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Farming systems and Conservation Agriculture: Technology, structures and agency in Malawi

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ABSTRACT

Conservation Agriculture (CA) is advocated as an agricultural innovation that will improve smallholder famer resilience to future climate change. Under the conditions presented by the El Niño event of 2015/16, the implementation of CA was examined in southern Malawi at household, district and national institutional levels. Agricultural system constraints experienced by farming households are identified, and in response the technologies, structures and agency associated with CA are evaluated. The most significant constraints were linked to household health, with associated labour and monetary impacts, in addition to the availability of external inputs of fertiliser and improved seed varieties. Our findings show that such constraints are not adequately addressed through current agricultural system support structures, with the institutions surrounding CA (in both Government extension services and NGO agricultural projects) focusing attention predominantly at field level practice, rather than on broader system constraints such as education and health support systems. Limited capacity within local institutions undermines long term efforts to implement new technologies such as CA. It is vitally important that the flexibility of farmers to adapt new technologies in a locally-appropriate manner is not closed down through national and institutional aims to build consensus around narrow technical definitions of a climate-smart technology such as CA. To enable farmers to fully utilise CA programmes, interventions must take a more holistic, cross-sectoral approach, understanding and adapting to address locally experienced constraints. Building capacity within households to adopt new agricultural practices is critical, and integrating healthcare support into agricultural policy is a vital step towards increasing smallholder resilience to future climate change.

1. Introduction

Climate change in sub-Saharan Africa (SSA) is contributing to increasingly erratic rainfall and prolonged dry spells (Niang et al., 2014), disrupted growing seasons and crop failures (Schlenker and Lobell, 2010). One country that is increasingly affected by this is Malawi, a small landlocked country in SSA with a long history of food insecurity (Vaughan, 1982; Harrigan, 2008; Devereux, 1997; Babu et al., 2018). Agricultural productivity within Malawi for the staple crop of maize has stagnated over the last decade, despite one of the fastest growing and highest population densities in SSA (National Statistical Office, 2015; FAOSTAT, 2017).

Increasing resilience to climate change for Malawi's smallholder farmers is critical to food security. Growing knowledge of current and projected impacts of climate change suggests that agricultural productivity will be constrained further in the future (Challinor et al., 2014). However, it is changes in the broader agricultural system that determine the effectiveness and appropriateness of technological changes (Berre et al., 2014). This is evident when outcomes such as increased yields and improved climatic resilience are investigated under experimental conditions (Steward et al., 2018) but are not easily replicated on-farm. This could be due to a range of factors including competing demands for limited resources; a heterogeneous set of institutional, informational, and structural constraints; and a prioritisation of resource-use efficiency over productivity (Tittonell and Giller, 2013; Whitfield et al., 2015).

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This research uses a case study in Malawi to examine the constraints experienced by smallholder farmers and the potential of Conservation Agriculture (CA) as a technological innovation to alleviate these constraints and improve agricultural productivity. The study takes a holistic approach to CA, discussing the technology, the structures and institutions developed alongside it, and the agency of the farmers who use it.

2. Background context

2.1. A systems approach

Investments in the intensification of African agriculture have focused on field-scale innovations and inputs: the application of inorganic fertilisers and herbicides, hybrid and genetically modified crops, irrigation, mechanisation and alternatives to cereal crops. However, these efforts have largely failed to deliver the wide-scale transformation of agricultural systems and increases in productivity that are associated with the Asian green revolution (George, 2014). Small-scale production in Africa often integrates crops and livestock; cereals are commonly produced for both markets and consumption; and systems are subject to multiple constraints. These all affect the appropriateness of agronomic interventions and counter the conventional logic of 'yields' as an absolute metric of agricultural performance (Berre et al., 2014).

From a systems perspective, there is growing realisation that suboptimal agricultural performance persists under conditions of degraded, nutrient- and organic matter-limited soils (Tittonell and Giller, 2013) and limited water availability; constrained access to inputs, labour and other resources at the household level (Vanlauwe et al., 2014; Denning et al., 2009); weak infrastructures, support systems, and supply chains (Poulton et al., 2006); and limited political voice and agency for marginalised groups within agri-food systems (Shackleton et al., 2015). Although emphasis is placed differently on these constraints from different perspectives, they rarely exist in isolation, and it is this combination of constraints that explains why transformation in small scale African agriculture is so challenging.

2.2. History of agricultural innovation in Malawi

Agricultural extension services in Malawi were developed in the early 1920s by the British Colonial administration to address issues focused on soil erosion (Green, 2009; Beinart, 1984). This led to the heavy emphasis on soil protection and the concept of creating ridges along contours was introduced (Woodhouse, 2009). However, most farmers tended to plant in mounds and there was resistance to ridge making, resulting in very low adoption until 1946, when it was made compulsory (Beinart, 1984). Ridge making, also called traditional or conventional tillage, remains widely practised today, and there is a similar reluctance to shift from this practice to reduced tillage, a key principle of CA, and this is a considerable barrier to its uptake. The colonial government provided information on production and soil conservation measures through extension officers, demonstration plots, and from 1950 'Master farmers' (now known as 'lead farmers') were paid and educated to demonstrate farming techniques to their fellow farmers (Green, 2009). A similar system of extension services has been adopted by Malawi following Independence in 1964.

Current agricultural interventions again address soil conservation in addition to improved productivity. Sasakawa Global 2000 promoted improved seed varieties and fertiliser through a combination of on-farm demonstration plots and the distribution of input packages in pilot areas, and succeeded in improving the resource capabilities and access to technologies that could address yield gaps. However, the assumption that adoption of these technologies would scale-out and be sustained beyond the life of a programme have not been realised, in part because of persistent challenges of access to inputs, the limited reach of supply chains and markets into remote areas, and limited technical support (Smale et al., 2013). Additionally, Ward et al. (2016) find that the provision of packages or subsidies can represent a false incentive for CA adoption and ultimately contribute to disadoption, where farmers revert to their previous practices once promotional activities cease.

2.3. The technology - Conservation Agriculture

CA is a set of land management principles that combines minimum soil disturbance, the maintenance of a permanent organic soil cover, and the rotation or intercropping of cereals with legumes (FAO, 2008). CA has been widely advocated across research and policy spheres in sub-Saharan Africa as a climate-smart agricultural technology that will increase resilience to climate change by both improving the water use efficiency of production and improving soil quality and structure (Wheeler and von Braun, 2013; Lipper et al., 2014). However, the evidence remains inconclusive on the overall net impact of CA, with metanalyses of global field trial data suggesting that incomplete application of the three principles reduces yields (Pittelkow et al., 2014) and that its use on poor draining soils increases vulnerability to waterlogging (Steward et al., 2018). On-farm data is revealing uncertainties relating to the local farming system context, particularly when it comes to comparisons of labour savings (Ngwira et al., 2013; Umar et al., 2012), or pest and disease incidences (Thierfelder et al., 2013). Impacts on labour, gender equality and nutrition have been relatively understudied, with existing evidence pointing to the context-dependent nature of such impacts (Thierfelder et al., 2017). Furthering understanding of the on-farm application of CA within smallholder farmer systems is critical to advocating its future use.

2.4. Structures and institutions surrounding CA

CA promotion in Malawi has, since the 1990s, been driven by third sector organisations, initially Sasakawa Global 2000 and later Total Land Care, Concern Worldwide, World Vision International and the International Maize and Wheat Improvement Centre (CIMMYT) (Dougill et al., 2017). This relatively autonomous activity has become formalised through the National Conservation Agriculture Task Force and the Climate Smart Agriculture Alliance under the direction of Department for Land Resources and Conservation (DLRC) in the Ministry of Agriculture, Irrigation and Water Development (MoAIWD), and is referred to as part of the Ministry of Agriculture's Sector Wide Approach (ASWAP) and Malawi's 2016 National Agricultural Policy, which lists 'promote conservation agriculture' as an explicit strategy. The model for CA implementation in practice is that externally funded projects are run by the third sector organisations for a period of time, alongside government agricultural extension services (hereafter 'extension services'). At the end of the funded projects, the extension services are expected to continue their support of the programme. A range of tools including demonstration plots, lead farmers and farmer schools are used to disseminate information about CA.

2.5. Agency of farmers

Despite its political support and the mainstreaming of CA within the programmes and projects of non-governmental organisations, adoption of CA by farmers has been lower than anticipated (Andersson and D'souza, 2014), and 'disadoption' (where farmers previously practising CA revert to conventional tillage methods) is common (Pedzisa et al., 2015). Factors directly related to agricultural production such as household size, gender, perceptions of labour requirements, the influence of neigbouring farmers, and market accessibility are recognised as influential on farmers' decision making on CA (Van Hulst and Posthumus, 2016; Bell et al., 2018), yet do not fully explain why adoption rates are so low.

It is increasingly recognised that it is a combination of soil and climatic conditions and access to inputs (Andersson and D'souza, 2014), in addition to tillage and crop retention practices, that affect both the labour requirements of the system and its productivity (Vanlauwe et al., 2014). Competing uses for land and maize stovers within mixed farming systems; socio-cultural practices of communal land sharing; and alternative labour opportunities have all been recognised as contextual constraints that can limit the appeal or viability of CA (Andersson and D'souza, 2014). Moreover, critiques about the absence of sustained support and information sharing around CA (Brown et al., 2018a, b), the inequities of access to support, and the unequal burden of labour on women (Giller et al., 2011) have also been associated with some CA programmes.

Given this range of constraints that influence the adoption of CA, we explored the scope to identify constraints that may affect agricultural productivity for smallholder farmers beyond those directly related to the practicalities of cultivation. This enabled the identification of constraints that operate within the farming system as a whole, such as health and education. These constraints, and the ability of CA to alleviate them, are considered through the rest of this paper as follows:

(1) We present the findings of a combination of household surveys and focus groups conducted in three districts of southern Malawi, immediately following the 2015/16 El Niño event by outlining agricultural system constraints as experienced and described by those households.

(2) Drawing on the experiences of households practising CA and those that were not, as well as insight from agricultural extension providers, published literature and a wider institutional analysis, we analyse the compatibility of the technology, structures and agency around CA in relation to farmer-defined constraints.

(3) We conclude by discussing the implications and lessons that can be drawn from the case of CA in the 2015/16 El Niño in southern Malawi for technology-centred agricultural development in Africa.

3. Materials and methods

3.1. Study area and context

Between 2014 and 2016 Malawi experienced unpredictable weather conditions including flooding and prolonged dry spells associated with the El Niño event of 2015/16, one of the strongest on record (NOAA, 2015). The 2015/16 growing season can be broadly described as being associated with the late onset of rains and reduced total rainfall (Fig. 1). The environmental conditions experienced during this time (low rainfall volumes, erratic timing of rains and prolonged dry spells) are predicted to be experienced more frequently by future climate change scenarios (Niang et al., 2014). Owing to its effect on soil structure and moisture retention, these are also conditions to which CA practices are expected to provide increased resilience.

Research took place in August and September 2016 in three districts of southern Malawi: Balaka, Machinga and Thylolo (Fig. 1). These districts are dominated by small scale maize agriculture and CA has been promoted here through both governmental and non-governmental channels over the past 10 years. The structure and responsibilities of agricultural extension services within Malawi is as follows: At district level staff disseminate information from national policies across the district and liaise between districts. The district is divided into smaller areas known as Extension Planning Areas (EPAs) where staff co-ordinate between the district and manage staff within sections – the smallest administrative areas, where staff work directly with farmers. Sections can be comprised of several villages. For this study, an EPA was selected within each district where both CA and non-CA is practised, and within each EPA two sections were selected (six in total). Sections were selected where an Agricultural Extension Development Officer (AEDO) was present, so that farmers had access to similar levels of formal agricultural extension advice. Sections were selected where CA had been practised for at least 3 years, given that yield improvements have been shown to improve with time (Thierfelder et al., 2015a) and therefore responses to El Niño were more likely to be detected. EPA and section selection were based on interviews with district and EPA staff held prior to the field research, and the descriptions below are based on these discussions and locally kept EPA records of famer participation.

CA has been promoted by Total Land Care for approximately three years within the two sections selected for study in Machinga District, and has been adopted by a small proportion (1.6 %) of the roughly 2,600 farming households in the two sections. Agriculture is maize dominated with only a small proportion of farms keeping livestock (mainly goats). Fishing on Lake Chilwa is also an important source of income for many households. The two sections within Balaka District have a longer history of CA promotion, due to the introduction of CA in 2007 as part of a five-year programme by the Food and Agriculture Organization of the United Nations (FAO). Four other NGOs are known to have promoted CA here in the last 10 years, and this is reflected in the higher proportion of CA adopters 5.5 %) within the two sections. Agriculture is the main livelihood activity, and there are few opportunities for other income generating activities. Within the two sections in Thyolo, it was estimated that 4.2 % of farmers practised CA with Trees (CAWT), initiated by a World Agroforestry Centre (ICRAF) programme in 2008. Agricultural production here is diverse and mixed livestock-crop systems are common. There are opportunities for additional household income through work on tea and tobacco plantations.

3.2. Methods

Throughout this research, engagement with actors involved at multiple levels within the agricultural systems took place. This was initiated in 2014 through a workshop with representatives of 18 governmental and non-government organisations involved in the promotion of CA in Malawi. Using group exercises and focus groups (Dougill et al., 2017) the workshop mapped the activities and organisational partnerships that comprise the institutional landscape around CA, and highlighted capacities and bottlenecks associated with its promotion and uptake at a national level. A similar national level workshop was then conducted in 2016 to introduce and discuss this study with stakeholders prior to expanding the research to district and section level.

Key informants were selected based on their current involvement with CA in the study area. This led to limited key informants from NGOs (n = 3) and higher representation of government agricultural extension officers at district, EPA and section level (n = 17). Semi-structured interviews were conducted with all key informants. The interviews were structured to cover three main categories – the history and delivery of CA within the area, the impact of the El Niño on harvests, and challenges and opportunities experienced by smallholder farmers and within the extension/NGO services. To ensure anonymity key informant interviews were coded according to their administrative level and assigned a number.

Within each section a focus group was conducted with separate groups of self-defining CA and non-CA farmers, each lasting approximately four hours. Focus groups consisted of 6–12 male and female farmers who volunteered to participate, and 12 focus groups were conducted in total. Focus groups were coded by section (1–6) and by farmer group: CA (CA) or non-CA (NCA). Participants were first asked to describe a typical year's seasonal calendar, including at which points they would expect rain and what activity they would be conducting. Following this, they were asked to consider each of the stages that they had described on the seasonal calendar, and to describe the factors that would constrain their agricultural productivity at each of these stages. Finally, they were asked to rank the factors based on their overall influence for the whole year. The process was repeated for 2015/16, and then for 2014/15 to gain an understanding of the interaction between farming system constraints and the spectrum of weather conditions that incorporates an El Niño event. The findings captured through the focus groups were used to inform and guide the development of a household questionnaire survey, designed to gather details of agricultural practice

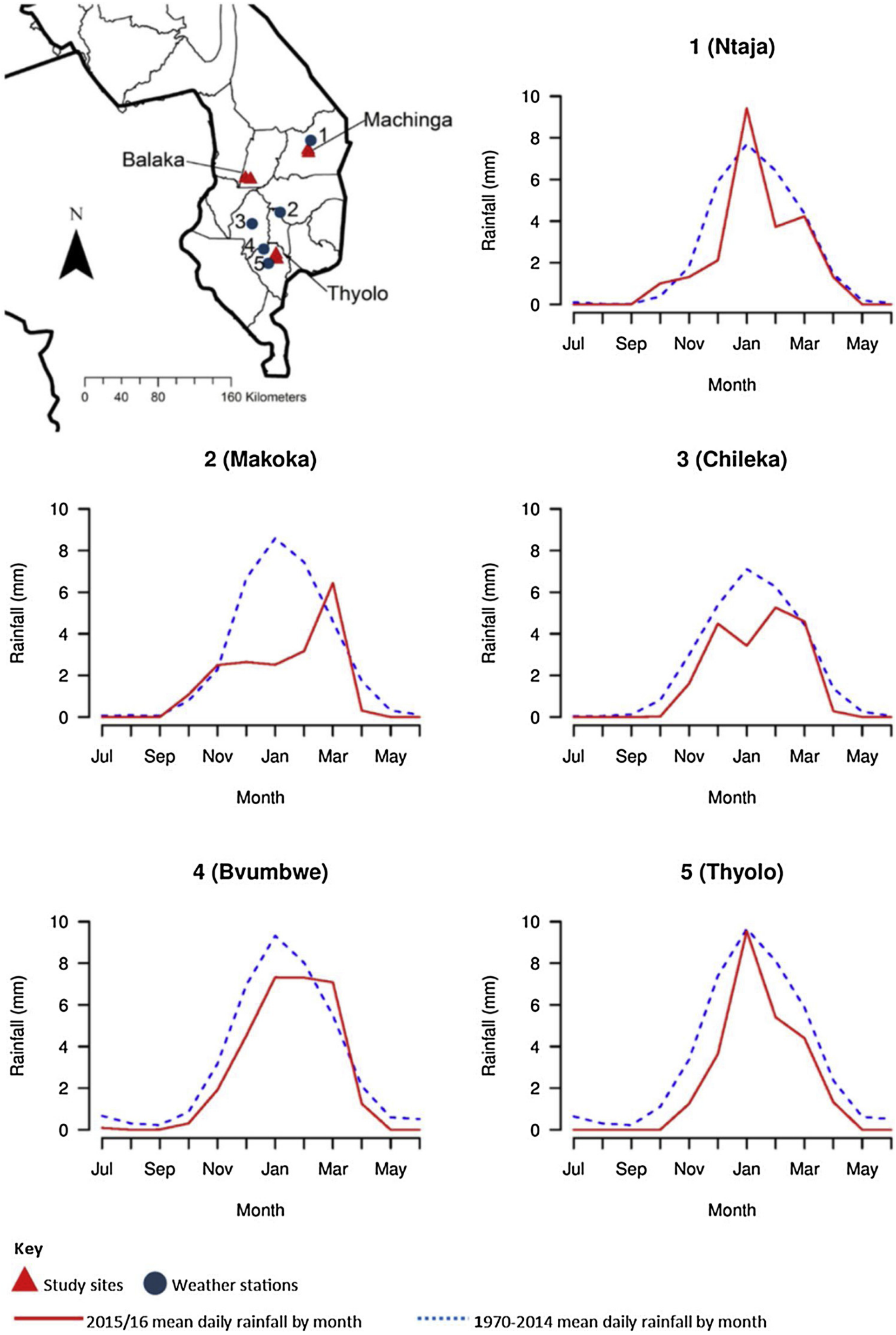

Fig. 1. Mean daily rainfall by month for 2015-16 (red solid line) and the 1970-2014 average (blue dotted line), for 5 Malawi Meteorological Services stations (indicated by the blue circles on map) in closest proximity to the survey sites (red triangles). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

and livelihood conditions. The survey was conducted in all six sections and considered the previous farming season (2015/16). Sample size was constrained by numbers of available practising CA farmers, and for the final analysis both sections in Thyolo were excluded due to insufficient CA farmer availability. The sample population for CA farmers consisted of all those who considered themselves to practice CA, whether or not they learned through official training programmes. Therefore farmers self-identified as CA farmers, and this classification was checked against their answers for their cultivation practices. Focus group discussions illustrated that farmers considered CA to be the application of one or more of the three pillars of CA, and therefore those farmers who did not use any of these on their farms were removed from analysis. In total 201 questionnaires were completed; 97 non-CA farmers, and 104 who practised CA.

Following a grounded theory approach, qualitative data were coded across focus groups and across key informant interviews according to the constraints, opportunities and benefits experienced throughout the farming year using NVivo software (QSR International, 2015). Descriptive and inferential statistics were performed in R 3.3.2 (The R Foundation for Statistical Computing, 2016). Households were described using wealth indicators (clothing, building material and assets (Hargreaves et al., 2007)) into five wealth categories (much worse off, worse off, average, better off and much better off). Chi-squared and Fisher's exact tests were used to test for associations between these categories and variables including gender, type of farming and type of support.

In May 2018, results were discussed with the project participants, including all levels of extension services, NGOs and within two National conferences, the National Adaptation Symposium (30-31st May) and the CSA Policy Dialogue (June 7th). Insights from these meetings were added to the qualitative analysis described above.

4. Results

Household survey data indicated that most farmers cultivated several plots of land (average 2.33, max = 7, min = 1) which have an average size of 0.4 ± 0.27 ha (min = 0.002 ha, max = 2.02 ha). The majority (83 %) of the 104 CA farmers who responded to the household questionnaire also cultivated land under non-CA. In total there were 346 cultivated plots of land, of which 112 (32 %) were cultivated under CA. In 93 of these plots (83 %) all three CA principles were applied (zero tillage or planting basins; mulch or cover crops; intercropping, alley cropping or crop rotation).

4.1. Constraints experienced by farmers

Focus group discussions revealed a variety of farm production constraints manifesting at different points across farming seasons. Comparison of seasonal calendars and associated constraints across the focus groups indicated that variability between seasons and between CA and non-CA farmers was minimal, therefore constraints for a 'typical' year (described as 2013/14) are illustrated in Table 1. These were the top 10 most frequently mentioned constraints across the farming calendar, and where they were mentioned within the seasonal calendar by at least one focus group.

4.1.1. Health and labour

The predominant story told by farmers was poor household health which reduced labour availability and placed constraints on family farms that are highly dependent on household labour across the farming calendar. Across all farming households, an average of 23.2 days of labour were lost in 2016 due to illness and a further 7.6 days were spent attending funerals (Table 2). Land preparation, planting, weeding, harvesting, and storage are highly labour intensive in these low input small scale production systems, and at critical periods loss of household labour to illness can translate directly into negative impacts on production.

While the average household size was 5.6 people, average family labour available was 4.4 people, and child labour accounted for the largest amount (average female labour = 1.2, average male labour = 0.9, average child labour = 1.4). Given that farming in Malawi is predominantly the responsibility of women, child illnesses can be particularly important in terms of farm labour lost. Commonly cited illnesses such as diarrhoea and malaria could be reduced through treatment of water and use of mosquito nets, however there are currently limitations in access to appropriate health resources across the study communities. Chronic illness such as HIV/AIDS and TB are prevalent; long term, debilitating illnesses can have particularly negative impacts throughout the farming season, reducing the productivity both of those affected and other household members who need to provide care.

Table 2
Reasons for loss of labour (Household survey, n = 201).

Reason	Respondents (%)	Average number of days lost
Personal illness	69	14.4
Other household members unable to work due to illness	32	15.3
Looking after sick family members	54	10.9
Funerals	48	7.6
Too hungry to work	40	10.6
Piecework	57	11.9
Community work	36	5.2
Climate conditions	37	7.4
Lack of access to tools	12	5.5

4.1.2. Availability of inputs

Availability and access to inputs (fertiliser, pesticides and seeds) were considered to be a persistent constraint. Due to problems with the affordability of inputs sold on the open market, many farmers were dependent on the Malawi Government's Farm Input Subsidy Programme (FISP) to obtain fertiliser and seeds. The household survey indicated that 91 % of farmers used fertilisers (NPK [nitrogen, phosphorus and potassium] and urea). These were widely used, with fertiliser applied to 78 % of CA and 75 % of non-CA plots. On average, farmers used 89 kg ha^{-1} of urea on non-CA plots, 116 kg ha^{-1} on CA plots, and for those farmers who used it across CA and non-CA plots 67 kg ha^{-1}. Use of NPK was similar (92 kg ha^{-1}, 111 kg ha^{-1} and 67 kg ha^{-1} respectively). This is considerably short of the 123.5 kg of fertiliser recommended per hectare by extension services, and reflected by 72 % of farmers indicating that they had problems obtaining inputs. The most commonly cited problem was a lack of capital (60 % of respondents), while issues with FISP such as poor timeliness of inputs at the distribution points and long queues were cited by 20 % of respondents. Where input limitations result in reduced productivity, the potential for food shortages to be experienced in the subsequent season and labour days to be lost as a result is increased, exacerbating this labour-centred low productivity trap.

Table 1
Top 10 constraints affecting agricultural productivity at different stages in the growing season (source: Focus groups, n = 12).

Rank	Constraint on Productivity	Land Preparation	Planting and Weeding	Harvesting and Storage
1	Household health	●	●	●
2	Access to tools and equipment	●	●	●
3	Availability of fertiliser		●	
3	Availability of seeds		●	
3	Availability of pesticides			●
4	Availability of money	●	●	●
5	Rainfall quantity and timing	●	●	●
6	Availability of food	●	●	
7	Availability of labour	●	●	●
8	Availability of stover/manure	●		
9	Transport	●		●
10	Willingness/interest	●	●	

4.1.3. Food shortages

Food shortages in the "lean season" (pre-harvest months, typically January – March) were identified as a significant source of labour loss (Table 2), and were described as "*annually a problem*" (Focus Group 5NCA), exacerbated by poor harvests the year before (Focus Group 5CA). Household surveys indicated that 40 % of households were too hungry to work in their fields in 2015/16, losing an average of 10.6 days labour. When asked how long the harvested food supply would last following the 2015/16 season only three households thought that it would last until the next harvest. The impact of this was evident in the need for external food aid throughout 2016 (UK Government, 2016). In addition to poor harvests resulting in reduced energy and poor health, households need to use any cash obtained through employment to purchase food, and it is therefore not available to purchase inputs (Focus Group 4CA).

4.1.4. Limited capital

Lack of capital affects every stage in the farming calendar, and has implications for other constraints. Broken or missing tools, including machetes, wheelbarrows, sacks and hoes can lead to a loss of labour days when there is no available capital to repair or replace them. Lack of capital to purchase inputs reduces productivity, and low productivity exacerbates deprivation during the lean season when households lack the capital to buy extra food, members undertake piecework to obtain cash, with 57 % of farmers losing labour days on their own farms.

4.1.5. Productivity traps

Tracing the roots and experiences of on-farm labour shortage reveals the systemic nature of farm production constraints, highlighting important links to health and positive feedback loops between dependence on input subsidies, lost labour days, low productivity and food shortage. Fig. 2 highlights two cross-season feedback productivity traps that illustrate: (1) the self-reinforcing impact of low productivity on health and labour availability; and (2) the impact that low production has on abilities to access inputs and consequent pressure that lack of inputs places on labour burdens. Within the farming calendar the constraints on accessing the means to intensify production - machinery, fertilisers, herbicides, seeds and other inputs – and on accessing the means to extensification – labour and land – create a continually compounded constraint on production, which is sustaining those broader cross season feedback loops. These feedbacks can be compounded by broader system factors as demonstrated in cases of inefficiencies in input subsidy programmes delaying access to inputs or where health services inadequately provide for those in need.

4.1.6. Rainfall

The 2015/16 El Niño event provided an opportunity to examine differences in constraints between CA and non-CA farmers under conditions where CA farmers should benefit from CA cultivation. In discussions surrounding the constraints experienced in this year similarities were evident across the groups. While rainfall was considered to be a significant constraint in terms of erratic timing and volume, only constraints relating to limited food and capital were highlighted. This was exacerbated by the previous year (2014/15), where flooding resulted in widespread loss of crops. Going into the 2015/16 season households had little food or capital, which reduced their capacity to prepare their land in time for the rains. This was aggravated by false onsets of the 2015/16 wet season where farmers reported having to replant seeds up to three times, and lack of capital to buy seeds was a significant constraint. This was illustrated by Focus Group 2CA: "*It was a lean year, so most people would rather use the money they find to buy food rather than seed*". The importance of capacity within the farming system to support households during dry periods was evident in discussions around past dry events. Of the 12 focus groups, 10 thought that past events had been worse in comparison to 2015/16 (notably 1991/92 and 2001/02), due to a lack of maize on the market and poorer access to fertiliser. Three of the CA focus groups cited the use of CA as improving their resilience to drought.

4.2. Is CA addressing these constraints?

We now consider the potential in the agronomic performance, structures and institutions, and agency associated with CA for overcoming constraints and driving agricultural transformation.

4.2.1. CA technology

CA is considered to reduce labour constraints across the farming calendar through reduction of labour during land preparation and weeding if herbicides are used (Thierfelder et al., 2015b). However, our findings show that if herbicides are not available the labour burden may increase, as CA farmers tend to weed by hand (Focus Group 6CA). Household surveys indicated that 54 % of CA farmers did not use herbicides, and all CA focus groups indicated that weeding was a significant labour burden. Weeding is usually required during January and February, which is the peak lean season in Malawi (FEWSNET, 2015) and also the peak time for malaria cases (Lowe et al., 2013). As such, there are instances in which the limitations of substitutability between labour and inputs are exacerbated within CA systems.

A key benefit of CA is thought to be increased resilience to dry spells due to improved infiltration as a result of increased biological and reduced surface disturbance (Mupangwa et al., 2013), and mulch layers reducing water loss through evaporation from soils (Thierfelder and Wall, 2009). Extension officers considered that those farming using CA in 2015/16 were able to produce more than those using traditional

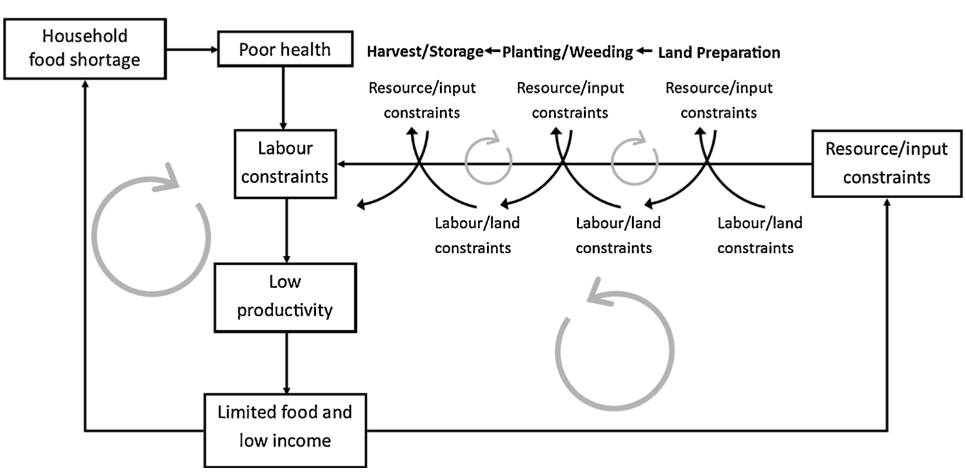

Fig. 2. Relationships between factors affecting agricultural productivity. Poor health reduces labour intensity, which results in lower productivity and limited food and income. This interacts with the ability of the household to purchase inputs such as fertilisers and herbicides, which increases the demand for labour. Throughout the farming calendar different constraints interact, exacerbating the low productivity trap.

tillage: "*Those who did CA were able to harvest two to three 50 kg bags [of maize]. Those who didn't got nothing, not even green maize*" (Section Extension Officer). This was supported by household surveys, which indicated that hybrid maize yields on fertilised land under CA were twice as high as those not under CA (average yield CA: 892 kg ha^{-1}, non-CA 420 kg ha^{-1}). Farmers in focus groups commented that their crops survived for longer in CA fields than in non-CA fields, but that the dry spells were so long that often the crops didn't last all the way through, indicating that CA can provide resilience to short dry spells.

4.2.2. To what extent do structures and institutions support farmers?

NGO-led and internationally-funded programmes, such as those driven by Total Land Care, the FAO and ICRAF in the study sites, have been the drivers of CA promotion since 1998. Whilst such programmes have typically worked with, and through, governmental extension services for local operationalisation, there is limited strategic governmental oversight and coordination, despite the re-launch in 2007 of the National Conservation Agriculture Task Force (NCATF).

At section level, the lack of coordination between NGO-led programmes promoting CA and the activities of the extension services was highlighted repeatedly. This resulted in farmers receiving mixed messages: "*We teach the farmers to dig30 × 30 cm pits and plant a seed in each corner, whereas they [the NGO] tell them to have a 50 cm long pit and plant three seeds in a line*" (Section Extension Officer). Such discrepancies are recognised throughout all NGO and Government levels, and guidelines are currently being developed for use by all CA practitioners (CSA Policy Dialogue, 2018). A further issue is the lack of collaboration with the extension services during the project, particularly when the NGO uses its own field staff, and extension services are then expected to continue supporting farmers "*There is no support for the projects once they [the NGO] leave*" (EPA Agricultural Officer).

Resource constraints within the extension services are considerable. Most AEDOs were responsible for at least two sections, meaning that they were expected to provide extension support for over 2000 farmers. One District Agricultural Officer in Machinga explained that while there are 140 sections within the district there are only 56 extension staff. Another District Agricultural Officer explained that a rapid turnover of agricultural staff meant that they often did not know who was working at the time, and that it was difficult to co-ordinate extension programmes. A lack of transport was reported across key informant interviews, for example a Section Extension Officer explained that within the EPA in Balaka there were only three pushbikes available for all the sections. Lack of transport means that farmers in remote areas are excluded from extension support.

A significant discrepancy was revealed between the agricultural constraints experienced by farmers and those that extension staff perceived farmers to be experiencing. Extension staff consistently considered rainfall to be the biggest issue, followed by lack of inputs and other factors including landholding size, extension support and poor education. Health and labour issues were not seen as significant constraints to farmers by extension officers across the districts, even when asked about these issues directly: "*Health is not a problem*" (District Agricultural Officer), "*Labour is not an issue because the population is high, [so] households are large*" (NGO Extension Officer). While the availability of labour (having enough people available to work) was also not considered by farmers to be an important issue (Table 1), the ability of those people to perform labour tasks is impeded by poor health, and this is a critical constraint hidden within labour availability which is not recognised by extension officers. There was often a focus on the mental attitude of farmers: "*They don't want to work, they just wait for more things to be given to them*" (District Land Resources Officer); "*They think it is too much hard work to dig pits*" (Section Extension Officer). This incongruity suggests that that programmes implemented through the agricultural extension services, both government and NGO, are not targeting the most influential constraints affecting smallholder agricultural productivity.

4.2.3. Does CA increase farmers' agency?

One of the criticisms sometimes levelled at CA as a technology, and identified as an operational constraint within the institutional mapping workshop, is that it lacks a single clear definition. Although the institutions and structures around CA may incentivise or promote a prescriptive form of CA, there are many variations and different combinations of techniques within it that can be tailored to local conditions based on local and farmer knowledge. In principle, it should lend itself to the operationalisation of local knowledge and agency, rather than limit it.

Farmers that self-defined as practicing CA demonstrated a variety of practices and choices about the proportion of land dedicated to CA, varieties and patterns of legumes intercropped and rotated, and tillage and planting basin systems implemented. This is reflective of certain agency of farmers in the utilisation of CA principles. However, education was identified as a constraint to farming by extension service staff, and reflected in the household surveys which indicated that 16 % of farmers had no formal education, and 69 % did not receive more than 8 years of formal primary education, typically ending at the age of 14. This limits farmers' ability to fully understand and utilise the variations within CA.

Additionally, evidence that the incentives and structures around CA may be subject to inequity and elite capture. Whilst 70 % of non-CA farmers were female, only 46 % of CA farmers were female, indicating gender inequality in participation. This was supported by a strong association of gender with tillage type ($\chi = 10.834$, df = 1, $P < 0.001$). Gender bias was discussed with extension service staff in the Machinga EPA, who thought that there was inequality in participation with CA extension activities, and that they would expect more women to practice it given that within the EPA there are 25,314 farming households, and only 6,000 are male-headed.

Household questionnaire data captured the support each farming household received from NGOs, government extension support and peers, family and friends. A District Land Officer thought that *"There were no differences in access to training and support according to wealth groups*", and analysis of these data supported this in terms of government extension support (FET, $p > 0.05$). However, there was a significant association between support from NGOs and wealth (FET, $p < 0.01$). While 55.8 % of 'better off' and 77.8 % of 'much better off' farmers received support from NGOs, only 36.2 % of 'average', 30.4 % of 'worse off', and 21.1 % of 'much worse off' farmers received support. There was also a significant association between gender and NGO support ($\chi = 0.028$, df = 1, $p < 0.05$), with 31.9 % of women and 48.7 % of men receiving support from NGOs. There was no association between wealth and peer and family support (FET, $p > 0.05$), or between gender and government support ($\chi = 0.380$, df = 1, $p > 0.05$), or gender and peer support ($\chi = 0.318$, df = 1, $p > 0.05$). This suggests that wealthy, male farmers are more likely to get support from NGOs – indicating a degree of elite capture.

5. Discussion

The farmer-defined experiences of constraints in Malawian agricultural systems presented here highlight a number of apparent contradictions in smallholder systems. The research was also steered in surprising directions by the open nature of questions on constraints, most notably the emphasis that respondents placed on household health. These insights are revealing not only of the socio-economic complexity of small-scale agricultural systems, but also of the potential for limits in labour, land and access to inputs to interact in ways that can become mutually reinforcing and leave farmers embedded within poverty traps.

The diversity of CA practices and their different sensitivity to environmental conditions (soils, climates) and treatments (fertiliser inputs) make controlled agronomic research challenging (Giller et al., 2011). However, efforts in this regard are improving understanding about the technology of CA from an agronomic perspective (Thierfelder et al., 2015b), and illustrating the importance of adapting CA principles to agro-ecological and climatic contexts in order to maximise yields or drought tolerance. However, from a socio-economic and land use policy perspective, the metrics of success for CA may be somewhat different, and a focus on the resource use efficiency of CA, particularly in contexts of limited land, labour, inputs, and access to markets, results in different conclusions. In fact, certain forms of (high-input or labour-intensive) CA, may add further pressure on limited resources. In contexts in which cycles of low productivity quickly become self-reinforcing (e.g. through its impact on food availability and therefore labour) CA may exacerbate rather than alleviate low productivity traps.

It was evident across interviews conducted with agricultural extension officers that there are substantial discrepancies between the opinions of farmers and extension officers when considering constraints on agricultural productivity. This results from the diminished capacity within the extension services, with few staff and a lack of ability to reach a range of farmers (Djurfeldt et al., 2018) and may also be symptomatic of the top-down nature of extension approaches (Brown et al., 2018b). A participatory farming systems approach, as taken in this study, can reveal the lived experiences of agricultural systems by those farmers that know the system most intimately and are responsible for making decisions about land management (Hermans et al., 2020). In this case, it has revealed the importance of effectively targeting improvements in household health through the structures and institutions associated with agricultural development. As Dangour et al. (2012, p.223) argue: "*we require integrated research, policy and advocacy across the agricultural and health sectors*". This demonstrates a need for integrative rural healthcare and agricultural development programmes, but beyond this a holistic, cross-sectoral approach which also includes education is needed.

Within the recent history of attempts at sustainable intensification and the land use policy transformation of African agricultural systems, there is arguably little that is significantly different about the contemporary push for CA. The extension system in Malawi operates today much as it has done since colonial times (Green, 2009). Voluntary adoption of agricultural changes – in particular the use of contour ridging – in the early 20th century was very low, similar to the low rates of approximately 3% adoption of CA in Malawi today. Understanding why farmers are so reluctant to adopt measures that are supposedly conceived in their best interests is as valid today as it was then (Beinart, 1984). Past agricultural schemes have left a legacy in the minds of both farmers and the extension service staff and the reversal of rhetoric in relation to ridging is an important barrier to the adoption of CA. It is unsurprising therefore that smallholders in Malawi remain reluctant to change their farming practices today despite the strong push in both national policy and from donor organisations.

Some of the persistent issues of access to inputs and markets in rural areas and the limited technical support that compromised the Sasakawa Global programmes two decades ago, and the failures to address inequities and achieve truly participatory forms of development within schemes elsewhere across SSA (Sanchez et al., 2007; Wilson, 2016), are evident too within the push for CA in Malawi. However, whether CA represents an extension of the neoliberal project of high-input, maize dominated agricultural modernisation, which has been advanced through programmes such as FISP, or whether it runs counter to this, is not inevitable. Forms of low input CA, through which farmers may become less dependent on markets, are a possibility, even if these do not represent the mainstream vision in national policy statements on CA and Climate-Smart Agriculture from the Department for Land Resources and Conservation (DLRC) and the National Conservation Agriculture Task Force (NCATF). Certainly there are experiences, documenting within the mainstream programmes operating in the study areas described here, of inequities in access to the provisions, structures, inputs and support around CA. However, the technology has an inherent flexibility to it and in adapting these principles there is room for the expression of agency of farmers, not only to disadopt technologies and disengage from projects, but to choose combinations of practices and inputs, including those that reduce dependence on markets and institutions.

There is a push towards a more integrated and coordinated institutional landscape around CA in Malawi, and this brings important benefits in terms of linking research to policy and ensuring coordination (Dougill et al., 2017). However, there is also a danger in forcing consensus around narrow technical definitions of CA technology, setting adoption targets, and standardising systems of incentivising and monitoring CA practices. Closing out alternative pathways of CA – those that are bottom-up, organic or agro-ecological, for example - may negate the flexibility of CA and limit its inclusivity and potential for empowering farmers.

6. Conclusion

Lessons from the recent history of technology-centred agricultural development initiatives in Africa suggest that it is not only the technology itself, but also the structures, institutions and building of agency associated with them that determine success. This research on the case of CA in Malawi found that the constraints to agricultural productivity are beyond those directly related to agriculture, demonstrating that a systems approach is critical to the development and implementation of agricultural development projects. Household health was identified as a pervasive constraint, and severely restricted the capacity of households to achieve higher levels of agricultural productivity, which in turn reduces their access to capital, access to food and inputs. It is crucial that agricultural development projects consider such factors and adopt a more holistic approach, working with sectors beyond agriculture to develop household capacity to adopt agricultural technologies, improving their resilience to future climate shocks. This will require the participation of farmers, facilitating discussion of the farming system constraint and co-designing interventions to address issues of access, information and provision across scales (from agricultural extension officers to broader government ministries). Appropriately targeted and more holistic interventions will have a greater chance of success, and should result in increased adoption rather than disadoption, as is currently witnessed in association with present CA methodologies. This is increasingly recognised in Malawi's development strategies, including the National Resilience Strategy and the Agriculture Sector Wide Approach (ASWAP III) which offer scope to explicitly consider cross-sectoral linkages in enhancing the resilience of Malawi's agriculture and food systems.

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CRediT authorship contribution statement

Eleanor K.K. Jew: Writing - original draft, Methodology, Investigation. **Stephen Whitfield:** Conceptualization, Writing - review & editing. **Andrew J. Dougill:** Writing - review & editing, Supervision, Funding acquisition. **David D. Mkwambisi:** Project administration, Resources, Writing - review & editing. **Peter Steward:** Formal analysis, Writing - review & editing.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

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