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The adoption of conservation agriculture by smallholder farmers in southern Africa: A scoping review of barriers and enablers

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ABSTRACT

The Anthropocene has brought with it many challenges, the primary of which are climate change and food security. The growing global population increasingly demands more from a shrinking resource base, while variable climate conditions make future provision uncertain. To address issues of low agricultural productivity and land degradation, conservation agriculture (CA) has been promoted in smallholder settings across Africa. CA is an agricultural package that consists of three key principles (minimum soil disturbance, mulching, and crop rotation) and its success depends on the simultaneous implementation of all three principles. However, CA has met with limited success. A scoping review was conducted to assess the barriers and enablers of CA for smallholder farmers in the Southern African Development Community (SADC) – a regional inter-governmental economic community. The scoping review included peer-reviewed articles, book chapters, reviews, and grey literature written in English that focused on the contextual links between CA adoption and the smallholder context, since 2015. Six electronic databases were consulted, and included records were charted according to a pre-defined data extraction form. A total of 66 records were included. A qualitative content analysis was performed. The findings indicated four central themes – physical resources, human resources, informational resources, and financial resources. The four central themes and their respective categories, detailing barriers and enablers, were combined to produce the Conservation Agriculture Suitability Framework for Smallholder Farmers. The review contributes to the knowledge base of the CA discipline and practice by revealing the contextual determinants of successful CA implementation. Ultimately, the success of CA in southern Africa will be underpinned by how well it fits into the broader smallholder farming system.

1. Introduction

The Anthropocene – a human dominated geological epoch (Crutzen, 2002) – has brought with it many challenges, the primary of which are climate change and food security (Mugandani and Mafongoya, 2019). The growing global population increasingly demands more from a shrinking resource base, while variable climatic conditions make future provision uncertain. To tackle these challenges, feed and fibre need to be produced in a way that preserves and enhances the natural resource base as well as the environment (Pittelkow et al., 2015a).

The issues of food security and climate change are particularly severe for Africa as much of the continent is drylands and farming systems are predominantly rain-fed (Abegunde et al., 2020). Over the next 50 years, rainfall is projected to decrease by 10–20% or more in southern Africa (Mkuhlani et al., 2020). The IPCC Sixth Assessment Report confirmed the likelihood of heat extremes and agricultural and ecological drought in southern Africa (IPCC et al., 2021). The smallholder farming system is therefore highly susceptible to climate variability, temperature increases, and precipitation decreases. This is a serious issue as the majority of African households are sustained by smallholder agriculture (Brown et al., 2020). Further, in sub-Saharan Africa (SSA), the population is expected to more than double by 2050 and this will triple the demand for cereals (Brown et al., 2020). Currently, growth in agricultural productivity across sub-Saharan Africa has been unable to match population growth (Brown et al., 2020). To address these food security challenges, conservation agriculture (CA) has been promoted to sustainably intensify production and increase profits (Pittelkow et al., 2015a).

CA is an agricultural technique that consists of three key principles: minimum tillage, mulching, and species diversification through crop rotations or intercropping (FAO, 2017). While there are debates around the benefits of CA, literature claims it benefits smallholder farmers in

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three ways (Brown et al., 2018a). Firstly, CA is reported to have physical resource benefits by increasing yields, improving soil fertility, reducing erosion, and increasing soil moisture retention. Secondly, CA is reported to have human resource benefits by reducing labour requirements; and thirdly, CA is reported to have financial resource benefits by reducing the need for hired labour and draught animals, and increasing profits. For the purpose of this review, smallholder farmer has been defined according to Murungu's (2012) definition: a smallholder farmer is a farmer with limited resource endowments, especially regarding land, who cultivates 10 ha or less while also potentially rearing livestock.

CA has not only been promoted as a climate-smart agricultural technique, but it is seen as a solution that will address low agricultural productivity and simultaneously reduce excessive land degradation (Murungu, 2012). Consequently, governments and developmental agencies across Africa have encouraged the adoption of CA through incentivised and non-incentivised adoption programs (Michler et al., 2019). CA adoption has increased dramatically since 2008 and in 2015 it was estimated to be practised across 13.9 million hectares (Kassam et al., 2019). It is important to note that adoption statistics are often flawed, largely due to definitional ambiguity of what constitutes CA (Brown et al., 2017). However, to reap the benefits of CA, its three principles need to be applied simultaneously (Kassam et al., 2019). In the smallholder context, this is often not possible due to resource constraints, and smallholder farmers have experienced adverse effects when practicing CA. Despite CA's great potential, it has failed to live up to its panacea claims, and debates around the limits of CA in Africa are rife (see: Giller et al., 2009; Pittelkow et al., 2015b; Corbeels et al., 2020; Descheemaeker, 2020). The controversial claim of increased yields was scrutinised in a continent-wide meta-analysis conducted by Corbeels et al. (2020). The meta-analysis sought to understand yield responses to CA and the influence of environmental conditions. Corbeels et al. (2020) show that the average yields of CA systems are only slightly greater than conventional agricultural systems and that the greatest effects are seen when all three principles are implemented together, combined with low rainfall and herbicide use. Consequently, the barriers and enablers of CA for smallholder farmers need to be determined to assess whether CA is the appropriate climate-smart agricultural technique for Africa.

Analyses of current literature show that there are diverse barriers and enablers to CA that are dependent on the setting and community that the program takes place in. A barrier is a physical, social, financial or informational obstacle that prevents successful adoption and implementation of CA's three key principles, while an enabler is a physical, social, financial, or informational asset that makes successful adoption and implementation possible. Key enablers include market opportunities and equipment availability (Pittelkow et al., 2015a), the integration of crop and livestock production systems (Murungu, 2012), and awareness of land degradation and soil infertility issues (Michler et al., 2019). These enablers, however, are frequently unavailable as smallholder farmers are trapped in low-input-low-output systems (Brown et al., 2018a). Barriers to the adoption of CA include initial yield decrease (Pittelkow et al., 2015a), issues with information delivery (Brown et al., 2017), competition for crop residues by livestock (Brown et al., 2017), high initial investment costs (Murungu, 2012), limited or unavailable inputs (fertiliser, seeds, herbicides, machinery) (Murungu, 2012), and increased labour demand (Michler et al., 2019). Overall, there is a lack of physical, financial, human, and informational resources for the effective implementation of CA's three principles in the smallholder context (Brown et al., 2018a). These barriers have complex causal mechanisms that need to be further explored to explain the low adoption rates of CA.

The scoping review documents the available knowledge on the barriers and enablers of CA for smallholder farmers. The aim of the review was to assess the dominant barriers and enablers of CA for smallholder farmers in the Southern African Development Community (SADC) (see: SADC, 2012a) member states and present the barriers and enablers in a way that allows program managers to predict the success of CA. Two research questions guided the review process: (1) are the barriers and enablers of CA context-specific? and (2) are the identified barriers and enablers unique to CA or are they indicative of the broader smallholder farming context? A scoping review approach was chosen as it is an effective tool for synthesising current knowledge about CA. Scoping reviews allow for key concepts in a field to be rapidly mapped while simultaneously analysing the literature at large (Arksey and O'Malley, 2005). The CA academic debate is broad; utilising a scoping review allowed for the inclusion of diverse CA studies, and their differing designs, to be included. There is limited academic literature that focuses on the barriers and enablers of CA (see: Andersson and D'Souza, 2014; Lalani et al., 2016). A more thorough investigation of CA's constraints across different countries and agro-ecological contexts is needed. The review contributes to this literature gap.

1.1. *Rationale for the focus of the review*

Smallholder farmers have been selected for this review due to their vulnerability to climate change, their limited capacity to respond to climate change, and their important contribution to food security and economic development. Further, smallholder farmers are the target group for many CA programs in Africa.

The defined time period for source inclusion in the scoping review is 2015 or later. The reason for this is linked to the Sustainable Development Goals (SDGs). The SDGs were created to complement the Millennium Development Goals (MDGs) and build on their progress to end poverty and protect the planet. However, the majority of African countries failed to achieve the MDGs; particularly MDG 1, that of cutting national hunger rates in half (Adenle et al., 2018). CA has been suggested as a means to create food security and reverse land degradation and thus the review uses 2015 as a starting point to assess whether CA will contribute to southern Africa's performance in relation to SDG 2 (Zero Hunger) and SDG 15 (Life on Land).

The member states of the SADC have been chosen for this review. The primary objective of the SADC is "to achieve development, peace and security, and economic growth to alleviate poverty" (SADC, 2012b). Many of the member states (such as Zambia, Malawi, Tanzania, and Mozambique (Asfaw et al., 2016; Brown et al., 2020)) have incorporated CA into both national and regional agricultural policies to achieve the objectives of the SADC. For this reason, the SADC member states are the ideal candidates due to their politically aligned objectives of development and their promotion of CA. Further, since the SADC member states are primarily located in SSA, they will need to intensify their agricultural production to feed the increasing population (Brown et al., 2020).

2. Materials and methodology

The scoping review was conducted according to the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines and checklist (Tricco et al., 2018). The review has not been registered with a third party.

2.1. *Strategy for literature searches and selection*

An electronic literature search was carried out to identify relevant records. The literature search was restricted to peer-reviewed articles, reviews, book chapters, and grey literature. As the reviewer speaks English, only records written in English were included. The help of a Principal Librarian from Rhodes University was enlisted in order to create a comprehensive search string. Four key search terms were used in combination to conduct the literature search: 1) conservation agriculture OR CA; 2) minimum tillage OR zero tillage OR no till OR NT; 3) permanent soil cover; 4) crop rotation OR intercropping. The reviewer independently conducted the database searches between 19 June – July 31, 2020. Six electronic databases were consulted: Web of Science, Science Direct, Springer Link, Scopus, Taylor and Francis Online, and

Google Scholar. Table 1 describes the number of records returned by each database. The literature search returned a total of 629 records and reference list scanning returned 13 records (Fig. 1). The inclusion and exclusion criteria were applied on these 642 records. The criteria for literature inclusion were: year of publication (2015–2020), population (smallholder farmers) and geographical region of the study (the SADC). Included literature had to explicitly focus on the barriers and enablers of CA and its three principles. Studies that focused on the biological effects of CA (such as soil health and yield) without mentioning encountered barriers or enablers, were excluded. Included studies did not have to focus on all three principles of CA simultaneously (as this severely restricted the quantity and diversity of included studies) but had to show links between contextual factors and CA adoption. Further, studies that focused on southern Africa, as well as Climate-Smart Agriculture (CSA) and sustainable intensification in general, were included as long as they mentioned the SADC countries and CA specifically. Literature that did not meet the inclusion criteria were excluded. A total of 66 records were finally included; these records were reviewed in full detail and analysed further.

2.2. Management of included records and their data

Data capture and management was facilitated through ProQuest RefWorks. The reviewer exported the identified records from each database into RefWorks. Records were screened for eligibility first through abstracts and then through full-text assessment. Included full-text records were charted according to a pre-determined data charting form to extract the necessary information, as outlined by Arksey and O'Malley (2005).

2.3. Coding and analysis of extracted data

Qualitative synthesis of the collected data, extracted via the data charting form, was undertaken through a qualitative content analysis. Qualitative content analysis (QCA) consists of multiple techniques for systematic text analysis which endeavour to preserve the methodological strengths of quantitative analysis (Mayring, 2014). QCA allowed for a mixed methods approach where inductive and iterative categorisation of text from included records was followed by an analysis of category frequencies as a quantitative step, as outline by Mayring (2014). QCA is methodologically dynamic and allows for a rigorous review of literature that is thorough and theoretically relevant while establishing well-rooted links between identified themes. The solid methodological value of QCA is seen in its transparency, and its constant comparative and iterative analysis (Mayring, 2014). While not without criticism, the use of QCA in the review allowed for systematic categorisation of the barriers and enablers of CA across a diverse range of literature and the creation of the Conservation Agriculture Suitability Framework for Smallholder Farmers.

3. Results

3.1. Number and type of publications

The number of included records published per year are displayed in Fig. 2. The number of records increased from 2015 to 2017 and then steadily decreased from 2017 to 2020. The majority (91%) of included records were peer-reviewed articles, while the rest were book chapters (9%). While the scoping review allowed for the inclusion of grey literature (for example, unpublished literature and CA program reports), identified grey literature was excluded as it did not focus on the barriers and enablers of CA, but rather project-specific challenges or broad dissertations.

Table 1
The number of records returned by each database.

Database	Number of results
Web of Science	324
Science Direct	168
Springer Link	48
Scopus	35
Taylor and Francis Online	32
Google Scholar	22
Total	**629**

3.2. Geographical concentration of included records

Despite the SADC consisting of 16 member states, relevant CA literature was only present for seven of these states (Lesotho, Malawi, Mozambique, South Africa, Tanzania, Zambia, and Zimbabwe) (Fig. 3). There is a relative paucity of publications focusing on the barriers and enablers of CA for the SADC countries. However, there were eight included records that focused on southern Africa in general. These provided insight into common barriers and enablers across countries. Overall, the 66 included records provided data from roughly 92 944 households across seven countries. The map in Fig. 3 displays the concentration of studies per SADC country. It is important to note that some records analysed data from multiple SADC countries and that this inflates the number of studies per individual SADC country.

3.3. Overarching themes influencing CA adoption

The thematic content analysis brought to light four central themes, adapted from Brown et al. (2018c), that govern the adoption of CA. In ranked order, the four central themes are: physical resources, human resources, informational resources, and financial resources. Each central theme has several categories which describe variables that are barriers and enablers to the adoption of CA. Tables 2–5 detail these categories and their respective variables as well as frequency counts for each theme.

Table 2 displays physical resources categories and the physical resource variables that influence CA adoption. Notably, the productive asset and land ownership category was the most influential. Implementing CA was often impractical due to a lack of machinery access and availability, lack of access to inputs, and tenure insecurity.

Table 3 displays human resource categories and the human resource variables that influence CA adoption. The most prominent constraint to CA was labour; most studies cited a significant labour increase after implementing CA, with a significant shift of the workload to women, and a lack of labour availability at the household level.

Table 4 displays the informational resource categories and the informational resource variables that influence CA adoption. The complex and knowledge-intensive nature of CA was made more difficult by poor information delivery systems and extension services, which resulted in knowledge gaps and inadequate modification and adaptation.

Table 5 displays the financial resources categories and the financial resource variables that influence CA adoption. The practice of CA, and the necessary machinery and inputs, was not economically viable at the household level. Further, the significant initial start-up costs required for CA, such as purchasing herbicides, were often not feasible at the smallholder scale.

4. Discussion

4.1. Theme 1: physical resource barriers and enablers

Physical resources refer to the on-ground implements and infrastructure needed to carry out CA, as well as important environmental variables which are context-dependent (Table 2).

4.1.1. Productive asset and land ownership

The primary physical resource category influencing the adoption of

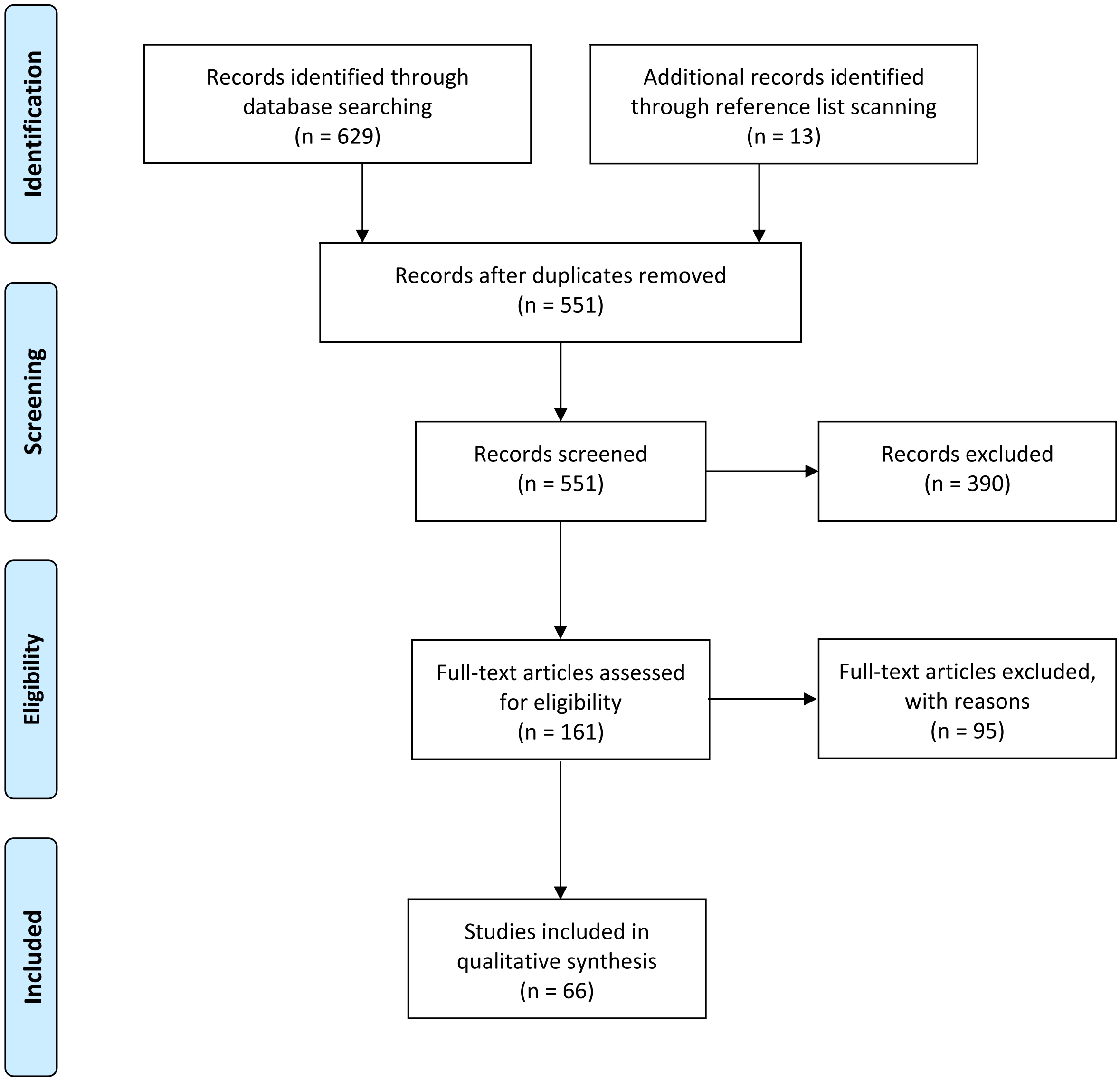

Fig. 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram for study selection and inclusion.

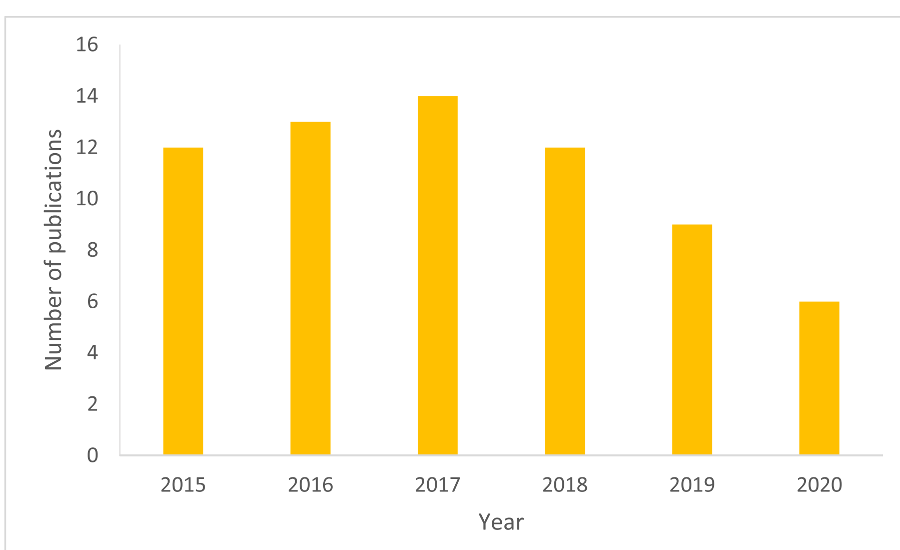

Fig. 2. Number of included publications per year (2015–2020).

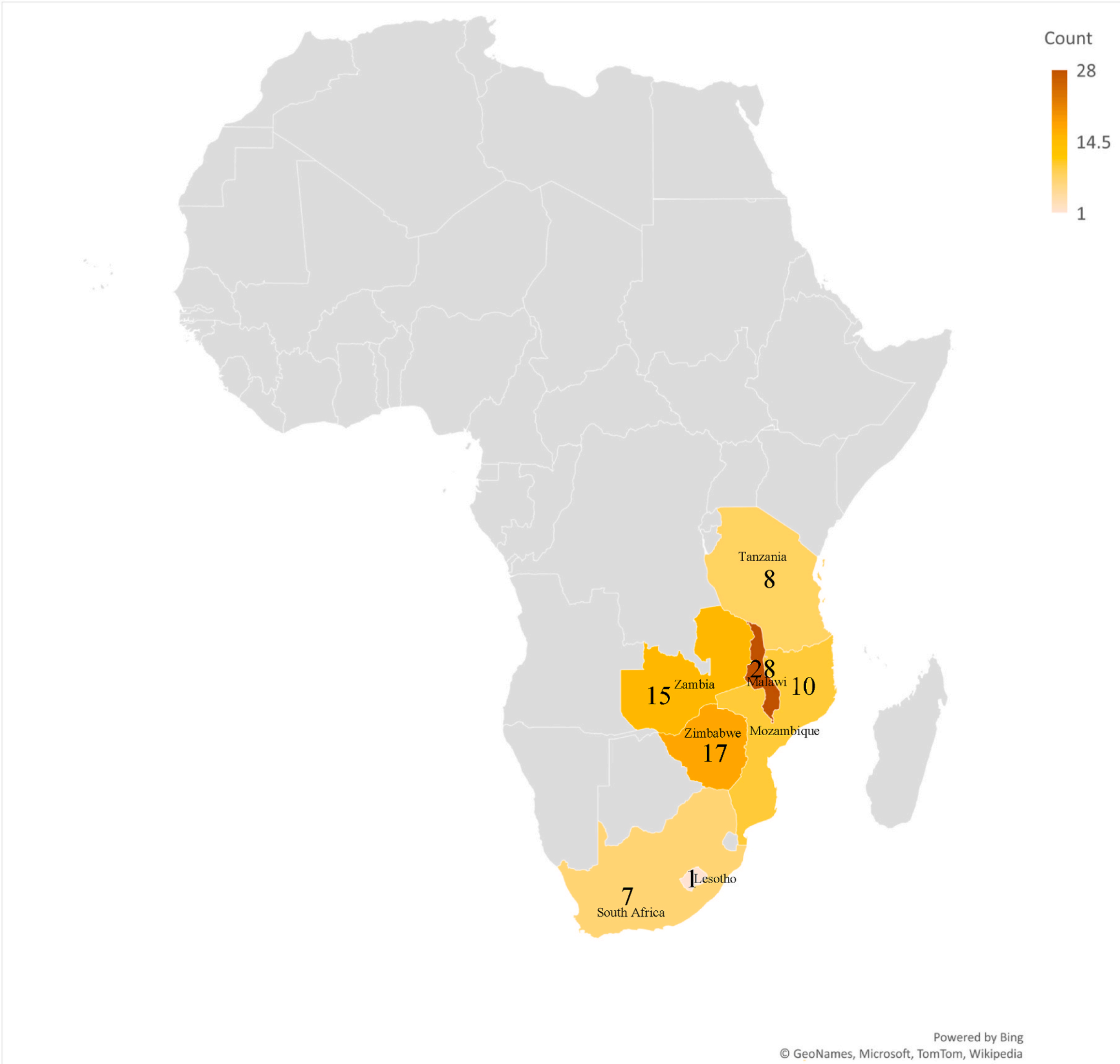

Fig. 3. Map of Africa displaying the number of studies per SADC country.

CA was productive asset and land ownership. Within this category, the top three variables were: lack of machinery availability and access; limited/lack of access to inputs; and tenure insecurity. These three variables acted as substantial barriers to CA adoption. Without the necessary machinery, CA becomes a severe labour burden, particularly for basin-based CA (the digging of small pits as planting basins), and can result in yield penalties (Abdulai, 2016; Mugandani and Mafongoya, 2020). To reduce the time spent on labour, small-scale mechanisation at the smallholder level is required (Lee and Thierfelder, 2017; Brown et al., 2020). Not only is the machinery expensive and beyond the financial capacity of smallholders, but it is also not locally available in many countries (Grabowski et al., 2016; Mugandani and Mafongoya, 2020). As a result, the acceptability of CA is low (Muzangwa et al., 2017). Further, without the necessary agricultural inputs (herbicide, fertiliser, seed), CA is impractical in the smallholder context and has adverse effects (see detriments category in Table 2) (Bunderson et al., 2015; Grabowski et al., 2016). The lack of access and availability of inputs (Nhamo and Lungu, 2017) is related to a lack of capital and limited credit facilities (Ndah et al., 2018). Land ownership was the single enabler in the 'productive asset and land ownership' category. This is closely linked to the third most important barrier – tenure insecurity. Tenure insecurity arises from the unavailability of formal land use rights, stemming from statutory law's failure to recognise customary tenure systems (Kunzekweguta et al., 2017), and it severely restricts the implementation of sustainable agriculture practices (Adenle et al., 2018). Smallholders who face insecure tenure are at risk for losing their land and are, consequently, unwilling to invest in the land for its long-term productivity (Cheesman et al., 2017). Instead, short-term gains are maximised, and long-term detriments are ignored. Smallholder farmers who own their land are more motivated to invest in its long-term productivity (Kassie et al., 2015).

4.1.2. *Farm characteristics*

The secondary category in the physical resource theme was farm characteristics. From Table 8, it is clear to see that the influence of farm characteristics is context dependent. While the top three variables can be identified (large farmlands, location, and livestock ownership), the influence of these variables is not consistent due to their dynamic nature. For example, large farmlands were noted as a significant enabler to CA as farmers could experiment without risking their subsistence crops and livelihoods (Abdulai, 2016; Abegunde et al., 2020; Asfaw et al., 2016; Brown et al., 2017). However, negative effects of large farmlands were also present as a result of the increase in labour required if CA was expanded to the entire farm (Adenle et al., 2019; Hove and Gweme, 2018; Kassie et al., 2015; Maguza-Tembo et al., 2017). Similarly, livestock ownership had an almost equal effect as a barrier and enabler as

Table 2
Theme 1 – Physical resource categories and frequency of variables, in descending order, influencing the adoption of CA. The parentheses denote the number of studies within which each variable was mentioned (n = 66).

Rank	Physical resource categories	Influential variables
1	*Productive asset and land ownership*	Lack of machinery access and availability (16)
		Limited/lack of access to inputs (11)
		Tenure insecurity (9)
	Farm characteristics	Size of farmland (large) (19)
		Location (12)
		Livestock ownership (7)
3	*Residue retention*	Trade-offs due to livestock feed (15)
		Low biomass production (8)
		Lack of protective fencing (5)
4	*Markets*	Great distances (13)
		Lack of access and availability of inputs (10)
		Unstable/underdeveloped markets (8)
5	*Detriments*	Increase in weeds (15)
		Increase in pests (7)
		Soil detriments (waterlogging/ compaction) (4)
6	*External support*	NGO support (inputs) (7)
		Government support and relief programs (6)
		Input subsidies (4)
7	*Climatic conditions*	Experience of hazards (drought/flood) (6)
		Exposure to climatic variability (4)
		Seasonal rainfall variation (3)
8	*Basic infrastructure*	Poor road infrastructure (4)
		Lack of transport (4)

Table 3
Theme 2 – Human resource categories and frequency of variables, in descending order, influencing the adoption of CA. The parentheses denote the number of studies within which each variable was mentioned (n = 66).

Rank	Human resource categories	Influential variables
1	*Labour*	Labour increase (21)
		Limited labour availability (10)
		Labour reallocation (women) (8)
2	*Household characteristics*	Household head's education level (15)
		Age of household head (12)
		Gender of household head (female) (11)
3	*Conflict with context*	Cultural resistance to change (8)
		Social, cultural, and political context (7)
		'Mindset of the plough' (5)
4	*Social capital*	Social networks (peers) (informal) (10)
		Agricultural associations (formal) (6)
		Adoption by neighbours (3)
5	*Mixed perceptions*	Perceptions of individual benefit (6)
		Unfulfilled expectations (4)
6	*Mindset constraints*	Lack of motivation and commitment (5)
		Sabotage (5)
		Existing inequalities (4)

livestock require crop residues as feed during the dry season, which restricts mulching (Baudron et al., 2015), but also provide manure as organic fertiliser (Grabowski et al., 2016). Every community has context-specific preferred practices and as such, the variable of location can be used to explain these seemingly contradictory effects. While only a portion of records included location as an explanatory factor (see Table 2, farm characteristics category), each record produced varying results based on where the study was located, not only across countries but also within.

4.1.3. Crop residue retention

The third category in the physical resource theme was crop residue retention. The variables of this category were all barriers, with the top three variables being trade-offs as livestock feed, low biomass production, and a lack of fencing to protect residues from free-roaming livestock. This category is particularly important as the beneficial effects of CA are dependent on all three principles being implemented simultaneously (Kassam et al., 2019), and particularly, that minimum tillage performed without mulching will have poor yield outcomes (Brown et al., 2017). As the majority of smallholder communities practicing mixed crop-livestock systems (Rusinamhodzi et al., 2015), mulching with crop residues is often not possible without sacrificing livestock productivity. The inability to produce sufficient biomass for mulching, and the prevalence of free-roaming livestock, further complicates this problem (Bunderson et al., 2015; Pedzisa et al., 2015b; Rusere et al., 2020). Insufficient mulch prevents implementation of CA's residue retention principle and is a key stumbling block to CA's success in southern Africa.

Table 4
Theme 3 – Informational resource categories and frequency of variables, in descending order, influencing the adoption of CA. The parentheses denote the number of studies within which each variable was mentioned (n = 66).

Rank	Informational resource categories	Influential variable
1	*Information delivery*	Knowledge gaps (lack of information) (19)
		Inadequate modification and adaptation (7)
		Not linked to information systems (4)
2	*Extension services*	Access to/contact with extension (19)
		Poor-quality service (16)
		Access to training (9)
3	*Knowledge intensive*	CA experience (6)
		Farming experience (4)
		Knowledge intensive nature of CA (3)
4	*CA programs*	Program participation (6)
		Being a lead farmer (2)
5	*Awareness*	Awareness of soil problems and soil fertility (5)
		Perception of climate change (3)

Table 5
Theme 4 – Financial resource categories and frequency of variables, in descending order, influencing the adoption of CA. The parentheses denote the number of studies within which each variable was mentioned (n = 66).

Rank	Financial resource categories	Influential variables
1	*Economic viability*	Lack of credit (16)
		Lack of capital/purchasing power (13)
		Household income (10)
2	*Start-up costs*	Cost of herbicides (14)
		Cost of machinery (13)
		Cost of fertilisers (7)
3	*Incentives*	Material incentives (10)
		Agglomeration payments (3)

4.2. Theme 2: human resource barriers and enablers

Human resources refer to unique household characteristics and contextual social, cultural and political factors that influence the adoption of CA (Table 3). The variables within the human resources category influence the level of risk that can be tolerated, how decisions are made, the capacity to evaluate new technologies, access to resources, and the accumulation of capital (Makate et al., 2019a). This theme was highly unpredictable, and no consistent variables were identified across or within countries. The entirety of this theme points to the notion that smallholder farmers and their contexts are not homogenous, but rather extremely heterogenous; indicating that CA programs should be tailored to the unique local conditions present (Ortega et al., 2016).

4.2.1. Labour required for CA

The primary human resource category was labour. The top three variables in this category were labour increase, limited labour availability, and labour reallocation to women. Despite CA's promotion as a labour-saving technology, the majority of records (Table 3, category 'labour') stated that labour for land preparation was the primary constraint, and the labour increase was significantly linked to basin-based CA (Thierfelder et al., 2015a; Ngoma et al., 2016; Nhamo and Lungu, 2017). A study by Bunderson et al. (2015) in Malawi found that basin digging was five times more labour intensive and time consuming than conventional agriculture (ridging). It is the result of this labour burden that has caused smallholder farmers in Zimbabwe to coin basin-based CA as "diga ufe", translated as "dig and die" (Mugandani and Mafongoya, 2020). The espoused labour savings from CA are based on the ability to plant in the same planting stations (basins) from the season before, however; this is context specific and often customary land tenure and communal grazing systems prevent this (Hove and Gweme, 2018; Ngoma, 2018). The labour-intensive nature of CA also arises from the issue of weeds. From Table 2 (detriments category), the increase in weeds as a result of CA is described. Increased weed prevalence is the result of minimum tillage (Thierfelder et al., 2015a) and the retention of crop residues (Muzangwa et al., 2017). The issue is compounded by the lack of access, availability, and affordability of herbicides. Muzangwa et al. (2017) show that the problem of high weed infestation and its associated labour burden was a major impediment for would-be adopters in South Africa.

Further, many smallholder households have limited labour available. While household size was considered to be an indicator of available labour, the literature showed conflicting results. Some records argued that larger households had more members available for labour and that this enabled adoption (Habanyati et al., 2018), while others argued that households with fewer members were more likely to adopt as CA was promoted to reduce labour burdens (Tambo and Mockshell, 2018). On the other hand, Ngoma et al. (2016) found that there was no direct correlation between household size, labour availability and CA adoption in Zambia and that the simple arduousness and drudgery of CA's labour requirements restricted adoption. Additionally, the hiring of labour was not feasible due to financial constraints (Ndah et al., 2018). Limited labour combined with labour-intensive CA practices led to large negative trade-off values that reduced the feasibility of CA for smallholder farmers (Ortega et al., 2016).

The last variable of the labour category is labour reallocation to women. This was an interesting finding that arose from gender-focused CA studies (see Farnworth et al., 2016; Murray et al., 2016; Wekesah et al., 2019). With the implementation of CA, a shift occurred in the gendered responsibility of land parcels. Weeding, digging and planting is seen as a 'woman's job' (Farnworth et al., 2016; Wekesah et al., 2019), while tillage with draught animals is seen as a 'male task' (Murray et al., 2016). Consequently, much of the labour for land preparation has shifted to women under CA systems as there is a decreasing need for male labour (machinery and tillage), especially in resource-constrained smallholder contexts. This has had mixed effects on CA adoption. CA systems are therefore not gender neutral, but rather tend to increase the workload of women. Similarly, gender-related access to extension and resources arose as a meaningful issue within the literature, highlighting the far-reaching implications that the gender social construct has for agricultural activities in southern Africa (Wekesah et al., 2019).

4.2.2. Household characteristics

The secondary human resources category was household characteristics (Table 3). Many of the variables had inconsistent effects as either barriers or enablers, reinforcing the contextual determinants of CA's success. The top three variables were the education level of the household head (literacy), the age of the household head (older farmers), and the gender of the household head (female). Education was found to be a significant enabler contributing to the adoption of CA (Kassie et al., 2015; Lambert et al., 2016; Khoza et al., 2019). If the household head had a higher literacy level, they were better able to access and interpret new information about CA and understand its importance and benefits (Manda et al., 2016; Muzangwa et al., 2017; Abegunde et al., 2020). Further, higher education levels were found to better facilitate the adoption of all three CA principles simultaneously, as farmers with greater literacy levels possessed the technical knowledge and skills needed to combat the knowledge-intensive nature of CA (Tambo and Mockshell, 2018).

Along with the household head's education level, their age was a significant factor. It was found that labour-intensive CA practices were not well-suited for older farmers who minimised activities that demanded too much labour and management skills, due to their declining physical ability; and who tended to be more risk averse and short-term oriented (Maguza-Tembo et al., 2017; Abegunde et al., 2020; Makate et al., 2019b). Further, some older farmers were resistant to mindset changes (Senyolo et al., 2018) and were more resilient to climate-related shocks due to acquired indigenous knowledge and therefore did not see the need for modern technology and CA (Maguza-Tembo et al., 2017). This finding, however, was not consistent and it appeared that age could be an enabling factor too. Some older farmers had more farming experience and knowledge, combined with greater social capital, with which to implement CA (Lambert et al., 2016; Branca and Perelli, 2020).

Lastly, the gender of the household head contributed significantly to whether the adoption of CA was possible. A female household head had diverse effects as both a barrier and an enabler. As a barrier, households headed by women faced discrimination by extension services, who prioritised educating men; these female-headed households therefore had less access to information and inputs, along with restricted access to crucial farm resources, such as land, labour and credit, with which to implement CA (Grabowski et al., 2016; Abegunde et al., 2020). A study by Amadu et al. (2020) in Malawi found that female headed households were 50% less likely to participate in CA programs. This is the result of patrilineal societies that restrict women's access to productive assets, education, wealth, and decision-making, which compromised the adoption of CA (Manda et al., 2016; Khoza et al., 2019). Considering that rural women make up the majority of smallholder farmers in southern Africa, gender is of great concern for the success of CA (Mugandani and Mafongoya, 2019). On the other hand, a study by Mutenje et al. (2019) in southern Africa found that female headed households comprised more than 50% of adopters, particularly for basin-based CA; with similar results found by a study by Mango et al. (2017). Female headed households tend to be more open-minded to new technologies and are more likely to experiment and persist in the face of challenges (Pedzisa et al., 2015a).

4.2.3. CA's conflict with context

The third category of the human resources theme was conflict with context. The top three variables in ranked order were: cultural resistance to change; the unique social, cultural and political context of smallholder farmers; and the 'mindset of the plough'. Cultural resistance to change can arise when traditional agricultural practices are questioned and farmers are shown new techniques (Hove and Gweme, 2018). For example, in many smallholder communities there is a culture of field ridging and clearing, often through slash-and-burn practices (Bunderson et al., 2015; Farnworth et al., 2016). The CA practices of minimum tillage and residue retention do not fit with these traditional practices. Further, cultural beliefs, for example that leaving crop residues in the field is associated with laziness and brings pests, act as barriers to adoption as they are firmly engrained in the mindsets of smallholder farmers (Scheba, 2017). Part of this cultural resistance to change is the 'mindset of the plough' (Brown et al., 2017). The 'mindset of the plough' refers to common beliefs that ploughing is necessary to combat weeds and that it increases soil fertility and productivity (Scheba, 2017). This static mindset about the importance of ploughing, often promoted by governments, means that CA principles are not easily accepted and implemented (Scheba, 2017; Ndah et al., 2018). This stems from the broader enabling environment of the social, cultural and political context (Mutenje et al., 2019). For successful CA implementation, the social, cultural, and political context needs to be accommodative of CA practices, and the acceptance and support of village leaders is needed (Ndah et al., 2018). Conflict can arise between CA and the village rules, making CA incompatible with the social, cultural and political context (Ndah et al., 2018).

4.3. Theme 3: informational resource barriers and enablers

Informational resources refer to the issue of information delivery through extension services, government infrastructure, and CA programs, as well as the knowledge intensive nature of CA (Table 4).

4.3.1. Challenges with information delivery

The primary informational resource category was information delivery. The top three variables were: knowledge gaps (lack of information); inadequate modification and adaptation; and the failure to link smallholder farmers to information systems; all of which are barriers. Knowledge gaps are one of the major impediments to the adoption of CA (Bunderson et al., 2015; Nhamo and Lungu, 2017). While many smallholder farmers claim to be aware of CA, most lack the necessary knowledge, skills, and capacity to integrate the three CA principles and implement the practice as a whole (Thierfelder et al., 2015a; Muzangwa et al., 2017; Raaijmakers and Swanepoel, 2020; Rusere et al., 2020). Consequently, raising awareness of CA and providing the necessary knowledge and skills are key factors for successful implementation (Senyolo et al., 2018; Rusere et al., 2020). However, it is important to note that Mugandani and Mafongoya (2019) show that closing knowledge gaps, without addressing other key barriers facing smallholder farmers, does not lead to adoption.

While the provision of knowledge and skills is essential, the successful implementation of CA is not possible without the modification and adaptation of CA approaches to local conditions (Brown et al., 2018b). Current CA programs have used top-down extension approaches to modify smallholder farmers' contexts to fit CA techniques, for example through the provision of resources, instead of fitting CA techniques to smallholder farmers' contexts (Brown et al., 2018c). This has led to questions about the feasibility, relevance, and practicality of CA for smallholder farmers. Adoption pathways need to be amended, allowing for flexible, transitional and participatory approaches that reflect local conditions and contexts (Ortega et al., 2016; Brown et al., 2020). One-size-fits-all CA promotion approaches, and dogmatic views about the implementation of all three CA principles, do not consider or appreciate the heterogeneity of the smallholder farming context (Ngoma et al., 2016).

Issues with information delivery are disproportionately experienced by smallholder farmers as they are not linked to major information systems (Brown et al., 2017). Smallholder farmers are not exposed to mass media as there is limited access to the internet via smartphones or computers (Abegunde et al., 2020; Raaijmakers and Swanepoel, 2020). Instead, smallholder farmers are dependent on communication via word-of-mouth, informal associations, and personal experience (Smith et al., 2016). To better facilitate CA knowledge transfer, smallholder farmers need to be better connected to information systems; this will simultaneously bolster household income by strengthening integrated farm activities (Abegunde et al., 2020).

4.3.2. The provision of extension services

The secondary informational resource category was extension services. Extension services are the primary mode of CA technology transfer to smallholder farmers. However, in southern Africa, extension services are often underfunded, understaffed and undertrained (Adenle et al., 2018; Brown et al., 2018d, 2020; Khataza et al., 2018). The top three variables of the extension services category were: access to/contact with extension, poor-quality service, and access to training. Both access to extension and access to training were significant enablers that enhanced adoption (Abdulai, 2016; Abegunde et al., 2020; Adenle et al., 2019; Manda et al., 2016; Ngoma, 2018; Tambo and Mockshell, 2018). Extension services are one of the main conduits of agricultural information and provide education about CA, and climate change adaptation and resilience (Abdulai, 2016; Brown et al., 2018c; Makate et al., 2019a, 2019b). Farmers who have greater contact with extension services receive more information, more training, and are better equipped to implement CA. Further, frequent contact of smallholder farmers with extension services establishes rapport and strong social networks that can facilitate awareness and learning (Abegunde et al., 2020). Extension services and support are crucial and are one of the strongest determinants of CA adoption and maintained interest (Brown et al., 2020; Maguza-Tembo et al., 2017; Nhamo and Lungu, 2017).

However, the number of extension visits to households is limited (Amadu et al., 2020). A study by Habanyati et al. (2018) in Zambia found that 74% of households had not been visited by extension services in over a year. This explains the barrier of poor-quality service. Not only is there overarching distrust in extension services, but the limited number of visits and lack of technical and advisory support have created overwhelming dissatisfaction and frustration among smallholder farmers (Brown et al., 2018b; Chinseu et al., 2019; Kassie et al., 2015; Raaijmakers and Swanepoel, 2020; Scheba, 2017). The limited capacity (financial and human) of extension services to provide training or set up demonstration plots means that CA messages are not reaching community members and that extension services are ineffective and inefficient (Brown et al., 2018c, 2018d; Lee and Thierfelder, 2017). For example, in Malawi, there is only one extension officer available per 1603 farming households, and in Tanzania, one extension officer available per 2500 farming households, (Kassie et al., 2015). The functionality of extension services is therefore crucial for successful and sustained CA adoption.

4.3.3. The knowledge intensive nature of CA

The third informational resource category was the knowledge intensive nature of CA. The top three variables for this category were: CA experience; farming experience; and knowledge intensive CA. Both CA experience and general farming experience were enablers and had a positive impact on adoption (Cheesman et al., 2017; Kunzekweguta et al., 2017), while the amount of agricultural knowledge and skills needed to practice CA was a barrier. The methods associated with CA's three principles are knowledge intensive and as such, acquired knowledge and experience through learning-by-doing increases CA's returns (Pedzisa et al., 2015a; Mugandani and Mafongoya, 2019). Consequently, a lack of knowledge and experience with CA resulted in disinterest or disadoption. Thierfelder et al. (2015b) found that a lack of CA experience was a farm level constraint which resulted in poor crop establishment and consequent disadoption. However, a study by Cheesman et al. (2017) in Zimbabwe found that the knowledge intensive nature of CA was not a sufficient explanation for the limited interest in, and adoption of, CA.

4.4. Theme 4: financial resource barriers and enablers

Financial resources refer to the economic potential of smallholder farmers and the practicality of implementing CA (Table 5).

4.4.1. Economic viability of CA

The primary financial resource category was economic viability. The top three variables in this category were: lack of credit; lack of capital/purchasing power; and household income (Table 5). Household income was the only enabler. A lack of credit and a lack of capital/purchasing power severely constrains the uptake of CA. CA requires significant initial investments, for example into labour, equipment, and inputs (Makate et al., 2019b), that make farmers who are liquidity-constrained less likely to adopt (Abdulai, 2016). Further, where credit is extremely limited, smallholders will usually implement conventional agriculture more intensively (Branca and Perelli, 2020), due to their risk averse nature. Essentially, a lack of capital and credit constrains smallholder farmers' access to productivity-enhancing agricultural inputs, which in turn constrains CA adoption. In this way, poorer farmers are side-lined from the CA adoption process, which favours wealthier farmers with greater household incomes despite claiming to be a pro-poor technology (Makate et al., 2019a).

4.4.2. High initial investment costs for CA

The secondary financial resource category, start-up costs, is intimately linked to the economic viability category. The start-up costs category consisted solely of barriers, the top three variables of which were: cost of herbicides; cost of machinery; and cost of fertilisers. Smallholder farmers are cash-constrained and resource poor, and as a result, they lack the financial means to secure the start-up agricultural inputs necessary for CA (Lee and Thierfelder, 2017). These high initial start-up costs often turn farmers away from CA, even if they are willing to experiment. Specialised CA machinery, for example direct seeders, is needed to drill seeds through mulched crop residues and into the soil (Mugandani and Mafongoya, 2020). A lack of machinery results in delayed planting and application of inputs, and, consequently, yield penalties (Mugandani and Mafongoya, 2020). Similarly, yield penalties arise due to a lack of fertiliser and herbicides.

4.4.3. Consequences of incentivised CA adoption

The third financial resource category was incentives. The only two variables were: material incentives; and agglomeration payments. To promote the uptake of CA, governments and NGOs have created CA programs that offer material incentives in the form of inputs (free fertiliser, herbicide, seeds), machinery and artificial market opportunities (Brown et al., 2017). While this generates spikes of adoption (Rusinamhodzi, 2015), and may be seen as an enabler, this adoption is in reality pseudo-adoption and is not sustainable. Once the support program reaches its expiry and the supply of inputs ends, smallholder farmers can often no longer afford to practice CA and resort back to conventional agriculture. Additionally, the supply of incentives alters the way in which smallholder farmers structure their decision to adopt CA (Bell et al., 2016); and some farmers only join CA programs to receive free inputs which are then used for conventional agriculture (Habanyati et al., 2018). A culture of financial expectancy is created from this historically politicised provision of inputs (Brown et al., 2018c). CA programs that supply material incentives create distorted adoption rates (Ngoma et al., 2016), that ultimately do not persist, and as a result, there is limited value in adoption statistics regionally (Brown et al., 2017).

To tackle the issue of incentivised adoption, agglomeration payments have been put forward. Agglomeration payments are a payment structure that provides bonuses to adopters whose neighbours have also adopted CA (Bell et al., 2016). Agglomeration payments harness peer-effects that are latent within the smallholder system, acting as a multiplier and enabler (Bell et al., 2018; Brown et al., 2018c). This links closely to the adoption by neighbours variable of the social capital category under the human resources theme. However, Ward et al. (2018) found that smallholder farmers participating in an agglomeration payment program in Malawi were less likely to comply when being monitored by the program. This further highlights the contextual nature of CA program success in southern Africa.

5. Recommendations for policymakers and practitioners

The scoping review generated a significant quantity of variables, both barriers and enablers, that affect the adoption of CA. For the sake of brevity, each variable could not be discussed individually, but rather, the top three categories of each theme and their variables were discussed. The overall findings of the review have shown that amongst the overwhelming diversity of variables, certain key barriers and enablers need to be considered when implementing CA programs. To facilitate the uptake of CA, by taking advantage of enablers and overcoming barriers, the Conservation Agriculture Suitability Framework for Smallholder Farmers (CASF) was developed.

5.1. The Conservation Agriculture Suitability Framework for Smallholder Farmers (CASF)

The CASF has been designed to aid policy makers and program managers (Fig. 4). The scoping review has revealed that CA is only successful when the unique contextual barriers and enablers of the target smallholder environment are considered. Consequently, the CASF acts a guide for practitioners. The CASF outlines three governing concepts – feasibility, context, and relevance. Feasibility refers to the ease and convenience of practising CA; context refers to the local enabling or disabling conditions present; and relevance refers to the appropriateness of CA given the circumstances. Under each governing concept, the key influential physical, human, informational, and financial resource categories are listed. The aim of the CASF is to act as a demonstrative outline of the salient contextual factors to be considered by CA programs. The CASF is not a prescriptive checklist, or a panacea, but is rather a conceptual framework intended to augment CA programs and facilitate the appreciation of smallholder farmers' heterogeneity. The CASF aims to assist practitioners in determining whether CA is the appropriate agricultural intervention, and if it is, to create CA programs with sound practices and community value The diversity of variables outlined in Table 2–5 should not be ignored and neither should the overwhelming number of barriers be a stumbling block. Instead, each CA program needs to conduct research into the specific barriers and enablers that face the target smallholder farmers, before implementation. Participatory approaches should be used so that community members can voice their concerns and perspectives and aid in the construction of agricultural interventions that most suit the context. While the institutional and policy environment were beyond the scope of this review, the CASF should be used at a farm level, in conjunction with assessments of suitability at municipal, regional, and national levels, to determine whether CA is the appropriate agricultural intervention and facilitate good CA practices which work best for the community involved.

5.2. Limitations of the scoping review

The scoping review's primary limitation is that it was conducted by a single reviewer, potentially resulting in bias (Peters et al., 2015). Further, the single reviewer is a novice in the field of scoping reviews and necessary skills were gained throughout the review process. The scoping review also excluded literature not written in English. Due to time constraints, the scope of the review was restricted to 2015–2020. However, similar findings and general deductions were apparent across the identified records, leading the reviewer to believe that the scoping review's overall conclusions are accurate and valid.

6. Conclusions

Conservation agriculture remains one of the primary climate-smart agricultural techniques with the greatest potential, given it is applied in the appropriate contexts. The scoping review contributed to the knowledge base of CA by outlining the numerous barriers and enablers of adoption for smallholder farmers, but ultimately, by revealing the contextual determinants of successful CA implementation within southern Africa. The review has demonstrated that smallholder farmers are not homogenous, and that interconnectivity exists between the uptake of CA and the geographical location and associated characteristics of smallholder farmers. The review indicated that universal barriers and enablers which consistently explain CA adoption in southern Africa

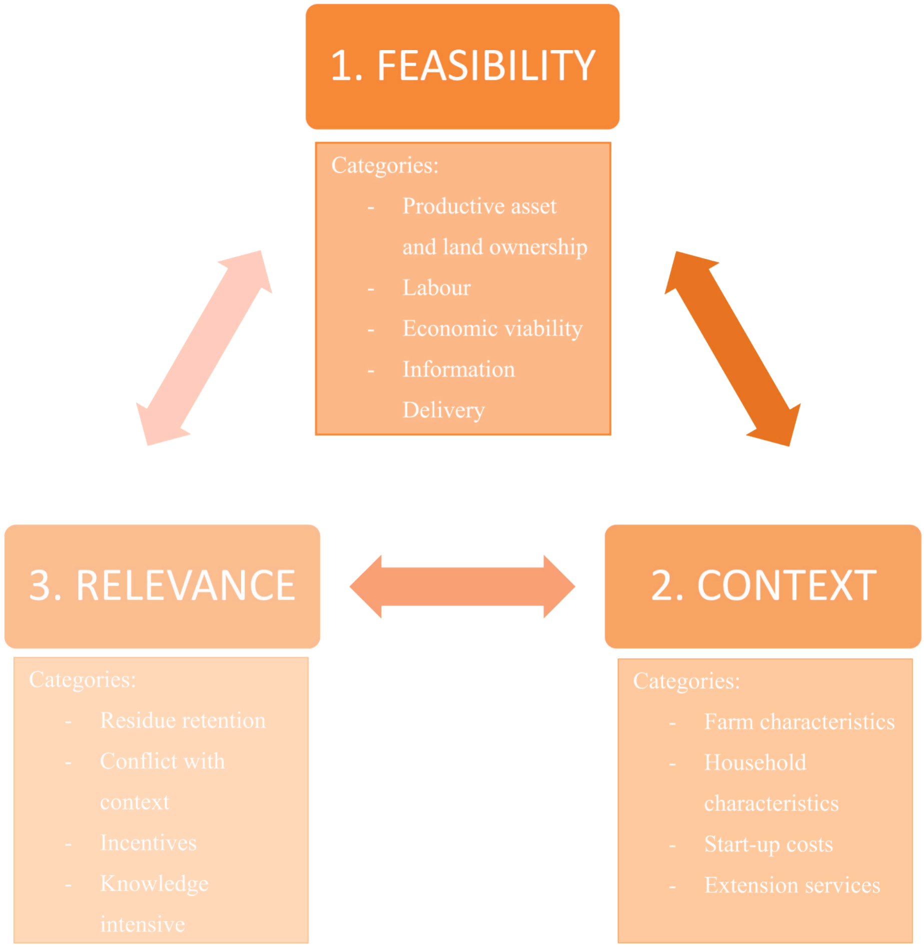

Fig. 4. The Conservation Agriculture Suitability Framework for Smallholder Farmers detailing the important categories of barriers and enablers of adoption. The governing concepts of feasibility, context and relevance are intricately connected and involve continuous feedback loops. Each concept is balanced upon the other such that if one governing concept fails, the others will fail too.

cannot be determined and that some barriers, in combination with CA programs, can have adverse effects (such as greater input costs, higher labour requirements, and gendered knowledge gaps). Further, the barriers and enablers identified are not necessarily unique to CA but are rather general constraints surrounding the livelihoods of smallholder farmers; CA is unlikely to be successful in southern Africa if these constraints are not taken into consideration. The smallholder farming context in southern Africa is a low-external-input system that consequently produces low outputs. The scoping review suggests that CA is not well-suited to the southern African smallholder farming context and as a result, partial adoption of the three CA principles will be commonplace, as smallholder farmers reduce the intensity of CA practices to match their resource endowments. Low CA adoption rates, and high disadoption rates, are therefore not necessarily the result of dissatisfaction with CA, but rather the result of practical limitations to its implementation. Given the restrictive smallholder environment in which CA is practiced, we do not see CA, the way it is currently promoted, as a significant regional contributor to the achievement of SDGs 2 and 15; numerous barriers prevent the implementation of CA's three principles and thus limit meaningful contributions to food security and the reversal of land degradation.

The review has called into question the relevance of one-size-fits-all approaches to CA implementation. The Conservation Agriculture Suitability Framework for Smallholder Farmers was created for practitioners to facilitate appreciation of the smallholder context and promote incremental change through flexible approaches that accommodate local barriers and enablers. Ultimately, the success of CA in southern Africa will be underpinned by how well it fits into the broader smallholder farming system. It is for this reason that the four major resource themes (physical, human, informational, financial) and the contextual nature of their respective barriers and enablers are brought to the forefront of CA implementation programs.

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