and showed how herbicide using households tended to become more food secure over time, while piecework-dependent households tended to become less food secure (Section 3.5). Since technology impact assessments attribute observed differences between groups or households to the technology, in this situation herbicides may incorrectly be seen as reversing an ongoing trend of growing food insecurity. Unfortunately, technological change and agricultural development have often been associated with both winners and losers (Bezner Kerr, 2012; Dawson, Martin, & Sikor, 2016; Stiglitz, 2014) meaning that impact analyses may often be confounded by such non-adopter welfare declines. Focused only on the outcome pattern, impact assessments that are mainly quantitative (for example, randomised controlled trials and propensity score matching) are ill-disposed to understand the social processes that shape outcomes for non-adopters of technologies.

As this study has revealed, gauging the impacts of technological change requires an appreciation of the social mechanisms at play, and of the manner in which new technologies reconfigure the social and technical components of the agricultural system (Glover et al., 2016, 2019). For instance, herbicides not only enabled better-off households to change their farming practices, but also afforded them the opportunity to opt out of existing *ganyu* labour relations, thereby altering existing social practices at the inter-household level. An interdisciplinary perspective, combining social and agronomic sciences, and qualitative research – like observational fieldwork – appear to be indispensable for arriving at such an understanding of technological change processes. Such a perspective and research approach contrasts with technology evaluations as found in the sustainable intensification literature, which focus on household or plot-level outcomes and neglect inter-household relations (Smith et al., 2017).

4.3. Herbicides, CA promotion and rural poverty: implications for development intervention

Next to revealing impact assessment problems when interventions have adverse effects on non-adopters, our study also suggests that we should be cautious about viewing CA with herbicides as a poverty alleviation strategy. While herbicide use increases profitability, their increased cash investment requirements impede their uptake among resource poor smallholder farmers. To overcome this problem, CA promoting organisations in central Malawi provided loans – ostensibly with the aim of ensuring that the cash-constrained could afford them. However, as this study has shown (Table 2), this did not lead to the inclusion of the poorest households in CA interventions. Rather, it resulted in the better-off households, who could afford the down payment required, to benefit from these interventions.

It appears herbicides present a problem for CA interventions in smallholder agriculture, akin to being stuck between a rock and a hard place. When CA is promoted without herbicides, it substantially increases labour demands for weeding and may reduce yields, making it unattractive and therefore unlikely to be taken up by many (Baudron, Mwanza, Triomphe, & Bwalya, 2007; Dahlin & Rusinamhodzi, 2019; Giller, Witter, Corbeels, & Tittonell, 2009). Conversely, when CA is promoted with herbicides it is likely that it becomes a technology for the better-off (as also suggested by Ngwira, Johnsen, Aune, Mekuria, & Thierfelder, 2014). Further, even when CA is promoted with herbicides and herbicide use is (heavily) financially supported, CA uptake may still not happen, as herbicides may become disassociated with CA. This was observed in the present study in which herbicide uptake far exceeded CA adoption and resulted in herbicide induced social harms.

Current CA promotion in Malawi de-emphasises the importance of herbicide use. The use of Harness® and Bullet® is discouraged for environmental reasons and the use of glyphosate and StellarStar® are now only considered to be complementary practices to CA (NCATF, 2016). Unfortunately, this approach undermines the degree to which CA in Malawi is evidence-based. Its promotion in Malawi is based on claimed yield benefits and labour implications that are mainly established through on-farm experiments that included the use of (now discouraged) herbicides (Bouwman, 2018; NCATF, 2016).

We do not dispute that labour-saving technologies can facilitate much needed yield increases in smallholder agriculture in SSA. Yet, it is also true that benefiting the better-off at the expense of the poor is not a poverty alleviation strategy. Promotion of labour-saving technologies needs to ensure appropriate targeting so that the livelihood strategies of the poor are not compromised. For example, the use of mechanisation by farmers who did not previously hire-in labour may increase labour efficiency and yields without leaving others empty handed. Similarly, development interventions need to be inclusive – rather than assuming that poorer households are beyond help as some did in the study area. As an employee of an herbicide-promoting NGO put it, *'Let them die if they cannot find* *a better way to find what they need'*. It is worth recalling that the drivers of poverty – such as small farm sizes, costly inputs, and the decline of *ganyu* are largely outside of their control. Further, such work does not necessarily imply a poverty trap (Orr et al., 2009)

Projects that promote technologies that might displace agricultural labour require an understanding of the wider (rural) economy. Labour-saving technology interventions demand accompanying strategies for labour absorption elsewhere in the economy – for example, through providing work in other sectors or through agricultural crops that can support higher wages. Where coping strategies of the worse-off are compromised and not replaced, further investment in rural safety net programs (such as food for education programs, dry-season public works programs with hunger-season advances, cash transfer programmes, or rural employment guarantees) may be warranted to compensate for reduced work opportunities and wages for the poor.

In situations of widespread cash shortage, as is common in rural Malawi, subsidies may help resource poor farmers to access agricultural inputs. Malawi has considerable experience with input subsidy provisioning to smallholder farmers, as evidenced by the government's Starter Pack, Targeted Inputs Programme (TIP), and Fertiliser Input Subsidy programmes – the latter already having run for over a decade (Chirwa & Dorward, 2013; Levy, 2005). Acknowledging that mobilising cash for farm inputs is for many poor smallholder farmers a daunting task, these policies have primarily sought to increase the yield potential (through mineral fertiliser use), as this is a more cost-effective way to increase resource poor rural households' access to food than providing food aid. The subsidising of cash-demanding agricultural technologies that can save labour, such as herbicides and CA, are unlikely to be taken up by resource poor producers as their cash-, area-, and soil fertility constraints are binding.

Finally, interventions aiming at sustainable intensification of agriculture should be aware that labour-saving technologies may lead to agricultural expansion rather than to intensification. This has been observed elsewhere in Africa, particularly in less densely populated parts, where land is less limiting than labour (Baudron, Andersson, Corbeels, & Giller, 2012). Haggblade et al. (2017b) reported that labour-saving herbicides also had this effect in Mali. The present study suggests that such herbicide-induced agricultural expansion may even occur in countries with relatively high average population densities, such as Malawi.

5. Conclusions

Guided by an agenda of the sustainable intensification and agriculture-led growth, interventions in African smallholder agriculture aim to improve food security for a growing African population by promoting yield-improving production technologies. However, this study shows that new technologies that displace labour may inadvertently assist the better-off at the expense of the poor – thereby aggravating food insecurity and inequality. Herbicide use, and donor-funded loans for herbicides, mostly benefitted the better-off who can afford them – through labour-savings, cost-savings, farm expansion, and potentially, yield benefits. However, the food insecure faced diminishing food and income earning opportunities, lower wages and intensified seasonal hunger. By depriving the poorer of the opportunity to work in the fields of the better-off, rising herbicides use in Africa has important implications for informal rural safety nets (such as *ganyu* in Malawi) and for the nature and extent of rural poverty. Agricultural interventions may avoid causing problems such by refraining from promoting labour-saving technologies where their use might compromise the livelihood strategies of the poor. Where they are promoted or adopted, policies that stimulate non-farm employment or enable social safety nets may become necessary to avoid widespread rural unemployment, poverty, and food insecurity.

Our study began as a study of the impact of CA adoption. The results suggest that we should be cautions viewing the promotion of CA with herbicides as a poverty reduction strategy. They also highlight the difficulty of reaching the poor, since loans for cash-demanding herbicides ended up aiding the better-off. Finally, we stress the importance of performing due diligence investigation into how a promoted technology may influence the worse-off in society and their coping strategies.

Commonly used impact assessments methods are ill-equipped for this purpose; instead, interdisciplinary research and fieldwork beyond the farm-level (that is on inter-household relations) are imperative for such investigation.

Acknowledgements

This work was made possible by farmers and extension officers in Central Malawi who graciously shared their time and experiences. The dedicated work of Ellen Mafuel, Alinafe Manjawira, Cidrick Kasinja, and William Simwanza as survey enumerators is gratefully acknowledged. William Simwanza also aided in managing the survey and facilitating interviews with village leaders. Joseph Kamwaza, the late Rodrick Brasho, Gabriel Masawoutso, Alsen Botha, Trent Bunderson, Richard Museka offered additional valuable assistance and insight in Malawi. We thank Joost van Heerwaarden for advice on the statistical analysis. This work was partly funded by the CGIAR Research Program on MAIZE (www.maize.org) led by the International Maize and Wheat Improvement Center (CIMMYT) in Mexico (Grants: *Rural livelihood-oriented research methodologies for social impact analyses of Sustainable Intensification interventions* and *Uptake and impact of climate smart, Conservation Agriculture practices in Malawi)*. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of CRP MAIZE or CIMMYT. Ken Giller is grateful for a grant from the NWO-WOTRO Strategic Partnership NL-CGIAR. Jens Andersson gratefully acknowledges Jankees van Donge, whose incisive insights into rural poverty in rural Malawi have been an inspiration in the development of this research project.

Funding

This work was supported by the CGIAR Research Program on Maize and NWO-Wotro [grant number 174231].

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes

1. These demonstrations were managed by farmers with the help of government extension officers and local NGOs. They are also set up as replicates to trial the performance of CA and data collected from the trials is published by CIMMYT.
2. This rate slightly underestimates herbicide adoption in the surveyed communities because *comparison households* were selected after the *CA adopters*. Nevertheless, since 40 per cent of all households in the survey (including *CA adopters*) used herbicides (n = 275) the degree of the underestimation is small.
3. They responded affirmatively to the question, '*Do you (or members in your household) work in other people's fields for hire during the growing season?*'.
4. They responded in the affirmative to the question, '*Do you hire workers from outside your household to work in your fields?*'.

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