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Positive tipping points for accelerating adoption of regenerative practices in African smallholder farming systems: What sustains adoption?

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Abstract

Regenerative agriculture (RA) practices have been promoted as a critical climate change resilience strategy and adaptation solution for smallholder farmers in Sub-Saharan Africa. However, most RA programmes struggle with securing and sustaining high adoption rates with many facing dis-adoption. We used Lenton et al.'s positive tipping points framework to assess the potential for fast and lasting adoption of Regenerative Agriculture (RA) in Sub-Saharan Africa. This involved reviewing literature and combining evidence from the successful expansion of the International Small Group and Tree Planting Program (TIST) in East Africa to examine the conditions and feedback processes that drive RA adoption. We found that the key leverage points for TIST wide and rapid adoption were: (1) the cultivation of reinforcing feedback processes that strengthened the social capital around adoption and (2) elimination of barriers to carbon accreditation. Integrating carbon accreditation protocols as standard in design or review of RA interventions could provide an essential leverage to boost adoption rates. Future studies could explore what drives variations in scaling rates and patterns between the sites to inform more site specific interventions.

Keywords: International Small group and Tree Planting programme (TIST), agroforestry, reinforcing feedback, climate change resilience

1.0 Introduction

Smallholder farms account for close to 80% of all farms in sub-Saharan Africa (OECD-FAO, 2016) and are often characterised by rainfed farming on highly degraded soils, where farmers have limited capital resources to invest in improving their production systems. These characteristics make smallholder farmers highly vulnerable to effects of climate change, placing them at a high risk of food and livelihood insecurity. The Intergovernmental Panel on Climate Change (IPCC) (2022) Working Group II report states that most smallholder farmers in Africa and the global south have already reached their soft limits for human adaptation. Implying that, while certain adaptation options could exist, they remain inaccessible to smallholder farmers due to financial, governance, institutional and policy constraints. At the same time, the impacts of climate change are worsening across Africa. For instance, under the current emissions trajectory, Coupled Model Intercomparison Project Phase 5 estimated that temperatures across Africa would increase by 2.7°C by 2050s while rainy seasons would shorten, accompanied by more intense rain events (Girvetz et al., 2019). Such changes could result in irreversible losses in productivity, and potentially the complete collapse of current agricultural production systems, leading to high food insecurity. The latter risk is amplified by the limited ability of smallholders to adapt.

In recent years, regenerative agriculture (RA) has gained traction in policymaking. Both the Sharm El-Sheikh Adaptation Agenda and the Breakthrough Agenda recognising the need for a mass transition to RA by 2030 to strengthen the resilience and adaptability of smallholder farmers to the impacts of climate change (FOLU, 2021; Marrakech Partnership for Global Climate action, 2022). RA here refers to farming practices that improve soil, water and overall ecosystem health, increase carbon sequestration, increase biodiversity, maintain or improve farm productivity and improve social and economic wellbeing (see Newton et al., 2020). Such practices could include conservation agriculture, agroforestry, and permaculture. According to the International Union for Conservation of Nature(IUCN, 2021), with just 50% adoption of RA, African smallholder farmers could potentially see a 30% reduction in soil erosion, up to a 60% increase in water infiltration rates (reducing run-off and increasing soil water storage), a 24% increase in nitrogen content and at least a 20% increase in soil carbon content. This could add approximately $70bn gross value per year to African farmers (IUCN, 2021). However, despite the evidence of the various benefits of RA, programmes promoting RA across the continent have struggled to quickly attain and sustain scale. While several studies look into factors that influence adoption of various RA practices across the continent (see Bouwman et al., 2021; Grabowski et al., 2016; Guteta & Abegaz, 2016), there is still little understanding of what could

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enable rapid scaling. As a result, most RA programmes, despite managing to secure some early adoption success, fail to reach adoption tipping points, instead stagnating or experiencing dis-adoption (Grabowski et al., 2016; Habanyati et al., 2020; Kehinde & Adeyemo, 2017). Without an understanding of processes driving rapid transition from initial early adoption success to continuously higher and sustained adoption rates, most RA programmes will continue to struggle to attain scale.

Lenton *et al.* (2022) advanced the idea that some actions can trigger or strengthen reinforcing feedback processes that in turn drive rapid adoption of interventions in social-technological-ecological systems. This reasoning was brought together in a conceptual framework for operationalising Positive Tipping Points (PTPf), which identifies typologies of reinforcing feedbacks and enabling conditions that can trigger positive tipping points, and interventions that could accelerate them. A corresponding report (FOLU, 2021) proposed that these dynamics could be occurring for farmers in parts of India but this has not been rigorously assessed in African farming systems.

In this paper, we build an understanding of the enabling conditions and reinforcing feedback processes for accelerated and sustained adoption of RA to help inform efforts to rapidly scale these RA strategies as an urgent response to the climate change pressures on smallholder farming systems. We first review literature on adoption of various RA practices such as conservation agriculture, agroforestry, and climate smart agriculture to identify various enabling conditions that seem to favour or discourage adoption. We then focus on The International Small group and Tree planting programme (TIST) in East Africa as a case study to illustrate how the various enabling conditions and reinforcing feedback processes function in a practical context. Finally, we explore what lessons could be drawn from the scaling of TIST to develop an understanding of potential leverages to trigger accelerated adoption of RA in Africa. In the next section we provide a brief RA focused introduction of the PTPf. After this we introduce how TIST applies various aspects of this framework and finally discuss what lessons can be drawn from the data on TIST to inform other programmes seeking to adopt this approach.

The PTPf identifies various enabling conditions, reinforcing feedback processes and possible interventions that could ignite system level transitions towards a positive tipping point (see Figure 1). See Ong et al.(2023) for an illustration of how some of these tipping points dynamics could operate in real world systems such as a packaging system.

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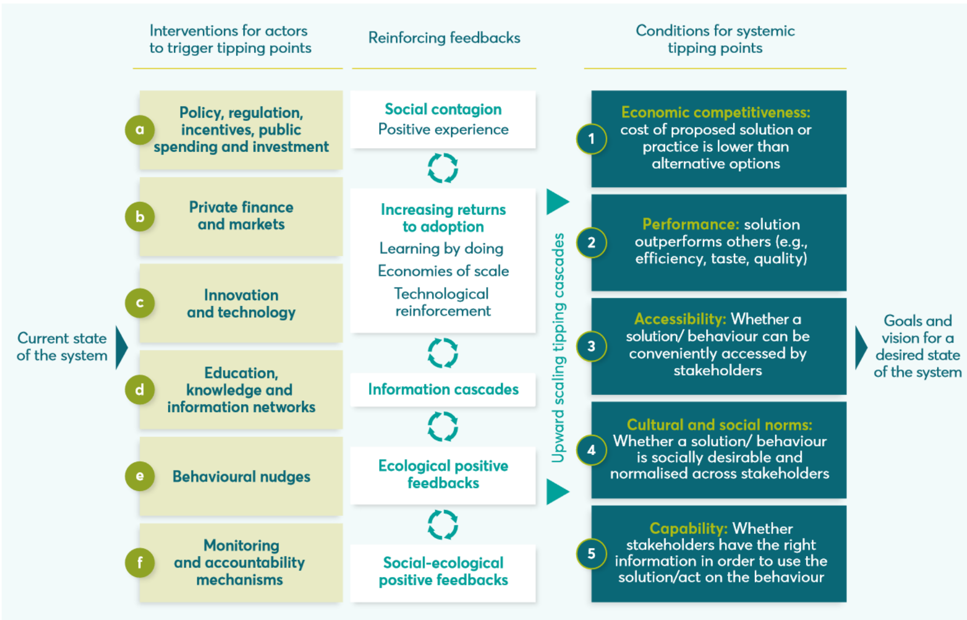

Figure 1: Framework for operationalising positive tipping points adopted from the Food and Land Use Coalition (FOLU) report on accelerating the 10 critical transitions (FOLU, 2021, p. 7).

2.0 Enabling conditions for successful adoption of RA in Africa

Adoption is a complex process with multiple possible outcomes; adoption (continued application of the practice) (Ainembabazi & Mugisha, 2014; Amadu et al., 2020), partial adoption (applying part of the practice) (Zulu-Mbata et al., 2016), changes in adoption intensity (applying more or less of the practice) (Kunzekweguta et al., 2017; Mujeyi et al., 2022), non-adoption (not-applying the practice) (Khoza et al., 2019), dis-adoption (stopping application of the practice) (Alpizar et al., 2022; Grabowski et al., 2016), and adaptation (editing the practice) (Bouwman et al., 2021). Several key factors increase the likelihood of successful adoption: the intervention has to be economically competitive, culturally and socially appropriate, easily accessible and outperform other alternatives on the criteria most relevant to the potential adopter, among other factors(Rogers, 2003). RA practices with these features are more likely to be adopted by farmers, and thus benefit them. Conversely, RA features are less likely to be adopted or may be dis-adopted later on.

Economic competitiveness and performance: In smallholder systems where households depend entirely on their farms for their livelihood, purchasing input to the farm could come at the expense of household subsistence. Thus, the economic competitiveness of an intervention is highly intertwined with its likelihood of being adopted. Economic competitiveness here could relate to the cost of applying the practice relative to the farmers capability to meet those costs (Grabowski et al., 2016; Razafimahatratra et al., 2021) or the opportunity cost of transition. The capacity to meet these costs is linked to performance in terms of yield, ability of the RA practice to reduce crop losses from erratic rain (Grabowski et al., 2016) or pest and diseases (Simtowe & Mausch, 2019) or any parameter most useful to the targeted farmer. It is worth noting that the ability to convert farm outputs (yield) into cash to meet the costs is affected by external forces like access to markets, the various market forces and supporting infrastructure and systems. By addressing the cost factors, optimization of performance of the intervention and diversifying the range of marketable products for instance inclusion of the sale of captured carbon alongside other products (Benjamin et al., 2018), it is possible

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to improve the financial outcome of farmers. To obtain the saleable farm products described above hence experience the performance of the RA intervention, the farmer has to be able to meet the RA practice requirements such as labour demands (Habanyati et al., 2020), time (Bouwman et al., 2021), and land (Kurgat et al., 2020). Therefore, a farmers' own resource limitations (Grabowski et al., 2016) and/or their ability to work around these limitations could be a major limiting factor. Therefore, interventions that could help bridge such resource gaps for instance improving access to credit could improve performance.

While mechanisms like persuasion, regulation and incentives have often been used to bridge the adoption gap for most interventions (Ajayi et al., 2008), positive perception of a RA practice plays a big role in driving continued adoption. Rogers famously argues in his book 'Diffusion of innovations' that perceptions come from observing and talking to neighbours who have adopted the intervention(Rogers, 2003). It is thus important to increasing duration of exposure particularly for interventions whose benefits could take a long time to get fully realised (Alpizar et al., 2022) while providing technical support (Habanyati et al., 2020) to address any issues that may emerge during the exposure period. However, it is important to manage expectations or otherwise risk potential dis-adoption if the practice does not deliver what it promised (Chinseu et al., 2019). Multi-disciplinary participatory research and project development processes that integrate farmer knowledge and experiences could play a big role in matching expectations to the local context and equipping farmers with the tools and information to effectively apply the RA practice in-order to derive the promised benefits (Entz et al., 2022; Noordin et al., 2001).

Cultural and social appropriateness: Cultural beliefs, norms and traditions shape what is acceptable and what is not within a given society. In relation to RA adoption, this could relate to; livelihood strategies for a given group (Agundez et al., 2022)(Agundez et al., 2022), gender roles and associated resource access rights (Kehinde & Adeyemo, 2017; Khoza et al., 2019; Kunzekweguta et al., 2017; Ngaiwi et al., 2023)(Kehinde & Adeyemo, 2017; Khoza et al., 2019; Kunzekweguta et al., 2017; Ngaiwi et al., 2023) and the social-cultural beliefs (myths about certain practices) (Agundez et al., 2022; Assogbadjo et al., 2012).(Agundez et al., 2022; Assogbadjo et al., 2012). For instance, in areas of Zimbabwe, pearl millet (*Pennisetum glaucum*) has been promoted as a drought-tolerant alternative to maize following maize crop failure due to droughts; however, some cultures believe that growing pearl millet would anger ancestral spirits (Mambondiyani, 2020).(Mambondiyani, 2020). In Northern Malawi, Bambara groundnuts (*Vigna subterranean*) has been promoted for its high nutritious value, drought tolerance and soil-enhancing qualities; however, certain groups associate it with death, which has greatly limited its adoption, distribution and marketing (Forsythe et al., 2015)(Forsythe et al., 2015). Many of these beliefs associated with particular crops and their uses have a gender element as well. For instance, while men and youth could support with some agronomic activities in Bambara groundnut production, it is taboo for them to touch the seed. To improve the tolerance and acceptability of useful interventions like Bambara groundnuts that could be considered alien in certain cultural contexts, Moore et al. (2015) suggests intensive education campaigns and extensive sharing knowledge and new practices through communities of practice, a process they describe as scaling deep.

As Moore et al. (2022?) suggests, society norms can be moulded and shaped through actions of third-party entities such as government, intergovernmental and non-government organisations, academia, faith-based organisations often with competing goals. In the smallholder farming space, one dimension of competition relevant here is between an approach focused on extending the 'green revolution in Africa' versus 'scaling RA'. While proponents for each of the possible pathways could justify their individual investment choices, it is important for the communities whose cultural beliefs, norms and traditions are at stake to be provided with sufficient information and supported in making an independent evaluation of their alternatives. In the smallholder setting, this often involves intensive and consistent agricultural extension, characterised by active farmer participation, practical

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demonstration of the RA practice benefits and working with common interest groups. Groups particularly provide a space for consultation between peers and leverage the power of social influence towards adoption of group norms (Alexander et al., 2022). In practice, agricultural extension services and community groups are often affiliated to certain entities whose viewpoints and norms they champion. Therefore, if one seeks to use existing extension and community structures, it is worth doing some due diligence on the norms, beliefs and traditions of the organisations overseeing these structures as well as the individuals implementing them.

Accessibility could relate to the intervention itself in case of a product (for example improved seed, seedlings) or essential inputs in case of a process (for instance, agroforestry, conservation agriculture). For a product, or process to be considered accessible, it must be available, farmers have to be able to physically reach the point of supply with ease, and they need to have the rights to use it. Availability refers to the physical presence of the intended product. In relation to adoption of RA, availability of land (Kehinde & Adeyemo, 2017; Razafimahatratra et al., 2021), water for irrigation (Maindi et al., 2020) and essential inputs (Murindangabo et al., 2021) stand out as key determinants. Physical access on the other hand relates to infrastructural barriers to reaching the point of supply for example poor road infrastructure (Maindi et al., 2020; Wafula et al., 2016), an isolated geographic location (Abebaw & Haile, 2013), physical proximity to markets (Abdulai et al., 2021; Kifle et al., 2022; Kunzekweguta et al., 2017; Mujeyi et al., 2022), and ownership of transport assets (Mujeyi et al., 2022). Rights to use relate to exclusion of certain groups. The most common example in smallholder context relates to land tenure (Murindangabo et al., 2021; Owombo & Idumah, 2017; Teklu et al., 2023) and rights to protect and own trees in agroforestry schemes (Kouassi et al., 2021).

A key aspect in moderating accessibility is information of what is needed, why, where to get it, how to get it, and so on. It is thus important to ensure that the farmer has access to or know where and how to access all the essential information associated with the intervention. Awazi et al. (2022) found access to information, along with access to land and household income as key determinants for choice of agroforestry system (between no agroforestry, agrosilvipastoral system, silvipastoral system and agrosilvicultural system) as a climate change adaptation mechanism. The level of access, perception and trust of any particular information source could vary from group to group thus to effectively communicate, one has to understand the most favoured sources of information for any particular group (Djido et al., 2021; Muriith et al., 2021).

Addressing the different dimensions of accessibility calls for often higher-level interventions spanning from infrastructural projects to policy and market-based interventions. Physical access challenges call for investments on infrastructure such as roads to improve connectivity and link rural areas to markets. It also calls for establishment of markets and associated infrastructure closer to the rural sites. On the other hand, market-based incentives designed to boost supply of these essential inputs could play an important role in improving and sustaining supply of such essential inputs. Though not a panacea, enacting appropriate policies to address issues of rights, extensive education, and enforcement of contracts and agreements could be a possible pathway to addressing issues of rights to access. While the appropriate solution could vary with the context and nature of the problem, it is likely that any solution will involve reaching out to different actors at multiple levels of the social-technological-ecological system. For instance, through enhancement of smallholder groundnut seed, the Southern Groundnut Platform contributed to 11% increase in area under groundnut cultivation in Southern Tanzania and resulted in 15% increase in groundnut production between 2012 and 2018 (Akpo et al., 2021). Akpo *et al.* (2021) reports various other cases of multi-stakeholder platforms improving smallholder seed access in Ghana, Mali, Nigeria, Burkina Faso, Ethiopia, and India.

Capability: Capability could be applied to the farmers themselves or to the RA practice being promoted. When applied to the farmer, capability implies one's ability to effectively apply the RA practice. Andersson and D'Souza (2014) observed that one of the key limitations to farmers trying out and adopting conservation farming is the added cost in equipment like the ripper, cost of labour to gather and apply mulch or control weeds in absence of herbicide. Under these circumstances, access to affordable credit could provide a viable pathway to improving the capability of smallholders to apply conservation agriculture practices hence increasing their chances to experience its benefits and adoption (Kehinde & Adeyemo, 2017; Mujeyi et al., 2022). When it comes the accessing credit from formal financial institutions, one of the main challenges for smallholders is the limited access to resources that could serve as security for the credit (Nkonki-Mandleni et al., 2022). Other than influencing access to credit, access to resources such as land and security of tenure could directly improve or reduce the capability of the farmer to engage in certain practices. Capability could also relate to perceived usefulness of the RA intervention, which as Mugandani & Mafongoya (2019) and Oduniyi & Tekana (2019) observed had a greater influence on adoption than awareness.

When it comes to capability and all the other enabling conditions discussed above, information is key. In the smallholder context, while multi-media sources such as radios, short term message services on mobile phones and newsletters could be useful (Oladele et al., 2019), extension service and informal farmer networks particularly play key roles in information flow (Brown et al., 2017; Djokoto et al., 2016; Habanyati et al., 2020). Extension here does not limit itself to public extension services (for examples agricultural officers, forestry officers) but also includes private, and NGO farmer support services. Beyond facilitating information flow, improvement of perception is favoured by adopting extension approaches that prioritise farmer participation (Entz et al., 2022) and practical demonstration of the RA practice benefits (Habanyati et al., 2020). When it comes to farmer networks, farmers are more likely to choose who to consult based on homophily (people similar to themselves, e.g., religion, tribe), kinship and/or physical proximity (Giroux et al., 2023). Therefore, strengthen the social capital in farmer networks, it makes sense to work with groups. Apart from creating rich information networks and generating peer pressure towards adoption of what the group considers preferable, groups also provide secondary services that could improve the capability of individual group members. For instance, cooperatives are formed primarily to support members with among other services, provision of improved inputs and loans. In-fact, Abebaw & Haile (2013) found that cooperative members were more likely to possess oxen, have leadership experience and have off-farm work compared to non-members.

3.0 Reinforcing feedback processes in adoption of RA

Throughout the various phases during which potential adopters interact with a particular RA practice, the various aspects of economic competitiveness, accessibility, cultural appropriateness, performance, and capability interact, influencing the system transition (see Figure 2 below).

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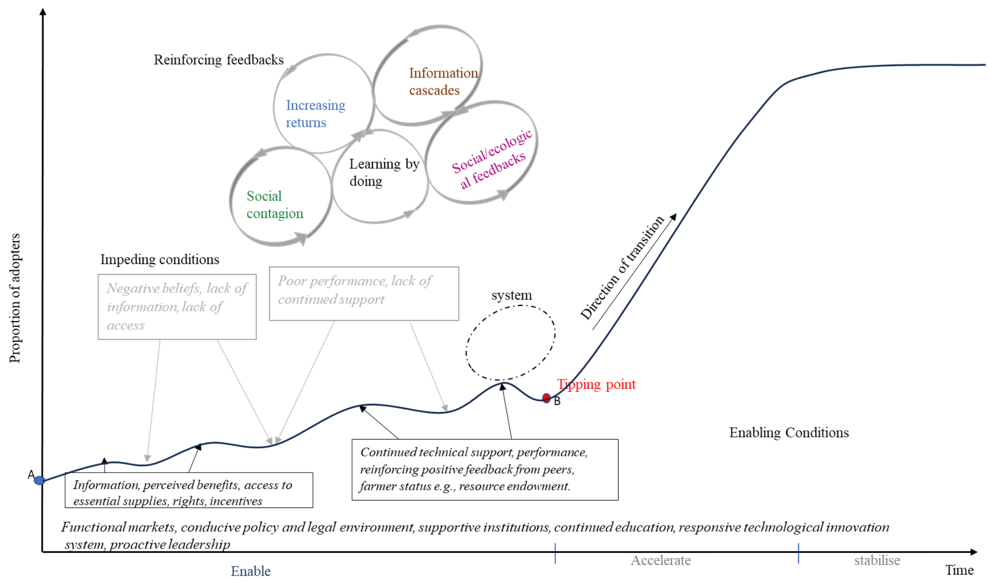

Figure 2: System transition diagram adapted from Fesenfeld et al. (2022) to show the enabling conditions that are influential at various stages of a farming system transition towards a tipping point. Across the entire transition process, functional markets, conducive policy, and legal environment (e.g., tenure security) coupled with supportive institutions, complementary infrastructure (e.g., roads), continued education to address cultural biases, a responsive technological innovation system (e.g., in terms of capability, functionality and cultural appropriateness) and proactive leadership play a major role.

In the Enable Phase from when the RA practice is first introduced (point A, Figure 2) to when there is a tipping point of accelerating mass adoption (point B, Figure 2), different factors (enabling conditions) gain importance for different people at different points in time. At the initial stages of introduction, access to information about the practice, perceived benefits of the practice, access to essential supplies and key resources play a key role driving potential adopters to try-out the practice. At the later stages, as people continue interacting with the practice, the performance of the practice, access to continued technical support and feedback from peers gain greater importance in sustaining continued use. As more people use the practice, and demonstrate evidence for its performance, they either attract or discourage others from engaging with the practice, new markets emerge for the products and/or inputs for the practice. At the tipping point (point B, Figure 2), a large enough proportion of the population has adopted the practice such that the rate of adoption becomes self-sustaining and creates further exponential growth in the target population (Lenton et al., 2022; Rogers, 2003). While the factors discussed above independently and in combination enhance the chances of successful adoption at individual and household levels, certain factors independently or in combination could trigger self-propelling, reinforcing feedback processes that could either accelerate or dampen the rate at which the whole community embraces the practice as the norm (scaling out).

Moore *et al.* (2015) describe three possible pathways to scaling of any development intervention; scaling out, scaling deep and scaling up. Scaling out involves impacting greater numbers of people, scaling deep impacting the cultural roots, while scaling up deals with impacting policies and laws. Scaling can occur at an institutional level but is not confined there. Beyond institutional boundaries, processes like scaling deep could influence the culture of an entire community while the influence of

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policy and laws in scaling up could extend to other institutional levels including national and International.

4.0 A case study of The International Small group and Tree planting programme (TIST) in East Africa.

TIST is an agroforestry payment for ecosystem service (PES) programme that also promotes conservation farming (Benjamin et al., 2018). The programme is running in Kenya, Uganda, Tanzania, and India and over the years, it has reached over 176,000 farming households in 26,996 small groups, maintained over 22 million trees, and offset over 7 million tonnes of carbon (https://programme.tist.org). In East Africa, Kenya (15,529 Groups) has the highest number of groups enrolled followed by Uganda (5,976 groups) (see Figure 3).

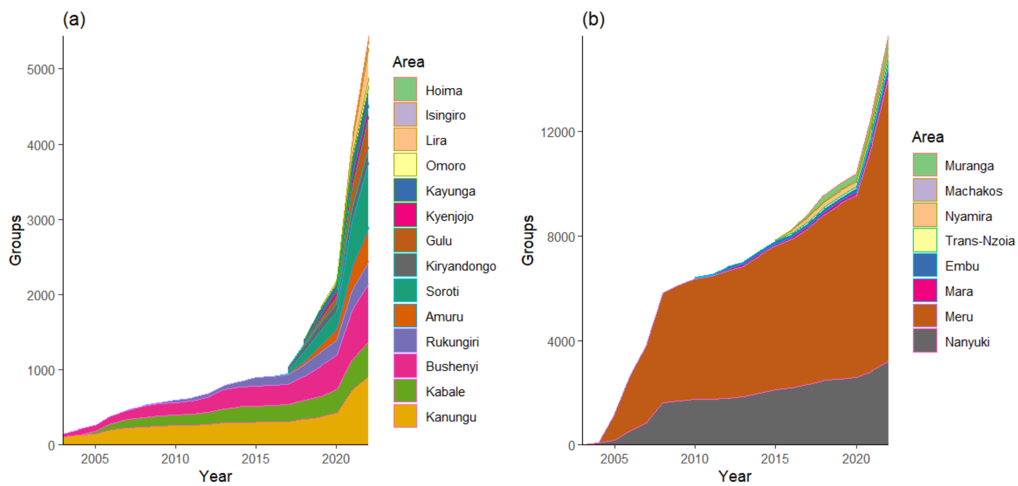

Figure 3: Enrolment of TIST participant in Uganda (a) and Kenya (b) between 2003 and 2022. The expansion of the programme takes on a different pattern in each of the countries implying that different factors are perhaps involved.

In Kenya, participant enrolment rates in Meru and Nanyuki overshadow all the other sites in the country and shape the national enrolment picture while in Uganda, the programme expanded to several new areas after 2015, with afew (Soroti, Gulu, Amuru and Lira) achieving relatively high rates of enrolment since introduction of the programme. For instance, of the five sites with the highest number of groups in Uganda, three sites are less than six years old and among these Soroti has the second highest enrolment rate of all the sites in the country.

5.0 Scaling of TIST

TIST demonstrates all three forms of scaling, scaling out, up and deep (see Table 1).

6.0 Table 1: Evidence for the different forms of scaling by TIST

Scaling type	Evidence for scaling and possible triggers in TIST

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Scaling-out (mass adoption of TIST practices)	• The number of participants enrolling into TIST in both Uganda and Kenya have continuously increased since initial introduction with 10 out of 18 sites in Uganda enrolling after 2015 (See Figure 3).
Scaling-up (TIST adopting good lessons as organisation policy)	• Good practices at group level are shared with other groups in cluster meetings and published in monthly newsletter across all the groups in the country. Through this process, good practices in different locations get integrated across the different project levels and informing programme policy revisions. Through these processes, TIST continuously adapts and changes its policy to deepen and extend its impact. • TIST rigorously documents and communicates its impact. Through by doing this, it is influencing changes in design and governance of agroforestry interventions in the region with a number of programmes Kilimanjaro project, itereka and others opting to adapt the TIST model in their implementation as part of the TIST DIY group.
Scaling deep (Impacting norms)	• TIST takes deliberate action to ensure that women farmers are represented in groups, constituting at least 40% of group membership composition (Masiga et al., 2012). With group leadership appointed on rotational basis and alternating by gender, women are assured an opportunity to lead the group and access the same trainings and information. The same pattern of alternating leadership occurs at all levels of the programme structure. Through these mechanisms, TIST facilitates gender balance in contexts where such privileges were lacking (Benjamin et al., 2018). • TIST conducts routine group trainings on various aspects ranging from financial services, appropriate farming practices and other group relevant aspects to complement the routine extension services provided by the cluster servants. Some of these trainings trigger responses that drive further adoption of the desired practices. For instance, TIST farmers that kept proper records were observed to have more favourable credit compared to those that did not. Proper record keeping was associated to the routine training's farmers received (Benjamin et al., 2018) . • Outreach to children of TIST group members who will likely inherit the farms and trees as an opportunity to improve programme stability and sustainability (Masiga et al., 2012).

7.0 How is TIST meeting the enabling conditions for enrolment in its sites.

Economic competitiveness and performance: By design, TIST prioritises the minimisation of input costs while at the same time maximising the benefits from participation in the programme. Being an agroforestry programme, tree seedlings are an essential input. In the programme, farmers choose which tree to plant and are encouraged to establish tree nurseries at group level. The localisation of supply and flexibility of choice potentially improves affordability of seedlings.

TIST further supports its members to access payments for the carbon captured by their trees. These payments are a supplement to the other benefits farmers already get from planting the same tree species if they were not in the programme such as soil improvement, erosion prevention, wind breaks, firewood, fruits from fruit trees, fencing material, timber, medicine, bee habitats, natural insecticides (Reid & Swiderska, 2008). Benjamin *et al.* (2018) found that women who participated in the TIST programme were more likely to get a higher profit margin from their agroforestry activities than those who did not.

Beyond the benefits from agroforestry, participants in TIST also have access to other benefits from participations like better access to credit(Benjamin et al., 2016), improved social capital, improved gender equality(Benjamin et al., 2018), livelihood diversification as groups engage in alternative activities like art and crafts. These various benefits improve the overall performance of the program and its impact to the lives of those involved.

Accessibility: Enrolment into the TIST programme is open to all interested smallholders. Participation was not restricted by farm size (Benjamin & Blum, 2015) implying that even those with very small farms could enrol hence increasing accessibility to the programme. Groups establish and manage their own nurseries which makes seedlings easily accessible by the farmers.

TIST offers farmers contracts of 10-30 years along with regular trainings and extension support in financial management, tree management and other relevant skills (Masiga et al., 2012). For these reasons, smallholders in TIST were less likely to be credit constrained and those that kept records enjoyed more favourable formal credit conditions (Benjamin et al., 2016).

Cultural appropriateness: TIST empowers the farmers to make decisions on what is most appropriate to their contexts for instance. By leaving decisions like what trees to plant, where to plant them and what group to join to the farmers, the programme ensures that the programme interventions are appropriate to the farmers context.

TIST farmers are organised in small groups of 6-12 members and 40-50 groups within walking distance of each other aggregate into a cluster supported by a cluster servant (Masiga et al., 2012). Farmers in a cluster meet at regular intervals to share good practices, trade experience and share profits from carbon trade. This localised coordination and knowledge sharing structures creates space for cultivation of context specific but organisation relevant knowledge, customs, and experience.

Capability: TIST does not offer restrictions to various aspects of participation like where to plant trees hence- increasing the likelihood that many farmers would be capable of participating in the programme.

TIST trains cluster servants in tree quantification and involves smallholder farmers in the quantification process hence building their capacity not only understand the processes but also explain it to others. Hence, empowering them (farmers) not only to access the voluntary carbon markets(Lenton et al., 2022) but also to support other farmers in the process.

Through the group structure and regular meetings at both the group and cluster level, newly enrolled participants get to engage with participants who have been in the programme longer. This creates more opportunities for the farmers to support each other through the adoption process.

8.0 Reinforcing feedback processes driving adoption of TIST

Different reinforcing feedback processes are often involved in driving adoption of any given RA practice. For the case of TIST the processes driving adoption at household and community level could be summarised into social processes, economic processes, ecological processes, and agronomic processes as illustrated in the Figure 4 below. The processes often interact at multiple levels, contributing to yield, income and eventually improved resilience and livelihoods.

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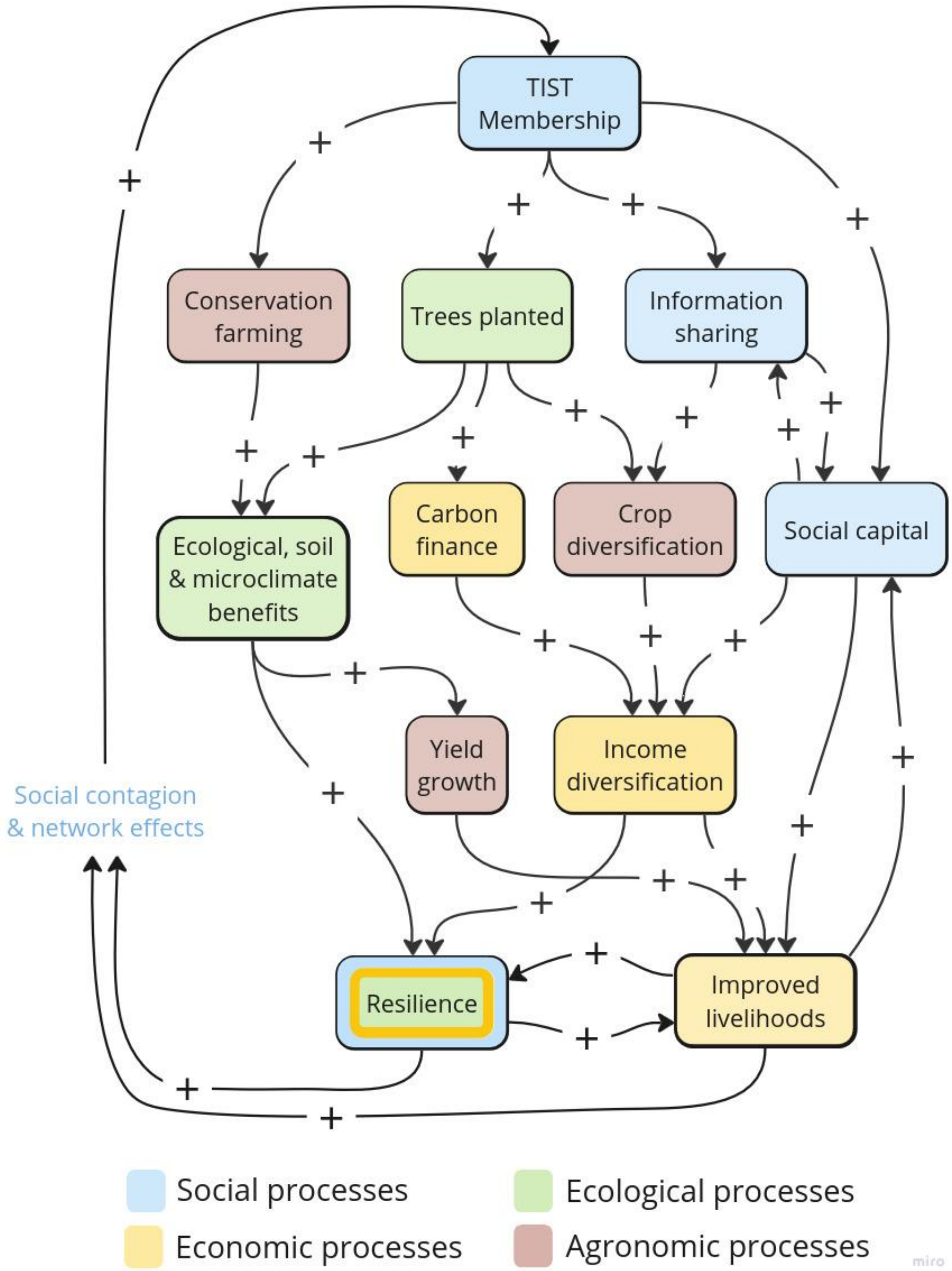

Figure 4:Reinforcing feedback processes driving adoption of TIST at community level. Conservation agriculture and agroforestry improve the soil ecological functioning hence contributing to improved and more stable yields, while the various tree products along with carbon finance contribute to income diversification. Through working in groups, there is better information sharing which in-turn builds and reinforces the social capital. All the various contribute to improved resilience as well as drive social contagion in TIST.

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In some cases, the results of adoption are not always positive, requiring careful analysis of the trade-offs involved. For instance, Masiga et al. (2012) describes the complex trade-off TIST farmers in Meru, Kenya have to make in deciding whether to plant eucalyptus (Figure 5). In this case, while the Green Belt Movement in Kenya discouraged planting of eucalyptus because it could damage the soils on which they were planted, the Kenya Forest Service promoted eucalyptus for its fast growth to meet demand for timber and utility poles. Furthermore, Kenyan Power had been vocal about their need for poles. While the demand for timber and poles could drive more people to plant eucalyptus, its negative effect on the soil could discourage its adoption.

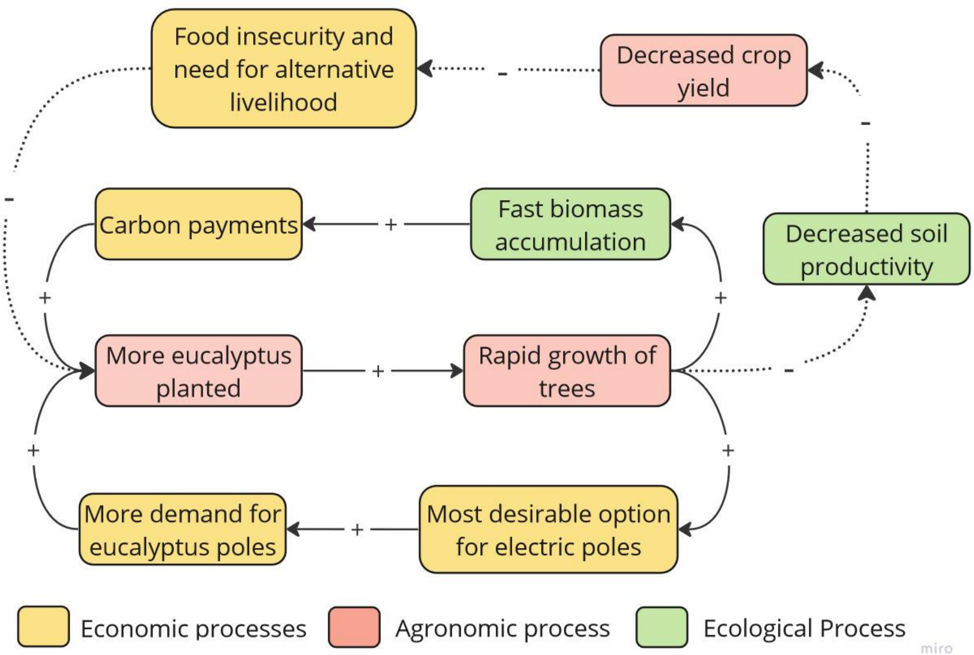

Figure 5: Reinforcing feedback loops influencing adoption of eucalyptus in Meru, Kenya.

Apart from reinforcing feedback process that could lead to opposite outcomes like the example above, some effects are more subtle but equally impactful on adoption. For instance, it has long been established that gaining information about an initiative precedes adoption (Rogers, 1963). However, if everyone knew about a practice yet no one has adopted, "*it appears that* the practice has been deliberately and publicly rejected by everyone" (Centola, 2021, p. 19) hence discouraging other potential adopters. Various other combinations of factors and actions could lead to different reinforcing feedback processes with effects that might not be fully predictable. As promoters of certain interventions, it is worth reflecting on the possible unintended reinforcing feedback processes triggered by one's actions and taking deliberate steps to strike balance between the factors involved to increase the chances of achieving the intended system level transition. For instance, to manage the effect of eucalyptus and its popularity, alongside education about the potential negative effects of planting eucalyptus, water conserving species such as *Bridelia* and *Sysygium spp* were promoted in riparian areas through training and additional payments for ecosystem services per indigenous tree planted within 100 metres of the waterway (Masiga et al., 2012).

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While most of our discussion and examples have focused on RA adoption among members of the same population, well managed reinforcing feedback processes could lead to chain reactions that drive adoption in populations that are geographically dispersed and also across different levels (see figure 6). For instance, the positive testimonies from TIST beneficiaries, studies illustrating its positive impact (see Benjamin et al., 2018; Buxton et al., 2021) and commentaries about its unique approach to sustainable agro-forestry has made TIST a unique and interesting case both for research and among development practitioners with various projects like iTeraka in Madagascar, the Kilimanjaro Project in Tanzania and MyTreesTrust in Zimbabwe adapting different aspects of the TIST mechanism in their individually unique operations.

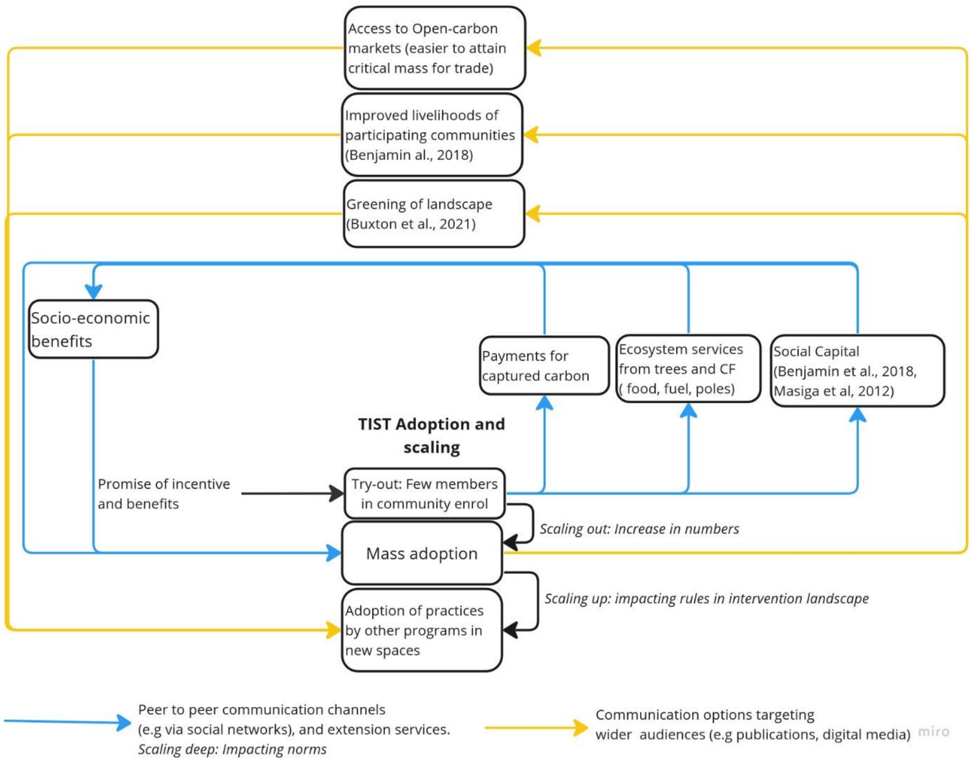

Figure 6: Reinforcing feedback processes driving multi-level adoption of TIST. Adoption progresses through levels with communication the transition from one level to another.

Moving from a few individuals trying out the RA practice to a tipping point for mass adoption relies on a series of multiple peer-to-peer interactions and action and the change occurs at the same level (community of peers). Success at this level draws attention of stakeholders at different levels or in different thematic spaces to which the programme lessons could apply, but only if they are communicated through channels familiar to the independent stakeholder groups. If an interested stakeholder decides to implement the programme in a new site, then the cycle repeats itself, with new participants potentially trying out the practice. However, the success in the previous site does not automatically predict success in a new site, but rather demonstrates the potential if the necessary enabling conditions can be met or created in the new site.

9.0 What does the TIST scaling pattern tell us about accelerating RA adoption?

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Most RA practices by their nature offer opportunity to benefit from payments for various environmental services with such payments potentially reducing the opportunity cost for their adoption. The successful adoption of TIST is largely attributed to the programme's ability to break the institutional barriers for farmers to access such payments, allowing them to supplement the numerous livelihood diversification options and co-benefits offered by agroforestry and CA. In TIST, Farmers are involved in the monitoring, verification and reporting of the trees carbon content along with quantifiers in collaboration with international TIST staff (Benjamin et al., 2018). Small groups receive 70% of all the profits from the carbon captured and sold. These profits are shared among group members in proportion to number of trees each member planted (Masiga et al., 2012).

The growth of TIST largely leverages social capital cultivated and nurtured through participant active involvement in the programme processes, continued capacity building and working in small groups with members within walking distance of each other. TIST operates in groups of 6-12 members with each group required to plant at least 5000 trees over five years depending on availability of land in order to qualify for payments (Masiga et al., 2012). The social network created by the group structure facilitates information sharing and support systems that drive adoption (Benjamin et al., 2018) while the fact that the whole group has a shared tree planting quota, enables distribution of risks and permits even for farmers with limited access to land to join the programme (Benjamin & Blum, 2015) .

10.0 Conclusion

Several studies look into factors that could affect the adoption of various RA farming practices across sub-Saharan Africa, however, little is still known about what could enable rapid scaling. In this Paper, we draw on the lessons from the rapid scaling of TIST in East Africa to understand what processes could be leveraged to rapidly scale other RA interventions in the Global South. We observe that the successful scaling of TIST could be attributed to: (1) cultivation of social capital through group structure which enables sharing of risk, facilitates information flow and grows a community of practice; (2) minimising barriers to farmers directly accessing payments for the carbon captured by their trees alongside the multiple benefits of agroforestry that they already access. While the subject of social capital has been relatively well explored in literature, carbon trading is relatively new with many potential opportunities; such as a catalyst to accelerate adoption of RA practices. A key lesson other NGOs and programmes can draw from TIST, it is worth thinking about carbon accreditation processes during RA programme design, the review of ongoing projects and that smallholder farmers can be an integral part with agency in these processes.

While the data on enrolment of TIST clearly reveals evidence of scaling, it also provokes important questions on factors and processes responsible for (a) the difference in rates of scaling and (b) variations in scaling patterns between seemingly similar sites? Finding answers to these questions could provide insights strategies to address site specific barriers to accelerated adoption. This could be a potential next step for future research.

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Competing Interests

The contact author has declared that none of the authors has any competing interests.

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