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The role of women empowerment and labour dependency on adoption of integrated soil fertility management in Malawi

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Abstract

This paper explores the role of women empowerment and labour on enabling farmers to cross two hurdles: adopt and intensify soil fertility management (SFM), coming after six decades of SFM research that disseminated several technologies. Despite the assertion that productivity gains cannot be realized unless drivers of soil degradation are addressed, SFM usage is low. We collected data from a systematically drawn random sample of 238 farmers, representing 30% of farming households in five villages in Malawi's Rift Valley escarpments and analysed using a double-hurdle model. Descriptive results show that 90% of the respondents used inorganic fertilizers, 72% planted legumes and 57% applied organic manure. The empirical analysis shows that one percentage point increase in dependency ratio reduces probability to apply organic amendments by 0.4 percentage points and erodes the positive influence of increasing labour on application of inorganic fertilizer. As women become increasingly empowered in decision-making, there are significant trade-offs: a percentage point increase in women empowerment in agriculture index (WEAI) potentially leads to a one-third percentage point increase in the area allocated to legumes but reduces the amount of organic manure applied with higher elasticity of two percentage points. Considering the trade-offs, sustainable intensification could be achieved by harnessing the positive influences while concurrently reducing the negative ones over a decision space. Notably, addressing the negative effect associated with women empowerment on manuring could unlock potentials for integrated SFM as women are already engaged in legume cropping.

KEYWORDS
dependency ratio, gender, labour, maize mixed farming systems, Rift Valley escarpments, soil fertility management

1 | INTRODUCTION

The demographic shifts in terms of women empowerment and labour in southern Africa are largely considered to give positive dividends (Bloom, Kuhn, & Prettner, 2016). Since rural societies rely on soil productivity to support their subsistence livelihoods, the low adoption of soil fertility management (SFM) practices is therefore one of the basic concerns in smallholder farming systems. Yet studies have not been conducted to explore how gender and dependency ratios might influence uptake of SFM. This is despite six decades of farming systems research and development that has furnished farmers with several technologies that potentially protect, maintain and build soil fertility (Vanlauwe et al., 2017). The last three decades have seen repackaging and disseminating sets of proven SFM technologies and promoting them as systems innovations, some targeting women farmers (Snapp, 1998). Among others, integrated SFM is touted to address multiple constraints (Vanlauwe et al., 2010). Farmers are expected to select a suite of technologies that fits best their land, cropping system and socioeconomic capacities.

Against the backdrop of shifting cultivation and natural fallows, organic resources have played a significant role in SFM through their short-term effects on nutrient supply and longer-term contributions to soil organic carbon (SOC) (Palm, Gachengo, Delve, Cadisch, & Giller, 2001). From the time farms transitioned into continuous cultivation in the 1960s, without external inputs SOC decreased by 41% in 25 years and maize grain yields dropped by 57% within 10 years (Chilimba, Shano, Chigowo, & Komwa, 2005). To address the declining productivity, farmers typically supplement inorganic fertilizers with locally produced organic resources (Palm et al., 2001). The SFM usage by farmers could be considered a response to diminishing nutrient levels, which have to be addressed first before farmers can realize the benefits from other farming practices (Sanchez, 2002).

In 2005, the Malawian government introduced farm input subsidies targeting smallholder farmers. Since then, the programme has during each year, on average, supported 30% of 3,280,000 households; supplying 43% of the total of 250,224 megatons of fertilizer applied to maize in Malawi (Figure 1). For the 12 subsequent years, fertilizers and improved seeds supplied through the programme shifted and stabilized maize yields from 0.7 ton ha^{-1} in 2005 to above 1.5 ton ha^{-1}. However, the current yield levels are not different from some pre-subsidy yields of 1.7 ton ha^{-1} (Figure 1) and much lower than the 4–15 ton ha^{-1} of potential yields for improved maize varieties in Malawi (Tamene, Mponela, Ndengu, & Kihara, 2016). As of 2015, some farmers were not applying inorganic fertilizers while the majority applied below the recommended rates (Mutegi, Kabambe, Zingore, Harawa, & Wairegi, 2015).

Although the use of manure has also been promoted since the 2000s (Chilimba et al., 2005), the subsidy programme primarily focused on inorganic fertilizers, which probably has led to neglect and consequential decline in SOC (Mpeketula, 2016) and land productivity (Messina, Peter, & Snapp, 2017). From as early as 1965, research revealed that significant crop response could be observed when 5 ton ha^{-1} of farm yard manure was applied to maize (Chilimba et al., 2005). In Zimbabwe, long-term manure application (>10 years) at rates of 3–5 ton h^{-1} increased SOC to moderate, while 10 ton ha^{-1} could replenish the SOC to pristine levels (Musinguzi et al., 2013). Considering these thresholds and the fact that SOC levels are lower than the critical levels required for structural stability of 2% (Tamene et al., 2019), the extent of organic inputs commonly applied in present day Malawi is insufficient to contribute to adequate nutrient supply and SOC build up (Chilimba et al., 2005).

In these nitrogen-limited soils and under low input farming, the nitrogen fixed by legumes is being explored and promoted as one of the major sources of the nutrient (Njira, Semu, Mrema, & Nalivata, 2017). There has been increased

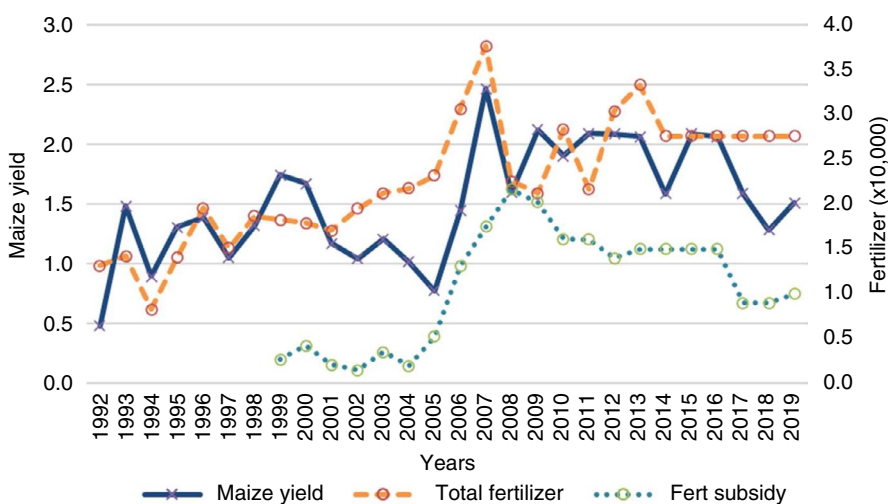

FIGURE 1 Maize productivity trends between 1992 and 2019: maize yield (ton ha^{-1}), quantity of fertilizer (megatons) applied to maize and the fertilizer subsidy (megatons). *Data sources:* Chirwa, Dorward, and Matita (2011); Dorward and Chirwa, (2011); FAO, (2016); Government of Malawi, (2007); IFDC, (20130; Messina et al., (2017); Ricker-Gilbert, Mason, Jayne, Darko, and Tembo (2013)

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cropping of legumes in Malawi as the three common types, that is groundnuts, soybean and pigeon peas, for instance in the Ntcheu District take up to 14% share of the cultivated land (Ortega, Waldman, Richardson, Clay, & Snapp, 2016). Apparently, legumes which were initially omitted are now part of the subsidy package (Messina et al., 2017).

Driven by the increasing impact of climate change on agriculture, the expectation is that climate smart technologies such as organic manures and legumes could be widely adopted and intensified (Zewdie, 2014). However, the recent study by Katengeza, Holden, and Fisher (2019) found that farmers' usage of these promising technologies is a short-term drought adaptation strategy and not a long-term solution. Clearly, the use of inorganic fertilizer, organic manure and/or legumes is not novel technologies; farmers have used them for decades. The low and variable usage emanates largely from lack of regulatory systems and incentives for farmers to conform to minimum SFM standards (Dalupan, Haywood, Wardell, Cordonnier-Segger, & Kibugi, 2015). Beyond the experimental and dissemination phase, farmers adjust the technologies to fit their farm and household conditions (Coe, Njoloma, & Sinclair, 2016). This leads to emergence of mosaic SFM patterns that are complex to visualize, analyse and communicate at landscape level (Giller et al., 2011).

Concealing the diversity, the objectives of previous studies were to reveal trends relevant for national or regional planning such as resilience to climate shocks (Katengeza et al., 2019) or shifts in labour markets (Sauer & Tchale, 2009) and role of off-farm income (Fraval et al., 2019). The sampling strategies used drew limited samples from individual villages and the results were not representative at village or even national level to provide insights into why farmers would not imitate their immediate neighbours (Katengeza et al., 2019).

The Malawi's Rift Valley escarpments are classified as having a medium agricultural potential (Li, Messina, Peter, & Snapp, 2017), but have been under continuous cultivation for over three decades and farmers report various forms of land degradation (Braslow & Cordingley, 2016). In the region, almost all farming activities are done by hand and haulage of heavy items by head (Amede, Tamene, Harris, Kizito, & Xueliang, 2014). Hence, household demographics in terms of availability of labour and the number of dependants compared to workers in a household are important investment factors that could influence SFM adoption.

The dominant marriage system in this region of Malawi is matrilocal, where the husband goes to live with the wife's community, and thus the role of women in decision-making is assumed to influence technology adoption (Lovo, 2016). The community is headed by a woman who transfers land to women of the same lineage. Such women empowerment has been considered as a decisive social capital for improved agricultural productivity and sustainability (Doss &

Morris, 2000). However, since the SFM technologies are generally promoted as an integrated basket, gender would have disproportionate effects. It is purported that social aspects, such as gender, may not be a proximate driver for a particular SFM, but could have indirect effects on complimentary or alternative technologies (Doss & Morris, 2000). A gender-segregated study in Ghana showed that the propensity to apply fertilizer by women-headed households was positively associated with farming experiences, whereas for male-headed counterparts, income from other sources reduced investment in fertilizer (Mensah, Villamor, & Vlek, 2018). Gender as a socially differentiated identity among men and women is invisible and its effects underpin other proximate factors. For instance, women's adoption of practices that require physical assets such as organic manure is premised on them having access to other productive resources (Mustafa-Msukwa, Mutimba, & k., Masangano, C., & Edriss, A. K., 2011). To highlight the influence of gender in this matrilocal society, the concept of women empowerment using the 'women's empowerment in agriculture index' (WEAI) is adopted (Alkire et al., 2012), and which is discussed further in the method section. A crucial element of empowerment is related to access to and control of material, human (including labour) and social resources (Mahmud, Shah, & Becker, 2012).

Linking gender (through women empowerment) and available labour with SFM technologies, the following research questions were addressed: (a) empower women, is it a curse or a blessing for SFM adoption? (b) is the demographic dividend a precursor for SFM adoption? and (c) are there trade-offs and synergies in factors associated with choice to use and level of usage of SFM?

1.1 | Methodology

1.1.1 | Case study area and sampling methods

The sampling frame comprised of smallholder farming households in the five adjoining villages of Malaswa, Amosi, Hiwa, Phikani and Kwangwala in the area of Traditional Authority Kwataine in Ntcheu District of Malawi. In 2015, the average population density was 137 persons km^{-2} with a household size of five members (Emerton et al., 2016). The main defining feature of these smallholder farmers is that they own and manage small plots of up to 5 ha—average 0.9 ha, fragmented mainly into two plots (Mungai et al., 2016)—and produce mainly for subsistence (Anseeuw, Jayne, Kachule, & Kotsopoulos, 2016).

The study area was purposely chosen because it has been a pilot and primary out-scaling area for research for development projects on sustainable land management (Braslow & Cordingley, 2016) and ecological intensification (Mungai

et al., 2016). A probabilistic sampling design was used to randomly select households from the list made available by the respective village leaders. This allowed for a plausible understanding of SFM strategies employed in the region (Tittonell et al., 2010). The required household sample size (s) was determined using the formula by Krejcie and Morgan (1970) as:

$$s = x^2 NP(1-P)/(d^2(N-1)+x^2 P(1-P)) \quad (1)$$

where, x^2 is the table value of chi-square for 1 degree of freedom at the desired confidence level of 0.5 in our case which is 3.841; N is the population size of 600 households; P is the population proportion which is assumed to have a probability of 0.5 since the adoption rate for the SFM practices is already high although at low intensities; and d is the degree of accuracy expressed as a proportion (0.05). This gives the representative sample size of 234 (+4), which is approximately 30% of the study population.

1.2 | Concepts and analytical methods

SFM practices are promoted to address the very basic challenge of soil fertility decline, which should be reversed if farmers in these fragile landscapes are to benefit from alternative technologies (Sanchez, 2002). Every year, when faced with the decision to use or not to use an SFM technology, the household's choice function is based on the utility expected from soil productivity gains, which is conditioned by resource endowments. We assume that households with more labour, in which women are empowered to make farming decisions, would use SFM in increasing intensities. However, in rural areas with unskilled labour, poor soils and variable production, the elasticity of substitution among production assets is high (Mburu, Ackello-Ogutu, & Mulwa, 2014). For instance, the role of women in legume cropping was deemed to be significant (Snapp, Rohrbach, Simtowe, & Freeman, 2002), but as the crops enter the market, men are more likely to take control (Joe-Nkamuke, Olagunju, Njuguna-Mungai, & Mausch, 2019).

Since a considerable proportion of the community does not use SFM strategies, the data contain zeros and are continuously distributed over the positive values. Despite the low levels of nutrient inputs, there have been increasing efforts by governments and non-governmental organisations to promote SFM. Hence, we assume that the zero observations emanate largely from non-participation decisions. Therefore, for a household to be considered a participant, it has to cross two hurdles, namely to (a) *choose* and then (b) *intensify*.

Several empirical models are used to analyse the truncated *choice–intensify* phenomenon (Wooldridge, 2012). We adopt the disaggregated model by Cragg (1971), the double-hurdle, which considers the fact that the observed zeros might also be linked to 'non-participation' decisions that could not be referred to as non-adoption. Moreover, in some situations, the decision to invest in SFM and the amount of investment may not be intimately related.

The participation in SFM technology and the corresponding extent of usage can be expressed as an underlying stochastic models where:

$$y*_{t1} = W_t \alpha + v_t \text{ Participation decision} \quad (2)$$

$$y_{t2} = X_t \beta + \varepsilon_t \text{ Intensify decision}$$

$$y_t = X_t \beta + \varepsilon_t \text{ if } y*_{t1} > 0 \text{ and } y_{t2} > 0$$

$$= 0 \text{ otherwise}$$

$$t = 1, 2, \ldots, N.$$

where, N is the number of households under observation, y_t is the dependent variable, W_t and X_t are vectors of independent variables, α and β are vectors of unknown coefficients, and v_t *and* ε_t are error terms. In this case, it is assumed that there is an underlying stochastic index equal to $X_t \beta + \varepsilon_t$ which is observed only when it is positive. The expected value of y_t is as follows:

$$Ey_t = X_t \beta * F(X_t \beta / \sigma) + \sigma f(z) \quad (3)$$

where, $f(z)$ is the unit normal density, and $F(X_t \beta / \sigma)$ is the cumulative normal distribution function. Therefore, the expected value of y being above the limit, referred to as $y*$ is $X_t \beta$ plus the expected value of the truncated normal error term.

$$Ey_t* = E(y_t | y_t > 0) = X_t \beta + \sigma f(z)/F(z) \quad (4)$$

Therefore, the expected level of SFM strategies computed as an index for all the sampled households, Ey_t can be expressed as a product of the expected value conditional upon having at least some practice, $Ey*$ and the probability of implementing more or intensifying SFM practices, $F(z)$.

The elasticities for continuous variables are estimated by decomposing the effect of a change in an explanatory variable on a dependent variable (McDonald & Moffitt, 1980). This implies that the total change expected in y is decomposed into two: (a) the change in y of those households above the limit, weighted by the probability of being above the limit; and (b) the change in probability of being above the limit, weighted by the expected value of y if above the limit which is expressed as:

$$\delta Ey/\delta t = F(z)(\delta Ey*/\delta X_t) + Ey*(\delta F(z)/\delta X_t) \quad (5)$$

TABLE 1 Demographic; resource endowments and farming practices among adopters and non-adopters during 2016–17 season

	Inorganic fertilizer (kg)				Organic manures (kg)				Legume cropping (% land)			
	Non-adopt (n = 24)		Adopter (n = 214)		Non-adopt (n = 104)		Aadopter (n = 134)		Non-adopt (n = 65)		Adopter (n = 173)	
	Mean	[95% CI]	Mean	[95% CI]	Mean	[95% CI]	Mean	[95% CI]	Mean	[95% CI]	Mean	[95% CI]
Demographic												
H_{AGEH}					46	[43 50]	48	[46 51]				
H_{EDUH}	4.8	[3.4 6.2]	5.9	[5.4 6.4]	5.4	[4.7 6.1]	6.1	[5.5 6.7]	4.9	[4.1 5.8]	6.1	[5.5 6.6]
H_{GENH}	0.4	[0.2 0.6]	0.5	[0.5 0.6]	0.5	[0.4 0.6]	0.6	[0.5 0.7]	0.5	[0.4 0.6]	0.5	[0.5 0.6]
H_{DEPR}					1.9	[1.6 2.3]	1.6	[1.3 1.9]	2.7	[2.3 3.0]	3.0	[2.8 3.3]
Resource endowment and income												
H_{TLU}					0.3	[0.1 0.5]	0.7	[0.4 1.0]				
H_{INCC}	30	[0.0 62]	68	[42 94]	57	[25 90]	69	[35 104]	61	[12 110]	65	[38 92]
H_{INCL}	1.4	[0.0 4.3]	7.7	[4.6 10.7]	4.0	[1.3 6.8]	9.4	[4.9 13.8]				
H_{INCR}	0.0	[0.0 0.0]	2.5	[0.0 5.3]	5.0	[0.0 10.8]	0.1	[0.0 0.2]				
H_{COMM}					0.1	[0.0 0.1]	0.2	[0.1 0.2]	0.3	[0.2 0.4]	0.5	[0.5 0.6]
H_{TRAN}	0.1	[0.0 0.2]	0.1	[0.0 0.1]					0.1	[0.1 0.1]	0.1	[0.1 0.2]
H_{IMPL}	2.0	[1.6 2.4]	2.1	[1.9 2.2]	1.8	[1.6 2.0]	2.3	[2.1 2.4]	1.7	[1.5 1.9]	2.2	[2.0 2.4]
H_{WEAI}	0.25	[0.15 0.35]	0.24	[0.2 0.28]	0.26	[0.2 0.3]	0.23	[0.18 0.29]	0.16	[0.1 0.22]	0.28	[0.23 0.33]
H_{GMEM}									0.3	[0.2 0.5]	0.4	[0.3 0.4]
Farm configuration and practices												
H_{PLOT}	1.6	[1.3 1.9]	2.2	[2.0 2.3]	1.9	[1.7 2.1]	2.2	[2.1 2.4]	1.6	[1.4 1.7]	2.3	[2.1 2.5]
H_{HACT}	0.6	[0.5 0.8]	1.0	[0.9 1.1]	0.8	[0.7 0.9]	1.0	[0.9 1.2]	0.7	[0.6 0.8]	1.0	[0.9 1.2]
H_{WILE}	0.2	[0.1 0.4]	0.4	[0.3 0.5]								
H_{CROP}	1.9	[1.6 2.3]	2.3	[2.1 2.4]	1.9	[1.7 2.1]	2.5	[2.3 2.7]	1.4	[1.2 1.5]	2.6	[2.4 2.8]
H_{CROT}	0.5	[0.3 0.7]	0.7	[0.7 0.8]	0.6	[0.5 0.7]	0.8	[0.7 0.9]	0.3	[0.2 0.5]	0.8	[0.8 0.9]
H_{ORGA}	196	[0.0 401]	172	[131 213]	100	[81 119]	310	[244 376]	75	[26 124]	212	[158 266]
H_{FERT}	107	[96 119]	107	[96 119]			95	[81 109]	82	[60 105]	103	[89 116]

Note: CI = confidence interval; H_{AGEH} = age of household head (years); H_{GENH} = Gender of the household head (1=male, 0=female); H_{EDUH} = formal education of the HH (years); H_{DEPR} = Dependency ratio (age 16-65/(16<age>65); H_{TLU} = Tropical livestock units; H_{INCC} = annual income from cash crops (US$); H_{INCL} = annual income from livestock (US$); H_{INCR} = annual income from natural resources (US$); H_{COMM} = communication index; H_{TRAN} = transport index; H_{IMPL} = farm implements index; H_{WEAI} = women empowerment in agriculture index; H_{GMEM} = group membership (1=yes, 0=no); H_{PLOT} = number of plot fragments; H_{HACT} = farm size (hectares); H_{WILE} = hectares under legume (%); H_{CROP} = number of crops; H_{CROT} = crop rotation (1=yes, 0=no); H_{ORGA} = organic manure applied (kg); H_{FERT} = inorganic fertilizer applied (kg).

The elasticity of probability, $F(z)(\delta Ey^*/\delta X_t)$, indicates how a variable affects the probability of implementing the SFM technique. The elasticity of conditional level, $Ey^*(\delta F(z)/\delta X_t)$, indicates how a variable affects the intensification level given that farmers applied inputs or planted legumes. The unconditional elasticity, $\delta Ey/\delta t$, is the sum of the two which indicates the overall responsiveness of the household to a particular variable in the application of the SFM.

The model was estimated in STATA (StataCorp, 2017).

1.3 | Data sources, variables and hypotheses

A one-off household survey was conducted to collect primary household socioeconomic and farming activity data for one calendar year. Prior to the household survey, a review of literature and the reports from the projects implemented in the area was done to get an overview of SFM research. A structured questionnaire was then administered by a team of interviewees who had academic qualifications in agriculture, rural development or natural resource management. After receiving training for 2 days, they pretested the questionnaire and were under supervision of the first author during the entire interview process.

The SFM *choice* was captured by asking whether a farmer used the practice while the *intensity* as the amount of inputs (inorganic fertilizer, organic manure) used in the 2016–2017 growing season and the amount of land planted with legumes, predominantly groundnuts (*Arachis hypogaea* L.), over a 5-year period (2012–2017). Measurement was easy for inorganic fertilizers as farmers access fertilizers in 50kg bags and for those that shared (as is mostly the case with subsidy), the stated proportions were used as divisor. To estimate the total fertilizer applied, a summation of the basal dressing—mostly a 23N:21P:0K + 4S (nitrogen, phosphorus and sulphur) fertilizer and top dressing—mainly 46N UREA (nitrogen) was computed. Organic manures comprised mostly of farmyard manure and household refuse. The quantities applied were estimated from either size of landfill or the transport used. Mostly, manures were transported on head and shoulders using 50 kg bags and 20 litter buckets and, in a few cases, using oxcarts. Unlike fertilizer and manure, the area under legumes was estimated as the size of the plots on which legumes grew, averaged over a 5-year period. Despite attempts to use land equivalent ratios and farmers estimates, it is still difficult for smallholder farmers to assess the land equivalence for each of the crops in an intercrop. Hence, we used the raw plot sizes and controlled for intercropping using the number of crops grown.

A desk review of literature on agricultural innovation adoption was done to identify factors that explain the variation in adoption of SFM by smallholder subsistence farmers (Doss, 2006; Pattanayak, Mercer, & E., Sills O., E., Yang, J.-C., & Cassingham, K., 2002). The factors scoped include the households' resource status, the farm characteristics and the farming practices are described Table 1. Dependency ratio was calculated as the ratio of non-working individuals (children 0–15 years and elderly > 65 years) to working age group (16–64 years). Typical of sub-Saharan Africa, the population is largely younger, and it is assumed that an increasing dependency ratio could significantly affect household labour allocation.

The WEAI was constructed using the Alkire–foster method which gives a rating of between 0 and 1 if a woman is involved in the household decision-making (Alkire et al., 2012). The WEAI was calculated from women's involvement in 3 of the 5 decision domains: production, resources and income but not leadership and time. Data on leadership in terms of group membership and public speaking as well as data on workload allocation and time spent on leisure were not captured. A higher WEAI is indicative of higher social and economic empowerment of women in the households. The decision on production was an average contribution to decisions on food crops, cash crops and livestock; resources included decisions on farm and household equipment; and income included decisions of sale of farm produce and marketing. We used the following domain weights to compute the aggregate WEAI: production (0.1), resources (0.07) and income (0.2).

Data on different livestock species were converted into standard livestock units (LUs) using nutritional and feed requirement factors for Africa (Chilonda & Otte, 2006). The communication, transport and farm items such as radios, bicycles and hoes were broadly standardized into monetary indices using the numbers owned and the prevailing market prices. Plot sizes were measured using the global positioning system (GPS).

2 | RESULTS

Inorganic fertilizer usage in the study region was widespread, yet amounts varied greatly. Among the surveyed farming households, 90% applied on average 106 kg (± 42 standard deviation [SD]) inorganic fertilizer during the 2016–2017 growing season (Table 1). Almost one-third of the households applied < 50kg, 28% applied 50–100 kg, 20% 100-200kg, 6% 200–300 kg while only 3% applied > 300 kg of fertilizer. More than half of the households (55%) applied organic manures, which included mostly farmyard and household waste. Out of the 55%, 16% applied < 100 kg, 32% applied 100–500 kg while only 7% applied > 0.5 tonnes. The proportion of farmers that planted legumes was 72%. The average amount of land under legumes for only those that planted was 0.45 ha (± 0.64 SD).

TABLE 2 Double-hurdle estimates of the probability to apply inputs or plant legumes and intensification

| | Inorganic fertilizer (kg) | | | | Organic manure (kg) | | | | Legume land (ha) | | | |
| | Apply | | Intensity | | Apply | | Intensity | | Apply | | Intensity | |
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
H_{AGEH}	0.01	0.01	1.03	0.99	0.01	0.01	1.52	1.13				
H_{EDUH}	0.07*	0.04	7.42*	4.11	0.02	0.03	12.17**	5.40	0.083**	0.04	−0.013	0.01
H_{GENH}	0.53*	0.29	−31.22	32.93	0.16	0.20	−21.56	33.71	0.067	0.25	−0.006	0.08
H_{LABA}	−0.01	0.09	19.30**	8.10					−0.087	0.11	0.011	0.02
H_{DEPR}	0.01	0.08	−20.10**	9.81	−0.13**	0.06	−17.39	11.57				
H_{TLUN}					0.01	0.07	10.90**	5.40				
H_{INCC}	5E-04	9E-04	0.12**	0.05	−4E-04	5E-04	0.03	0.06	−0.002**	7E-04	14E−005	1E−04
H_{INCL}	0.02**	0.01	−0.27	0.41	0.01	0.01	−0.06	0.53				
H_{INCO}	8E-04	6E-04	−0.14**	0.06								
H_{INCR}	1.75	1.08	−0.16	0.29	−0.13*	0.07	18.46	27.605				
H_{COMM}									−0.096	0.38	0.170*	0.10
H_{TRAN}	−2.55***	0.99	88.12	91.501	0.74	0.69	21.46	78.09	−1.902**	0.91	0.048	0.21
H_{IMPL}					0.13	0.11	35.56**	16.75	0.435***	0.17	−0.030	0.04
H_{WEAI}	0.16	0.69	43.88	71.32	−0.64	0.50	−179.57**	89.48	2.305***	0.9	0.154	0.20
H_{GMEM}									−0.203	0.25	0.042	0.09
P_{PLOT}	0.50***	0.19	62.64***	14.37	0.11	0.11	18.72	15.89	0.316**	0.16	−0.290***	0.07
P_{HACT}	0.82***	0.32	−12.18	16.74	0.05	0.14	−39.45**	19.16	0.648**	0.32	0.977***	0.03
P_{CROP}					0.28***	0.09	−10.93	14.09	1.052***	0.18	0.183***	0.04
P_{ROTA}					0.42**	0.21	100.21**	44.28	1.349***	0.24	−0.515***	0.09
P_{FERT}					25E−04**	12E−04	−0.11	0.20	2E−005	16E−04	1E−004*	4E−04
P_{ORGA}	−5E-04	3E-04	−0.05	0.05					−0.001	7E−04	−24E−005	1E−04
_cons	−1.27*	0.76	−196.10***	75.43	−1.35	0.49	−30.96	92.105	−4.187***	0.62	−0.256*	0.13
Log pseudolikelihood	−952.80				−1246.70				−16.18			
Wald Chi^2	44.70				30.90				109.80			
Prob>Chi^2	0.0002				0.006				0.000			

Significant at: $p < .1$*, $p < .05$**, $p < .01$***

Note: Coef. = coefficient; s.e. = standard error; H_{AGEH} = age of household head (years); H_{EDUH} = formal education of the HH (years); H_{GENH} = Gender of the household head (1=male, 0=female); H_{DEPR} = Dependency ratio (age 16-65/(16<age>65); H_{TLUN} = Tropical livestock units; H_{INCC} = annual income from cash crops (US$); H_{INCL} = annual income from livestock (US$); H_{INCR} = annual income from natural resources (US$); H_{COMM} = communication index; H_{TRAN} = transport index; H_{IMPL} = farm implements index; H_{WEAI} = women empowerment in agriculture index; H_{GMEM} = group membership (1=yes, 0=no); H_{PLOT} = number of plot fragments; H_{HACT} = farm size (hectares); H_{CROT} = crop rotation (1=yes, 0=no); H_{CROP} = number of crops; H_{WILE} = hectares under legume (%); H_{WILLE} = hectares under legume; H_{ACT} = farm size (hectares); H_{ORGA} = organic manure applied (kg); H_{FERT} = inorganic fertilizer applied (kg).
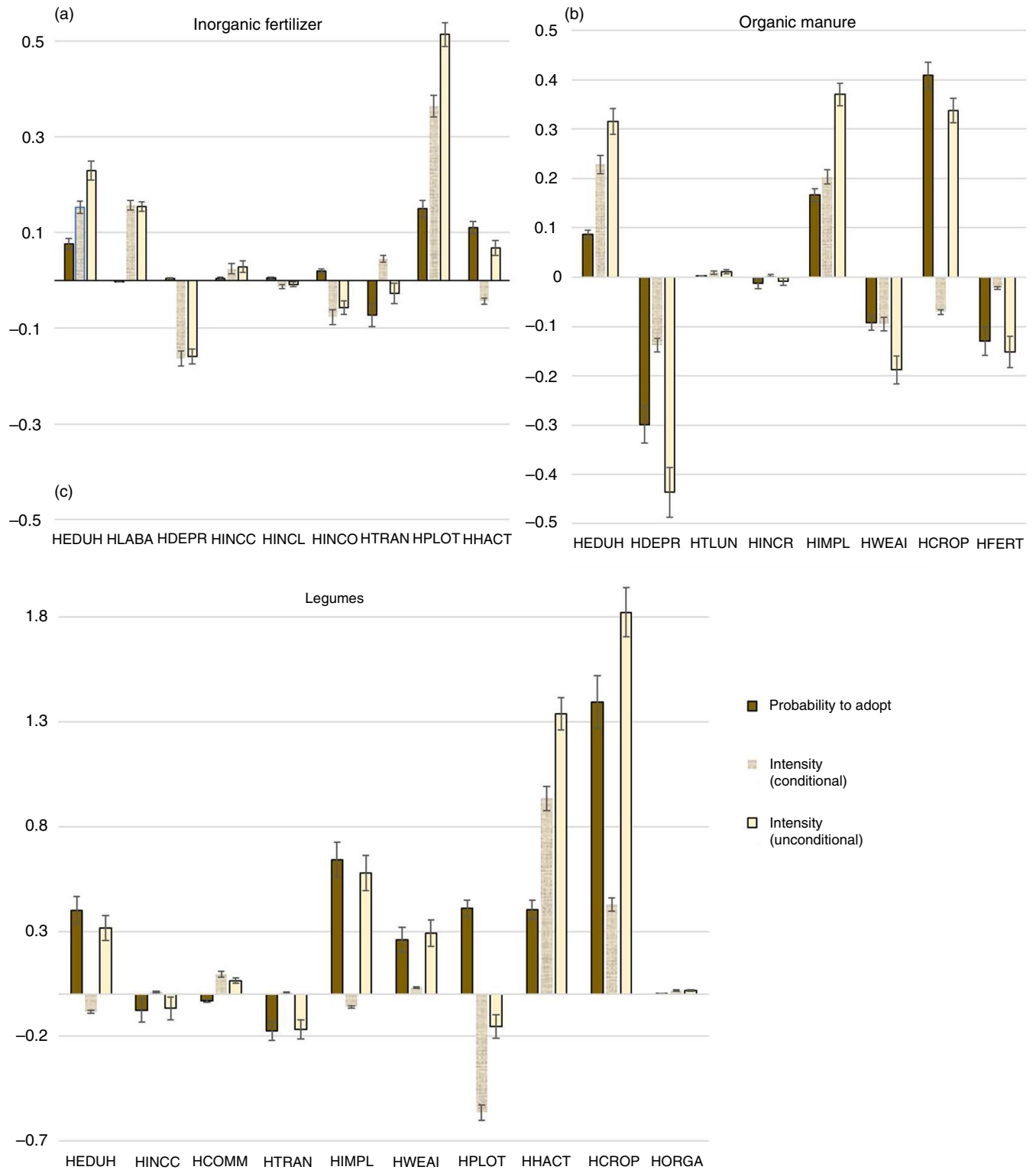
FIGURE 2 Elasticities for the probabilities to adopt and intensify (a) inorganic fertilizers, (b) organic manure, and (c) allocate land to legumes. HEDUH = formal education of the HH (years); HLABA = Household available labour; HDEPR = Dependency ratio (age 16-65/(16<age>65); HTLU = Tropical livestock units; HINCC = annual income from cash crops (US$); HINCL = annual income from livestock (US$); HINCO = annual income from other sources (US$); HCOMM = communication index; HTRAN = transport index; HIMPL = farm implements index; HWEAI = women empowerment in agriculture index; HPLOT = number of plot fragments; HHACT = farm size (hectares); HCROP = number of crops; HORGA = organic manure applied (kg); PFERT = inorganic fertilizer applied (kg)

Descriptive statistics show that adopters had a slight advantage over non-adopters in most of the factors considered (Table 1). As illustrated by the respective confidence intervals, adopters of inorganic fertilizers compared to non-adopters had significantly more plots ([2.0–2.2] versus [1.0–1.9]), larger land sizes ([0.9–1.1 ha] versus [0.5–0.8 ha]) and the majority practised crop rotation ([70%–80%] versus [30%–70%]). Adopters of organic manures and legumes also grew more crops and had more agricultural implements. In addition, adopters of legumes had more communication facilities and applied more organic manure ([158–266 kg] versus [26–124 kg]).

Table 2 and Figure 2 present the results for the double-hurdle model. For each SFM practice, the first table column and first figure bars show the estimated coefficient and the elasticity of probability that the household used an SFM practice. Similarly, the third column and the second bar show the estimated coefficient and elasticity for those above zero. The third bar shows the summed up unconditional elasticity.

The sample of 238 farmers who were interviewed was representative of a community of 600 family farms who are smallholders owning < 2 hectares of land and are located in the Rift Valley escarpments of Malawi. These results therefore can be used to identify reasons why some farmers despite being in the same location, did not adopt SFM technologies practised by their neighbours. In general, the results reveal households and plots factors that significantly differentiate the discrete and intensification choices among households in the five study villages (Table 2).

The findings show that those that used SFM options differ in terms of labour availability, women empowerment and other resource endowments. The results on dependency ratio and gender are strengthened by controlling for resource endowments such as education, income and land holding, whose potential effects are discussed below. In terms of level of responsiveness, inorganic fertilizer and organic manure usage are quite inelastic (elasticity < 1) to respective unit percentage changes in the household and plot attributes. The larger response is expected from differences in usage of legumes.

Notably, gender has a differentiated association with usage of manure and legume crops. Increasing women bargaining power tends to be associated with decreased amounts of organic manure a household applies but tends to increase the probability for farmers to plant legume. A percentage point increase in WEAI is associated with 0.1 percentage point decrease in the quantity of manure applied by those already applying. Considering the current low levels on women empowerment, averaging 0.23 for practising farmers, increasing this to 0.5 where a woman contributes to decisions in household would represent a 117% point increase. This would, all other factors being equal, be associated with 11.7% point increase in manure quantity, translating into 36 kg additional

manure applied. On the other hand, a percentage point increase in WEAI is associated with 0.2% point increase in the probability that non-participating households would grow legumes. Increasing WEAI from the current low level of 0.16 to the desired 0.5, ceteris paribus, would lead to 42.5% point increase in probability for legume cropping.

Households that have a relatively larger household labour pool increase their capability to apply large quantities of fertilizer. However, higher numbers of dependant individuals compared to working members in a household have a decreasing influence on fertilizer intensification. A percentage point increase in available labour is associated with an increase in quantity applied by current users by 0.2% but reduces the probability by 0.13%. Increasing dependency ratios also decreases the probability to apply organic manure. For households with higher levels of women involvement in decision-making, the level of organic manure application tends to decrease while the area under legume cropping increases.

The variables that we controlled for significantly influenced SFM usage. For instance, increasing farm sizes increases the probability to grow legumes and the use of inorganic fertilizers, but has a negative impact on the extent of inorganic fertilizer usage by current users. A percentage point increase in number of plots (fragmentation) is associated with a 0.4% higher probability to grow legumes. On the other hand, further plot fragmentation is associated with a reduction in the area under legume by 0.56% (Figure 2c). The results also show that a 1% increase in the level of education would be associated with a 0.22% increase in quantity of manure applied, ceteris paribus.

3 | DISCUSSION

Our empirical results corroborate earlier observations that farmers, farmlands and the technology preferences are heterogenous (Tittonell, Vanlauwe, de Ridder, & Giller, 2007). Much as opportunities exist to support farmers to cross the two hurdles by focusing on drivers with similar influence on both discrete choice and intensify decisions, no single driver is consistently associated with the two decisions for all the three technologies. There are trade-offs in terms of either opposing factor effects on one or two of the SFM practices. In absolute terms, the technology usage was found to be less responsive with most factors having elasticities closer to zero than to 1 in magnitude (Figure 2).

3.1 | Women empowerment shaping uptake of legume and manure

Bearing in mind that in most of rural Malawi promotion of gender equality and migration of men to town has led to increasing influence by women on household decisions (Anglewicz, 2012),

it was vital to examine their role in managing soil fertility. Our results show that increasing women empowerment in decision-making is associated with higher a probability to plant legumes but much lower likelihood for manure intensification. The negative influence on manuring is consistent with anecdotal observations by Mustafa-Msukwa et al. (2011) who reported that women, much as they want to apply manure, find preparation and transportation to be exceedingly labour demanding.

The positive influence on the decision to grow legumes is supported by the long-standing view that legumes, including groundnuts, are 'women crops' (Nakazi et al., 2017; Orr, Kambombo, Roth, Harris, & Doyle, 2015). Although our results support this, other findings in the region show that for the main legume grown in the area, groundnuts, households headed by women tend to allocate less land to it (Waldman, Ortega, Richardson, Clay, & Snapp, 2016) and are 20% less productive (Joe-Nkamuke et al., 2019) than their male-headed counterparts. The latter study, despite establishing a convincing empirical evidence, did not account for the influence of women in male-headed households and used data from regions where legumes are grown as cash crops such as the Mchinji District of Malawi (Joe-Nkamuke et al., 2019).

Noteworthy, the marriage system in our study region is matrilocal, and the role of women in household decision-making is quite consequential. Studies show that women-headed households tend to have more information about legumes than male-headed ones (Snapp et al., 2002), and female farmers have great preference to integrate legumes in their maize farms than male ones (Pircher, Almekinders, & Kamanga, 2013). This is usually the case when legumes are grown for subsistence needs and are intercropped with maize. When they enter the market and become profitable, they shift status from being subsistence to commercial. Then, men's participation increases but largely relies on women's knowledge for efficient management (Nakazi et al., 2017). However, the inclusion of women's role using WEAI even in male-headed households and its influence on both, the probability to grow legumes and their productivity, requires further scrutiny.

Since the SFM technologies are generally promoted as an integrated basket, gender would have disproportionate impact on usage of organic manures and legumes. Yet, social aspects such as gender may not be an important driver for a particular SFM technique, but could have indirect influence through its influence on complimentary or alternative technologies (Doss & Morris, 2000). A gender-segregated study in Ghana showed that the propensity to apply fertilizer by women-headed households was positively associated with farming experiences, whereas for male-headed counterparts, income from other sources reduced investment in fertilizer (Mensah et al., 2018). Gender is invisible and intersects with other factors. For instance, women's adoption of practices that require physical assets such as organic manure is premised on them having access to resources first (Mustafa-Msukwa et al., 2011).

3.2 | Labour dependency ratio and soil fertility investment decisions

In southern Africa, transport facilities are often limited (Amede et al., 2014), and with the usual way of transporting heavy products on people's heads and shoulders, bulky nutrient sources such as manure are bound to be constrained by labour allocation decisions. It is therefore not surprising that the increasing number of dependants, of whom the majority are young, lowers the likelihood of organic manure application and limits the quantity of fertilizer applied.

Our descriptive statistics results show that the dependency ratios for non-adopters of organic manure range (at 95% confidence interval) from 1.6 to 2.3 while for adopters from 1.3 to 1.9 (Table 1). Though statistically not significantly different, the empirical results from the double-hurdle model show that a percentage point reduction in dependency ratio would be associated with a 3% increase in probability to apply manure and 0.16% increase in quantity of fertilizer applied by the household (Figure 2).

This dependency burden on investment is consistent with a similar study in Ghana by Adeoti (2008) who found that households with high dependency ratio made significantly fewer investments in water management than adopters. An increase in the number of non-working household members as compared to those working is indicative of lower labour availability for productive economic activities. A high dependency ratio apparently discouraged manure adoption, which requires labour for preparation, transport and application. The increasing dependency ratio is also a hindrance to purchase more fertilizer. Archetypically, households with high dependency tend to spend more on food and other household necessities at the expense of re-investing in farm productivity (Tadesse & Belay, 2004).

In the light of these findings, reducing the dependency ratio is a desirable policy action but a significant change in the demographic structure to shift the dependency ratio may take a generation. Nonetheless, our study contributes to the ongoing debate on addressing the challenges of a potential demographic dividend. If left unresolved, high dependency ratios may hinder investments and lead to economic stagnation, especially for smallholder farmers as is the case in the majority of sub-Saharan Africa (Hadley, Belachew, Lindstrom, & Tessema, 2011).

4 | CONCLUSION AND POLICY IMPLICATIONS

This study explored the implications of women empowerment and dependency ratio on households' capacity to undertake SFM using the double-hurdle model, thereby entangling two important decision hurdles that farmers have

to cross. Currently, there is low but wide usage of SFM options. Most importantly, the results have reinforced the assertion that improved women's bargaining power favours legume cropping. However, there are trade-offs in that when women are empowered, manure application is constrained. Addressing the social and labour challenges that women face in manuring could offer greater opportunities for integrated SFM.

The results also highlight that preference for SFM practices is strongly influenced by the demographic dividend. We found that, with a wide-based population pyramid, there are more dependents per worker which affects labour allocation to manuring and erodes the positive influence of increasing labour on fertilizer application. Managing land in these ecologically fragile landscapes with hand-held tools requires judicious use of labour.

Much as opportunities exist to support farmers to cross the two hurdles by focusing on drivers with similar influence on both discrete choice and intensify decisions, no single driver is consistently associated with the all decisions for all the three technologies. There are trade-offs in terms of either opposing factor influence on one or two of the SFM practices. In absolute terms, the technology usage was found to be less responsive, with most factors having elasticities closer to zero than to 1 in magnitude (Figure 2).

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