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Pathways to intensify the utilization of conservation agriculture by African smallholder farmers

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Research Paper

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Abstract

If the United Nations Sustainable Development Goals are to be achieved, African smallholder farmers will need to embrace new technologies such as conservation agriculture (CA) in order to increase both their productivity and sustainability. Yet farmers have been slow to embrace CA and when they have, they are inclined to do so at limited intensities. Current investigations tend to apply binary frameworks that classify all utilizations as 'adoption', and do not consider in depth the farmer perspectives and contextual realities that affect farmer decision-making on the intensity of use. We analyze 57 in-depth, semi-structured interviews with farmers who implement CA to understand why they tend to do so at limited intensities and what is required to intensify their CA activities, both for them and others within their communities. While most farmers reported substantial yield benefits from using CA, this was mainly related to input intensification (particularly herbicides) and was limited by constrained financial resources. Overall, the intensity of CA utilization was constrained due to farmer-identified constraints across their physical, financial, human and informational resources. Because of this, stagnation at low intensities of CA utilization was common, reflecting the assumed transformational adoption pathway for CA and the focus on binary adoption, as opposed to modification and the broader utilization process. To overcome this, we propose a more nuanced transitional approach focused on the intensification of four broader principles of CA over time [i.e., (1) strategic tillage, (2) soil protection, (3) crop diversification and (4) input management] as opposed to the strict packaging of CA practices. Such a change in approach will foster increased positive perceptions within the community and allow farmers to locally adapt CA to build their own way toward complete CA utilization and with less need for subsidization.

Introduction

Agricultural production in sub-Saharan Africa (SSA) faces a challenging future in light of a more variable climate (Jones and Thornton, 2003) and increasing land degradation (Bai et al., 2008). Noting SSA's growing demographic pressures (Fuglie et al., 2012), demand for cereals is likely to triple over the coming three decades (van Ittersum et al., 2016). Yet current productivity for key food crops in Africa remains nearly stagnant (FAO, 2016), leading to rising concerns over food security and environmental sustainability.

Much of the discourse on these issues has focused on conservation agriculture (CA), defined as the grouping of three inter-related principles that are often promoted in a restricted way and thus interpreted as prescribed practices: minimal soil disturbance, permanent soil cover and rotation of diverse crops (FAO, 2014). CA has shown extensive potential for agronomic and environmental improvements (Ndah et al., 2014; Thierfelder et al., 2015, 2016; Mupangwa et al., 2016), yet despite more than five decades of CA within the research and extension systems throughout eastern and southern Africa, the uptake of CA remains limited. According to Brown et al. (2017b), this limited uptake reflects two key themes: (1) the limited uptake of CA by smallholder farmers; and (2) a tendency for the smallholder farmers who do apply CA to do so at low intensities.

The literature has generally addressed the limited uptake of CA through binary classifications of farmers as either 'adopters' or 'non-adopters'. In doing this, there has been limited exploration beyond the 'success' and/or explanation of 'adoption' and limited understanding of the intensity of CA use by farmers, and particularly of modification by farmers to meet their local contextual realities (Glover et al., 2016). This is in strong contrast to the growing body of literature suggesting that incomplete adoption of CA dominates uptake in Africa and that three-factor CA is rarely fully embraced (Baudron et al., 2007; Gowing and Palmer, 2008; Giller et al., 2009; Pannell et al., 2014). Brown et al. (2017b) found that while binary adoption of CA was considerable amongst eastern and southern African smallholder farmers (Ethiopia:

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57%, Kenya: 89%, Tanzania: 94%, Malawi: 94% and Mozambique: 98%), 99% of CA implementation was in modified forms and the intensity of CA use was constrainted to below 40% in all five studied countries. This highlights a need to specifically explore with farmers who are implementing CA why they do so at limited intensities, yet this is often overlooked due to the application of binary classifications that treat all utilizations as adoption.

The literature body also has a tendency to apply econometric lenses to household survey data (e.g., Bekele and Drake, 2003; Suri, 2011; Arslan et al., 2014; Baudron et al., 2014; Kathage et al., 2015; Ngoma et al., 2015; Pedzisa et al., 2015). While such approaches can identify commonalities in the features of 'adopters' or 'non-adopters', they tend to lack depth for understanding farmer decision-making and the determinants of the various forms and intensities of CA utilization (Andersson and D'Souza, 2014; Brown et al., 2017b). Chambers (2006) argued the need for a deeper exploration of perceptions of those involved in rural development programs, noting that such explorations are rare but important in understanding decision-making. Such qualitative explorations are critically important for probing farmer experiences and eliciting key lessons that can help to improve on farm outcomes, as well as R&D efforts in support of small farms, with several recent studies affirming such a need (Andersson and D'Souza, 2014; Glover et al., 2016; Brown et al., 2017b).

The purpose of this study is to deeply explore directly with farmers the reasons for their limited intensity of CA utilization, an area within the literature body that is yet to be deeply explored. Analysis of this subset of farmers is particarly improtant noting that the perceptions of users are influential and important in both the scale of their uptake and the generation of positive message for potential nearby users. Furthermore, these perspectives have rarely been analyzed beyond the success of 'adoption', leaving a void in the understanding of the diverse implementations of CA that occur in practice. Hence, we work from the example set in Brown et al. (2017a) who explored the negative evaluation of CA by African smallholder farmers with this study exploring positive evaluation, and more specifically the decision-making of farmers in implementing low-intensity CA activities once positive evaluation has occurred. Hence, all respondents in this study have positively evaluated CA and have been able to implement in some capacity. Farmers who negatively evaluate CA, who are currently evaluating without making an implementation decision, or who are yet to begin evaluation due to a lack of information are excluded in order to understand our specific research question: Why do farmers choose to implement CA at low intensities?

Exploring the perspectives of this subset of utilizing farmers provides an opportunity to increase our understanding of the benefits, feasibility and relevance of CA to African smallholder farmers based on utilizing farmers' lived experience. Such perspectives are largely absent from the literature, and hence this study provides a unique exploration of how to increase the intensity of utilization for both utilizing and non-utilizing African smallholder farmers.

Methods

This study implements qualitative methods to deeply explore directly with utilizing farmers the reasons for their resource allocation decision-making in general, and for the intensity of CA utilization more specifically. We acknowledge that qualitative methodologies have limitations as they may not be representative of larger populations and may lead to bias in reporting. Yet such work is required to reach beyond current understandings based on quantitative analysis of household surveys. The methodology outlined in this section attempts to address many of the known limitations of qualitative research methods.

Study implementation

Details of broader investigation

This paper forms part of a broader exploration of the sustainable intensification of maize–legume farming systems in eastern and southern Africa through exploration of various perspectives from the subsets of African communities, the first of which is Brown et al. (2017a) which explores the negative evaluation of CA by African smallholder farmers. Twenty case study locations were purposively selected on the basis of: (1) the importance of maize–legume systems for farmer livelihoods; (2) subsequent high potential impact of CA on farmer livelihoods (3) and existence of promotional activities on CA currently active in the district. Respondents were then purposively selected via a snowball sampling methodology (Fig. 1) to ensure a diversity of perspectives were obtained. Snowball methodologies have been variously used in qualitative research to access otherwise hidden populations (e.g., Browne, 2005) and it should be noted that this work is not intended to provide a representative sample of communities, but specifically seeks a diversity of perspectives and then investigates them in a disaggregated manner to avoid confounding different subsets of farmer decision-making.

Details of specific study

The total dataset of the broader study consists of 325 semi-structured interviews conducted in 85 communities across 20 case study locations in six countries (Ethiopia, Kenya, Uganda, Malawi, Zambia and Mozambique). As the purpose of this paper is to explore the experiences and decision-making of farmers utilizing CA, a subset of respondents from the larger dataset was utilized. As such, this study explores a subset of 57 respondents from 47 villages in 17 case studies from six countries. As per the snowball methodology (Fig. 1), this paper explores 'Farmer Set B' (current utilizers) which comprises:

Modified utilizers: Farmers implementing elements of CA but in a modified form (i.e., not in a 'complete' three-factor form; 29 respondents);

Semi utilizers: Farmers implementing CA in a three-factor form on some area of their farm, but not on all available area (25 respondents); and

Total utilizers: Farmers implementing CA in a three-factor form on all available area of their farm (three respondents).

Despite all efforts to identify total utilizers in each case study, only three total utilizers were identified. This reflects the strict classification of total CA utilization for the purposes of this study and hence the limited total utilizers that exist in each of the studied countries (see Brown et al., 2017b).

Details of interviews and analysis

An interview schedule was developed to provide the opportunity for each respondent to explore their decision-making regarding their CA activities and broader livelihoods. Written informed consent was obtained from all study participants prior to the interviews. Except in two locations in Ethiopia where custom demands it, no remuneration was made to farmers to participate

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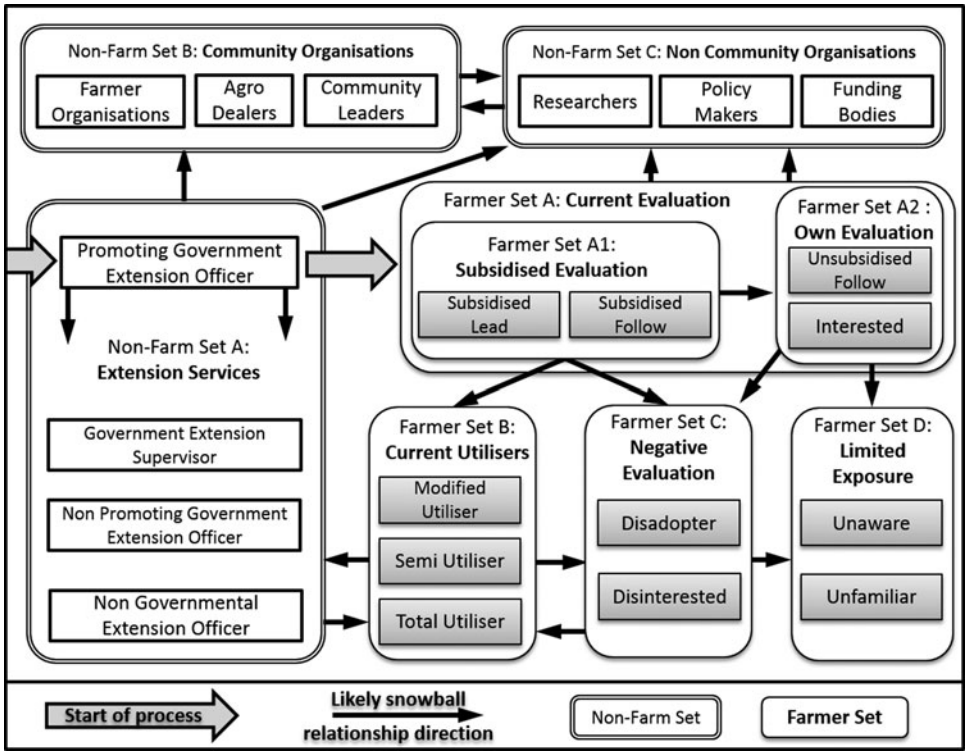

Fig. 1. The classification of respondent sets and snowball methodology employed in this study, first proposed in Brown et al. (2017a).

in the discussion. Interviews were conducted primarily in the preferred local language, except in cases where the respondent was comfortable expressing themselves in English. A translator was used from a local agricultural research station, and was, in the majority of cases, unknown to the respondent.

Interviews were digitally recorded and transcribed independently of the translator to English. All transcribed interviews were coded using Nvivo™ (Version 11) content analysis software. The average length of the interviews was 40 min, but ranged between 13 and 92 min. The interview subset for this article includes 40 h of interview. Figure 2 provides the characteristics of respondents in the subset, alongside an alphanumerical code that is used in the results to identify respondents by characteristic/s.

Theoretical framework

This paper implements the livelihood platforms approach (LPA) proposed by Brown et al. (2017a; Fig. 3). The LPA provides a framework to explore farmer decision-making embedded within the wider community and institutional context. Farmer decision-making is proposed as a function of three farmer evaluations:

(1) Will utilization of the practice be potentially beneficial?;
(2) Is the practice feasible with the resources I have or can access? and
(3) Does the technology fit within my livelihood objectives and broader context?

Farmers undertake these three evaluations based on the balance of four livelihood platforms (individual, household, community and institutional) which are supported by four resource pillars (physical, financial, human and informational).

Results

Respondents were generally involved in a CA program and averaged 3.7 years of experience with CA. A summary of characteristics of respondents, including the types of implementation, is given in Table 1. Despite specific efforts to locate utilizers (modifying, semi or total), we were unable to identify utilizers in three of our 20 case studies and only three 'total' utilizers were identified (Fig. 3). Respondents confirmed limited utilization of CA, with the majority of respondents estimating utilization of CA in any form to be below 5% in their community, and a quarter identifying themselves, to the best of their knowledge, as the only utilizers of CA in their community. Even where respondents identified some use of CA in their community, it was generally in limited forms (e.g., 'most of them are doing CA on just [0.025 acres]'—K3).

Perceived benefits of CA

Physical resource benefits

No respondent identified yield as decreasing under a CA system, and respondents generally estimated substantial yield benefits from CA (e.g., 'Since starting CA, I am now getting 18 bags not 10 bags, so double'—Q14). This reflected three perceived physical benefits of CA: improved soil fertility, reduced erosion and increased moisture retention (Table 2).

Human resource benefits

CA utilization was perceived to reduce labor requirements by 37 of our 58 respondents. The reduced need for weeding due to herbicide use was perceived to be a major benefit of the shift to CA (e.g., 'CA is better because once I apply the herbicides I don't go back again for weeding while in conventional fields I have to go back for weeding'—F15). Some farmers also identified that CA allowed them to

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Case Study		ID	Village	Category	Gender
Ethiopia	Pawe (P)	No 'utilisers' identified			
	Boset (W)	No 'utilisers' identified			
	Hawassa Zuria (H)	No 'utilisers' identified			
	Gobu Sayo (B)	B5	Gambella Tere	Semi	Female
		B6	Ongobo Bekenisa	Semi	Male
	Shalla (S)	S2	Auine Gema	Semi	Male
Uganda	Lira (G)	G11	Anai Obeare	Total	Male
	Kalongo (J)	J4	Kibmba	Modified	Male
		J11	Buruli	Modified	Female
		J14	Kyakabombo	Modified	Male
Kenya	Kyeni (E)	E3	Kariru	Total	Female
		E5	Kathunjuri	Modified	Female
		E6	Kathunjuri	Modified	Female
		E8	Moburi	Modified	Male
		E15	Kathuri	Modified	Male
	Kanduyi (Q)	Q6	Tembelela	Total	Male
		Q9	Kisuluni	Modified	Male
		Q13	Natundire	Modified	Female
		Q14	Kongoli	Semi	Male
		Q15	Kimoiyi	Modified	Female
		Q21	Siilila	Semi	Male
Malawi	Mitundu (C)	C3	Chimsamba	Semi	Female
		C10	Matambo	Modified	Female
	Rivirivi (D)	D7	Lakalaka	Semi	Female
		D9	Chimbalanga	Modified	Female
		D13	Rivirivi	Modified	Male
	Tembwe (F)	F6	Kaphatenga	Semi	Female
		F9	Fiampido	Modified	Male
		F15	Chicombo	Semi	Female
	Mtumthama (K)	K2	Mblanda	Semi	Male
		K3	Mblanda	Semi	Male
		K4	Mblanda	Semi	Female
		K5	Mblanda	Semi	Male
		K9	Puye	Modified	Female
		K11	Puye	Modified	Male
		K16	Mblanda	Semi	Female
		K18	Wimbe	Semi	Female
	Mwansambo (T)	T1	Nambale	Semi	Male
		T8	Masianhkuni	Semi	Male
		T9	Bwelekeni	Semi	Male
	Kululu (M)	M15	Kipiri North	Semi	Male
	Nsipe (N)	N7	Chagwamomwe	Semi	Male
Zambia	Lundazi (X)	X1	Kolowa	Modified	Male
		X3	Kapaeka	Modified	Female
		X6	Katayeni	Modified	Male
		X13	Mwalimo	Modified	Male
		X18	Vukankulu	Modified	Female
	Chipata (Z)	Z1	Mulonyeni	Modified	Male
		Z2	Chimonya	Semi	Male
		Z4	Chigangeni	Semi	Female
		Z9	Kefa	Modified	Male
		Z10	Kefa	Semi	Male
		Z18	Khokhwe	Modified	Male
		Z19	Rukuzye	Semi	Male
		Z20	Mgubudu	Semi	Male
Mozambique	Ulongwe (U)	U8	Chikudu	Modified	Male
	Sussendegnga (Y)	Y2	Mussacumbira	Modified	Male
		Y13	Munchinga	Modified	Female
		Y15	Munchinga	Modified	Female
		Y16	Munchinga	Modified	Female

Fig. 2. Location and classification of respondents (map courtesy of Google Maps, 2017).

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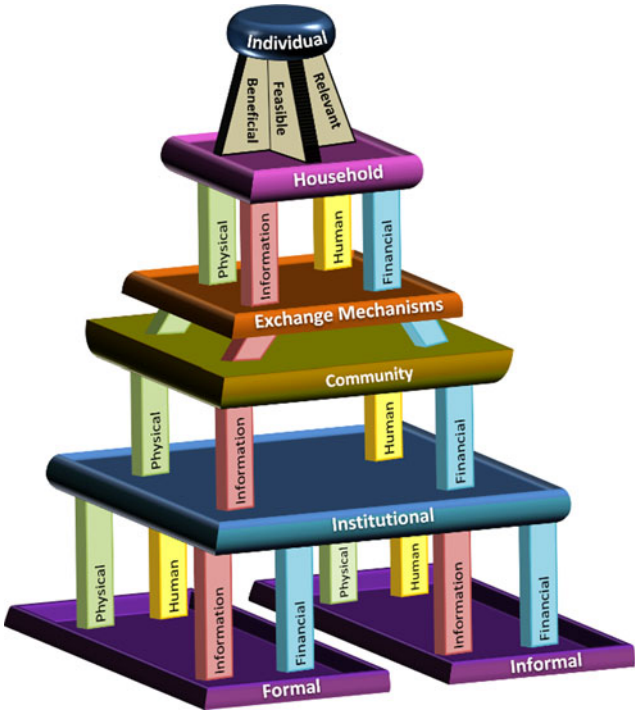

Fig. 3. The livelihood platforms approach (LPA) framework as proposed by Brown et al. (2017a).

modify their calendar of events and move labor to less constrained times (e.g., 'If we are serious that we are planting an acre [of CA], we can take four days to prepare and plant, but this can be done in the dry season'—J4). Traditional tillage practices were also perceived as labor intensive (e.g., 'we spend much time ridging the land which is wasteful'—G11).

Financial resource benefits

The major financial benefit of CA was linked to the use of herbicides (primarily glyphosate) and a reduction in the need for hired labor (e.g., 'If I buy one packet of 'Weedall' [non-selective post-emergence glyphosate herbicide], it is around 400 [Kenyan] shillings. My field is one acre so I use two packets to spray and it will enable me to prepare my land for just 800 shilling, which I am able to do. But ploughing, it might cost almost 3000 or 4000 shilling [with hired oxen]. For a tractor it is even 4500 shilling'—Q15).

Constraints, adaptations and pathways to greater CA utilization

Physical resources

Stover resources. Even with the identified increase in yield, respondents identified stover resources as the primary physical resource constraint (e.g., 'We are doing half an acre [of CA]. This size of the field is not ideal and we wished to do much more but we do not have stover'—K18). Stover constraints primarily reflected high competition for stover residues, limited community availability and the security of stover in CA fields (Table 3). To overcome substantial stover deficits, many respondents stated they address stover constraints through planting alternative forage and fuel sources (e.g., 'At every border of my farm I have Napier grass. So I can use that, and I have also established these fodder trees'—Q6; 'we will plant more trees so that we should be using them as firewood instead of using stalks'—U8). When this was not the case, respondents identified the need to concentrate CA in one location through the importation of stover from surrounding fields (e.g., 'I add from other fields because mine are always not enough'—M15). However, this often increased the cost of implementing CA (e.g., 'It is very hard [to find stover] as I have to travel far to find them…[and] I need money to pay for stover to be carried to my field'—Y13).

Due to stover security concerns, stover was often imported from fields nearby to residences to monitor stover loss (e.g., 'Our field hasn't been [burned] because we do it close to our house'—K16). An alternative adaptation was periodic removal of stover (e.g., 'If we just leave the stalks there sometimes they do burn so when we bundle them and lay them [when the rain comes] so they don't bother us'—X3). Kenyan respondents indicated that most animal rearing occurred in enclosures and this reduced stover security concerns (e.g., 'People keep the zero grazing in their place so their cows don't go to other places'—E5), while in southern Africa, some respondents indicated that local by-laws helped them ensure their stover security (e.g., 'We do not worry because there is a by-law that has been put in place by the chiefs'—K2). However, other respondents identified concerns over their implementation (e.g., 'They can put a rule that people should not burn… We have that now but it is not seriously enforced at the moment'—K5).

Input markets. Respondents identified that increasing the intensity of their CA activities was challenging due to issues with the availability and quality of, and access to, inputs required to implement CA (e.g., 'You want to use the method but you can't get what you want… I would say availability of those materials is a big hindrance'—E15) and most respondents emphasized that obtaining inputs took substantial effort (e.g., 'If herbicide is available widely, we could expand… The problem of herbicide is that it is not available, not a finance issue, but one has to go to Adama or even Addis Ababa to get the supply'—S2). The quality of inputs on the market was also an issue (e.g., 'That is something which is burning farmers. They are losing faith in buying inputs… these agro inputs like chemicals, like herbicides, they are fake. They don't do what they are supposed to do. That is what also is scaring the people'—G11). Despite project-aligned farmers obtaining inputs directly from their associated projects, there were often issues with the sharing of equipment which also limited their intensity of use (e.g., 'We do not have a sprayer, we just borrow… at times it becomes very busy and the owner is using it and I want to use it at the same time. By the time I have access to it the weeds have grown'—Z2).

Financial resources

More than half of respondents identified constrained financial resources as their reason for limited CA intensity, reflecting a lack of capital, limited credit and low financial return for output (Table 4).

In exploring the financial context of their communities, farmers tended to identify poverty as a key determinant of the limited CA utilization (e.g., 'Most people are poor so they fail to buy farm inputs'—F9). Because of this, when respondents interacted with others in their community to promote CA, there was an expectation that inputs be provided to facilitate CA adoption (e.g., 'people expect to receive something from the technology, so if the project brings nothing the adoption rate becomes very low'—T9). This was related to a history of input provision by projects to encourage

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Table 1. Summarized characteristics of respondents

Characteristics		Modified use	Semi use	Total use	Overall
Involvement with CA program		76%	80%	100%	79%
Years of experience with CA		4.0	3.5	3.7	3.7
Proportion of farm under CA		43%	22%	100%	37%
Area of CA (acres)		2.6	1.0	1.5	1.9
Herbicide use		76%	68%	100%	74%
Tillage practice	Riplines	14%	16%	0%	14%
	Basins	17%	72%	100%	46%
	Dibble	3%	12%	0%	7%
	Full use	*34%*	*100%*	*100%*	*67%*
	Periodic	52%	0%	0%	26%
	No	14%	0%	0%	7%
Soil cover	*Full use*	*28%*	*100%*	*100%*	*63%*
	Incorporation	17%	0%	0%	9%
	Periodic removal	17%	0%	0%	9%
	Low intensity	31%	0%	0%	16%
	No	7%	0%	0%	4%
Legume use	Rotation	31%	84%	33%	54%
	Intercrop	28%	16%	67%	25%
	Full use	*59%*	*100%*	*100%*	*79%*
	Low intensity	24%	0%	0%	12%
	No	17%	0%	0%	9%

the use of new technologies (e.g., 'People are difficult. They are accustomed to receive things when they are told what to do'—Z9).

Human resources

Only a minority of farmers identified that labor constraints were a reason for their low intensity of CA use. When respondents did identify labor constraints, they tended to assert that:

(1) Stover importation was a labor burden and poorly perceived by the community members (e.g., 'They think I'm crazy when I'm doing it… People laugh at you when carrying the stalks thinking that you are crazy'—M15) and often led respondents to reduced intensity of CA utilization (e.g., 'What stops me from expanding is when it comes to gathering stalks… it is a tiresome job'—F9).
(2) Community labor was often unwilling to import stover (e.g., 'It is difficult to find labour to lay the stover even if it is a cheaper method. The labour force prefers to make ridges rather than carry the stover'—K5).
(3) Herbicides were required to reduce labor compared with conventional practices (e.g., 'If you have not applied the herbicides that's when CA becomes a problem [for labour]'—F15).
(4) Irrigated production often limited farmers' time and hence ability to implement dry land CA activities (e.g., 'After harvest a lot of people produce in the lower lands with irrigation, so they go and spend a lot of time there'—Y2).

Table 2. Physical resource benefits of CA utilization identified by respondents

Benefit		Representative quotation(s)	ID
Soil fertility	Nitrogen fixation by legumes	'I understand that groundnuts fix nitrogen so when we plant maize where there was groundnuts the maize will do well'	X18
	Crop residue breakdown to hummus	'Every time I am putting the residues they are turning into manure, thereby increasing the fertility'	F15
Soil erosion	Reduction in loss of topsoil	'When you till the land the soil becomes very loose. After some time you notice that what remains in the fields where you make ridges is just sand, the good soil is taken by the wind and water. But when you do CA that is not happening'	K3
Soil moisture retention	Stover cover	'I covered the soil with the trash and the water remains in the soil and then maize grows well'	E3
	Climate adaptation	'Where I did CA, even though there was no sufficient rain, maize did very well while in the conventional field the maize wilted'	C10

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Table 3. Stover constraints identified by respondents

Constraint		Example quotation(s)	ID
Competing uses	Animal fodder	'We know that if we leave stover on field it is good for the soil. But in reality we need to feed our livestock'	S2
	Firewood	'It's not that we can't do CA but it is because of the problem of stalks. We need for fuel'	U8
	Manure production	'I collect some of the stovers to feed the livestock… then the manure I get from that animal I take it to the farm'	E8
	Tobacco preparation	'we use a lot of stover to go and burn where we plant the tobacco nurseries'	K16
	Income generation	'Some (crop residues) we sell to those who have cows'	E5
Transport issues		'I fail to expand because I don't have the means of stover transportation'	M15
Limited community availability		'What hinders is me is lack of stalks because others refuse to give me their stalks'	C10
Stover security	Rodent hunting	'The major problem in our area are the people that hunt mice. Mostly they burn the fields when then you are not there'	Z1
	Communal grazing	'The residues can be a big problem. Right now there is competition between us and the livestock of others'	F15
	Theft	'What makes it difficult is that there are only a few people in this area who practice CA so people have a tendency of taking our stalks and using them as firewood'	U8
	Fire (general)	'I and many other farmers fail to do CA because we think that other people may burn our stalks with their own reasons'	M15
	Uncontrolled wild fire	'I just worry that maybe my neighbour will burn his/her field and the fire will reach into my field'	K4
	Jealousy	'We are not able to increase the acreage because where we were getting the stover has been burnt… It is because of jealousy for these farmers saw our good harvest so they burnt the stover'	K18

Many respondents attributed their utilization of CA to their focus on farming activities and devotion of labor only to farming (e.g., 'I am not employed anywhere, as I am just totally depending on my farm'—Q6). The opportunity cost of agricultural labor was also important in case studies that were located close to major trading hubs and towns (especially near Embu, Bungoma and Lira), where farmers were not willing to invest their labor in farm activities (e.g., 'In our village, people plant maize but not well as they are busy doing other things … they go to town for trading and business, so they are not serious'—Q9; 'most people need to participate in business around town… Farming here is for home consumption and very few do it for business'—G11).

Informational resources

Access to and availability of informational resources. Respondents were generally well connected to information sources, with only 12 out of the 57 respondents not having been involved in a CA project at some point. The majority of the respondents identified themselves as CA lead farmers who were receiving inputs to provide CA demonstrations to the community, and often identified

Table 4. Financial constraints identified by respondents

Constraint		Example quotation	ID
Household	Capital requirements	'Farming inputs are also expensive such that we fail to buy what we require'	Z19
	Increasing price	'The inputs I use now are the same as before but the price is much higher. It used to pay 500 Ethiopian birr for DAP [fertiliser] but now it is 1600 Ethiopian birr'	S2
Credit markets	Credit availability	'without a finance agent we cannot do everything we want'	Y2
	Credit risk	'we avoid those loans because sometimes at the end of the year we have problems and cannot repay the loan so we sit in fear'	E12
	Credit cost	'Repayments are very high and require much money and cattle and other assets to guarantee the loan. So it is too expensive and I don't want to do it'	Y2
	Credit does not match requirements	'taking credit may be a burden on me in future… the amount they give is not as you want'	S2
Output markets	Unreliable markets	'Mostly we sell to vendors because we do not have reliable markets'	X1
	Low returns	'It is difficult to find the money to buy fertilizer even after we sell the produce'	K2
	No pathways to build capital	'It took me so long to expand because of the way I was finding resources. It was so hard for me to have funds to purchase fertilizer and seeds'	X1
	Market access	'the challenge is that we have to transport our produce to them [good markets]'	Z2

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Table 5. Strategies identified by respondents to increase the availability of informational resources on CA

Requirement	Example quotation	ID
More extension activities	'Increase the number of lead farmers to reach the remaining farmers'	T9
	'we need more field officers to change the community, more field days and they can also attend and change their way of farming and life'	Q14
	'I think if the extension workers can organise more meetings to address the farmers it can help'	F6
Reduce burden on extension officers	'There is few extension staff. You might find that in our case, our ward, we only have one extension officer handling the whole ward… We are praying hard for government to employ more extension officers'	Q6
	'In this sub-county, there is only one extension officer. But in the sub county you can find eight parishes. So as that one person cannot be able to move within those parishes to talk about this idea of CA. So the extension workers are low and they cannot do it'	J4
Increase practicality of learning opportunities	'If the extension would teach and then do the practical, going through fields and teaching, that would be helpful'	Z10
Provide ongoing follow up training	'What I say is teaching. Not only once and twice but continuous teaching. The extension agents once they train, they do not come and follow up'	B6

direct lines of contact with government extension officers (e.g., 'I will call my officer for agriculture… I like him because when I call him he runs to come here'—Q9) or substantial personal engagement (e.g., 'She comes often, three to four days a week'—C10). Despite this, respondents consistently asserted concerns about their knowledge of CA (e.g., 'I am satisfied with CA but I still need more information to continue with it'—Q13).

Respondents identified that information about CA was difficult to access in their communities (e.g., 'I am not able to learn anywhere, even though this year I am interested to learn'—Y15) and particularly so if a farmer was not connected with a project (e.g., 'It would have been difficult [for other farmers to gain information] because other than the (CA) project, we have never seen any group training in the use of CA methods'—J4). Overall, information constraints were generally seen as the largest inhibitor of wider utilization of CA in their communities (e.g., 'Training is the most important… Unless people get the necessary training change is not expected'—S2). To achieve this, respondents identified key strategies to facilitate greater informational exchange (Table 5).

Quality of informational resources. Respondents identified that a confusing informational environment existed for them and within their communities, which reflected incomplete information and multiple conflicting messages regarding CA (Table 6). Conflicting information manifested itself in issues such as stover incorporation due to prior messaging on stover management (e.g., 'we re-pack the soil so that the fertile top soil and the residues of the crop are moved lower. It is for fertility'—Y2).

Discussion

Benefits of CA implementation

The net benefits of CA utilization for African smallholder farmers continue to polarize the agricultural R&D community (Andersson and D'Souza, 2014; Giller et al., 2015; Pittelkow et al., 2015). A meta-analysis of CA studies by Pittelkow et al. (2015) found that, on average, no-tillage in itself resulted in a yield penalty. Our results indicate that utilizing farmers did not perceive a yield gap. This likely reflects that most studies compare tillage and no tillage systems with the same input usage, but the comparison generally made by African smallholder farmers is between a low input, traditional tillage system with a high input, CA-based system (visualized in Fig. 4). Our findings confirm that much of the perceived benefit of CA implementation is related to input use (Kirkegaard et al., 2014), particularly noting the nitrogen depletion common in the soils of SSA (Lundy et al., 2015).

Themes contributing to the low intensity of utilization of CA

Key themes emerged in the reasons why farmers were led to incomplete utilization, and why others in their communities

Table 6. Conflicting and incomplete information identified by respondents

Conflicting issue	Example quotation	ID
Herbicide safety	'they fear chemicals will spoil their soil when they plant'	Q13
	'some of them fear that if they spray and they have animals they will go and graze there and die'	Q15
Between projects, NGOs and government	'Right now, they [organisations] say different things and when it comes to the ministry, they tell you to plough and the NGO say plough and the project tell you to practice conservation agriculture. So it seems as if we are working separately'	Q21
Community leaders	'Extension staff should continue talking to the chief so that the chief can encourage the subjects on CA'	K18
Religious teachings	'Some are saying even in the bible there is chapter saying you dig the land in order to get enough air [for plant growth]'	E3
Government subsidizes	'They [the government] are contradicting themselves. Because now we have six subsidised tractors in Bungoma and 15 in Busia. So there is that confusion. As much as they try to tell us to practice CA, there is that contradiction'	Q14

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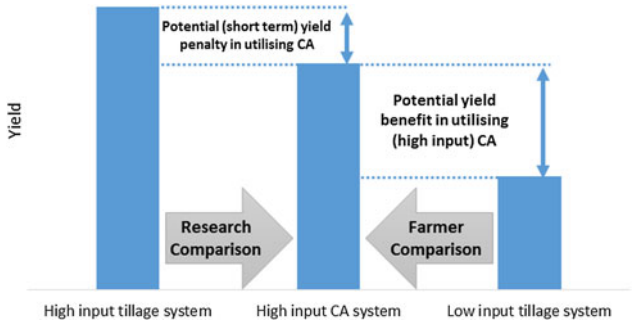

Fig. 4. Visualization of typical research and farmer comparisons being made to evaluate the yield benefit of CA.

failed to utilize CA. These issues tended to originate from issues at the community and institutional platforms, and as such are embedded within wider socio-economic and system constraints (Andersson and D'Souza, 2014; Arslan et al., 2014). There were key themes at each of the four resource pillars of the LPA:

Physical resources. Competition for limited stover resources defined a farmer's intensity of CA utilization, confirming the previously identified importance of stover resources to African smallholder CA implementation (Valbuena et al., 2012; Baudron et al., 2014). The functionality of input markets was also limiting, particularly when farmers were not aligned with a project promoting CA.

Financial resources. The overall financial viability of smallholder farmers hindered the intensity of CA utilization. This reflected a lack of household capital, and limited credit facilities and financial return through output markets, leading to the continued use of low input agricultural practices (i.e., although use of agronomic inputs may be financially beneficial, their use is beyond many farmers' financial means and hence benefit cannot be achieved). The limited use of inputs that dominates within communities also hampered the development of functional input and output markets, because demand is not sufficient to incentivize supply.

Human resources. Our results confirm the findings of various studies that assert CA without herbicides becomes challenging in terms of labor required (Giller et al., 2009; Marongwe et al., 2011; Grabowski and Kerr, 2013; Rusinamhodzi, 2015). The promotion of stover importation as a form of 'no-herbicide' CA was also poorly perceived due to the cost or type of labor involved, confirming a need to create more biomass through fertiliser application (Vanlauwe et al., 2014) to reduce biomass competition and labour requirements.

Informational resources. We find an overall information-poor environment for respondents, despite respondents being the most strongly connected to informational providers and hence having the greatest opportunity for learning about CA compared with other community members. Hence, there is further justification for the investigation of the functionality of informational exchange mechanisms that a growing body of literature question (Diagne, 2009; Simtowe, 2011; Wellard et al., 2013; Ngwira et al., 2014; Brown et al., 2018).

While a diversity of constraints are identified, there is a common narrative: the juxtaposition of the need for increased engagement with the community platform; and the limited resources present at that platform to facilitate CA use. A key example is respondents perceiving a need for financial resources for herbicides, fertilizer and/or stover importation, yet a limited ability to build or access financial capital to facilitate this. These results further contribute to the literature questioning the relevance of CA as a 'pro-poor' technology (Giller et al., 2009; Andersson and D'Souza, 2014; Corbeels et al., 2014; Pannell et al., 2014).

Current transformational CA adoption pathways

At the core of the identified constraints to CA utilization is the limited adaptation of CA to local contexts. CA has commonly been framed as a narrow amalgamation and promoted as a singular practice (Giller et al., 2009; Andersson and D'Souza, 2014; Stevenson et al., 2014; Glover et al., 2016). Because of the constrained financial context and limited input and output markets, implementation of CA has been dominated by project-supported adoption as evidenced by the high number of respondents that continue to be subsidized. In essence, the farmers' limited financial context has been altered through subsidization to enhance the 'fit' of CA and facilitate utilization. The assumed adoption pathway for CA is hence underwritten by a technology transfer approach, whereby CA is promoted as a singular technology as opposed to an amalgamation of principles. These adoption pathways tend to be based on the expansion of CA area, with CA as a singular technology (Fig. 5).

Such promotion is problematic to facilitating total adoption of CA, and usually culminates in low-intensity semi-utilization and modified adoption (Brown et al., 2017b), because:

- CA has substantial overhead costs that limit the feasibility of small area implementation (e.g., spraying equipment, tillage equipment, time invested in knowledge, costs of obtaining resources from distant locations) that create the need for subsidization;
- Such a system limits overall CA area within the community and does not allow a sufficient scale to be reached to demand facilitating by-laws, markets and policy changes (e.g., input markets, community grazing practices);
- Limited application is unlikely to build financial resources sufficiently to sustain the expansion of CA activities due to small return and considerable costs in meeting basic needs;
- Perceptions often arise that promoting farmers are 'playing games' because of the small size of such demonstrations and trials; and
- Promotion of CA as a singular technology lessens the importance of building on existing farming systems and tends to lead to CA being perceived as new, difficult or non-feasible.

These approaches also limit the understanding of modified and semi-spatial utilization because of the ambiguity around how to classify such utilization strategies (Brown et al., 2017b). This can be particularly important in the case of modification of CA and potential negative outcomes (Guto et al., 2011; Erenstein et al., 2012; Pittelkow et al., 2015). Because of these issues, we find there to be a significant need to re-evaluate the adoption pathways for CA.

Reframing the promotion of CA

To address these inadequacies, there is a need for greater adaptation of CA to local contexts, as opposed to adaptation of local contexts to CA (i.e., through subsidization). To do this, we propose a widening from CA practices to CA principles and a

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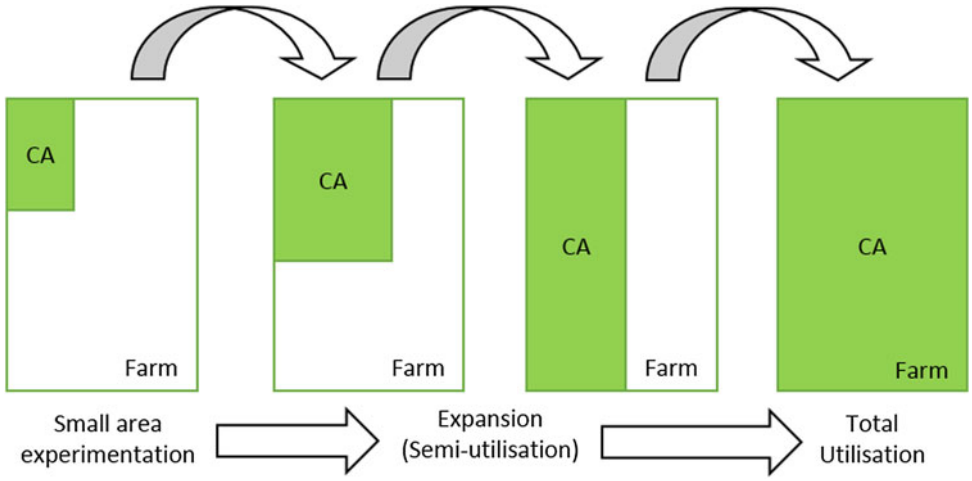

Fig. 5. Current adoption pathway using CA as a singular technology and based on the expansion of CA area through a field approach.

movement to transitional adoption pathways. An approach like this is integral to fostering locally relevant utilization of CA that meets the physical, financial, human and informational constraints that limit broader and total CA utilization.

From CA practices to CA principles

The current definition of CA as the simultaneous implementation of minimum tillage, stover cover and legume diversification (FAO, 2014) is highly restrictive and does not facilitate a stepwise approach to adoption. Instead a focus should be placed on finding the best suited set of practices for a farmer's realities, objectives and resource endowments (Tittonell et al., 2009). As such, the objectives of development organizations should not be to create CA adoption, but to facilitate locally relevant adaptation of CA within a set of broader objectives. This involves showcasing a set of options through which farmers choose their most suitable way to sustainably implement their agricultural livelihoods (Giller et al., 2009).

We propose that, in line with Vanlauwe et al. (2014), there are four principles around which CA *promotion should be framed*:

(1) *Strategic tillage*: Beyond prescriptive minimum or zero tillage, we propose a shift to strategic tillage, where the objective is to reduce soil disturbance, to strategic, necessary events required for healthy crop growth and ease of management. This may include a reduction in tillage events before an eventual movement toward direct seeding, periodic tillage or shallow strategic tillage.
(2) *Soil protection*: Promoting stover cover within the context of low biomass and high competing uses appears limited in potential over the short term, even in light of some emerging local by-laws to facilitate stover security. Hence, we propose a shift to soil protection, with the objective being to reduce erosion and maintain soil moisture. This may include green manure cover crops, permanent terracing and border plantations alongside crop residue retention, some of which are already present in African communities. The success of promotion must be tied within a flexible systems approach so as to address previous issues with their promotion.
(3) *Crop diversification*: Locally specific cash crops should be the focus of this principle, with the objective of maximizing profit to enable a household to meet its basic needs and re-invest in agriculture. This may be achieved through a broadening of CA promotion to non-food crops that are currently preferenced by farmers (e.g., sugar cane and cotton) in order to increase the financial relevance of CA, and then 'spill-over' into other food crops. This departs from the current approach that emphasizes legume diversification, often for legumes that do not have a ready market, but creates a need for alternative soil fertility management.
(4) *Input management*: The objective of this principle is to focus input management not only to maximize net returns, but to address the farmer's objectives in biomass and labor outcomes to ensure CA is both feasible and relevant. This might originally be addressed through organic inputs with an overall objective for farmers to reach an agronomically and financially sustainable production system. It is important to note that all intensification, conventional or otherwise, requires input management and will have implications on environmental outcomes as intensification occurs. However, we specifically propose this as a fourth principle for CA due to the integral requirements for biomass production and labor reduction as indicated by respondents. As the studied countries increase their local production of agrochemicals, the financial burden in addressing this principle should ease.

Transitional CA adoption pathways

Our findings indicate that transformational adoption pathways have shown a propensity to perpetuate financial dependency, as previously identified by Brown et al. (2017a) who highlighted that the current promotion of CA tends to lead to reliance on donor provision of input and donor dependency to implement CA. To alleviate these constraints, there is a need to rethink the adoption pathways for CA utilization. As opposed to the current intense focus of development organizations on achieving 'adoption' under a binary classification and an associated provision of inputs to enable immediate (but often short-lived) practice change, we propose a transitional approach that aims to foster utilization via stepwise, progressive intensification of our four proposed CA principles. Under this utilization pathway, we maintain the end goal of (four factor) CA, but have a series of progressive, locally relevant stepping stones to achieve total utilization. This is based not on expansion of CA as a singular technology,

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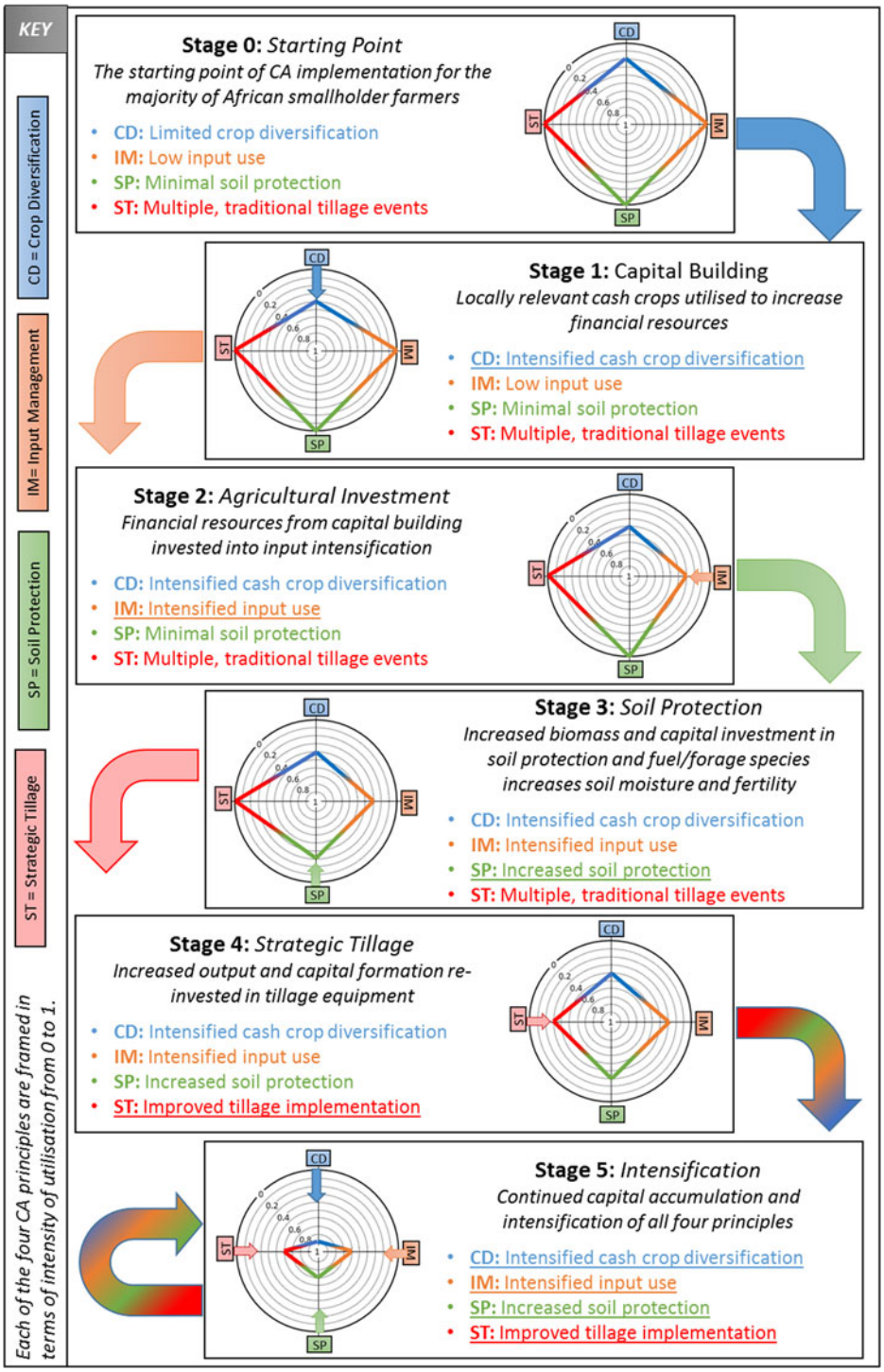

Fig. 6. Example of transitional CA utilization pathway based on the four principles proposed in this study.

but on disaggregation of the principles and stepwise intensification of utilization. It also places CA within a wider faming context, whereby the goal is to first diversify, then intensify resource use and this then makes the additional CA principles a more attractive proposition.

One such example is proposed in Figure 6. In the first instance, a locally relevant cash crop is used to build financial capital. This might be supported through soft loans of seed to stimulate local demand and hence overall community supply. Once sufficient capital is built to meet various household basic needs and reinvest into agriculture, financial capital could be used to invest in the input required for CA (such as herbicides, fertilizers and seed for alternative soil protection strategies and fodder/fuel crops). As soil protection is increased, further financial capital could be invested in strategic tillage equipment and other diversification strategies. The creation of financial capital in such a way is also likely to underwrite the improved functionality of credit facilities and build demand in both input and output markets over time. A transitional approach also provides a higher potential pathway for farmers to build their way out of subsistence farming over time and with minimized financial requirements from outside promotional organizations and governments.

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Such a change in focus would also allow promoting organizations to focus their efforts on enabling environments for CA utilization. This includes market development, local by-law creation and working with research and extension organizations to create a more coherent informational environment based on the four proposed CA principles. Particularly for the informational environment, CA can be framed more broadly, facilitating greater understanding and local adaptation within the four proposed CA principles. It will also decrease the complexity of CA utilization because change occurs transitionally over time, requiring less transformational change and therefore less perceived risk by farmers.

However, this approach will require greater investment in the extension systems of the target countries to ensure that modifications and stepwise iterations of CA are locally beneficial and feasible. In all of our six study countries, agricultural research is underfunded based on the ratio of agricultural GDP: investment in agricultural research (Lele et al., 2010), which will considerably diminish the ability of research and extension services to facilitate transitional adoption pathways. To facilitate both greater total use and utilization more generally, there is a need to address not only the adoption pathways, but funding for the institutional system that develops and delivers CA to African smallholder farmers.

Conclusions

This paper explores how to facilitate wider CA utilization in eastern and southern Africa, both in terms of the intensity of currently utilizing farmers and the uptake of CA within the broader community. We find that while perceived as beneficial to yield, financial and labor benefits are limited by the low use of inputs, particularly herbicides. The feasibility of CA implementation was also limited across all of physical, financial, human and informational resources, and usually related to constraints at the community and institutional platforms. We find this to be linked to the assumed transformational adoption pathway for CA and the focus on binary adoption, as opposed to modification and intensification of utilization. We propose a more nuanced approach focused on four broader principles as opposed to the strict packaging of CA practices, as well as the promotion of CA via transitional pathways that are focused on smallholder farmers building their intensity of CA utilization over time. This will reduce the burden of CA implementation, both financially and informationally and allow for spontaneous, as opposed to subsidized, utilization of CA. Implementing transitional pathways will require greater funding of research and extension services, but provides greater potential for African smallholder farmers to sustainably intensify their farming systems, noting the contextual realities that currently constrain the intensity of CA utilization.

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