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

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Abstract

Mass adoption of regenerative agriculture (RA) practices could improve the resilience and increase productivity of African smallholder farming systems in the face of growing climate change pressures. Recent research suggests that positive tipping points in the adoption of such sustainable technologies and practices can be driven by amplifying feedback processes such as social contagion. However, most research on scaling agricultural practices has not focused on the factors and processes with the potential to drive rapid and self-propelling scaling. To address this gap, we combine Lenton et al. (2022)'s framework for operationalisation of positive tipping points with Moore et al. (2015)'s conceptualisation of scaling to understand rapid scaling in a case study in East Africa (The International Small group and Tree planting programme, TIST). We present three key insights: (1) To achieve rapid and sustained scaling, it is essential to scale out (reach more people) while at the same time scaling up (impacting policy and institutions) and deep (impacting beliefs and norms); (2) these different dimensions of scaling continuously interact, often reinforcing each other and; (3) interactions between and across scaling dimensions are mediated by feedback processes. If amplifying feedbacks are strong enough, scaling could be rapid and self-sustaining. TIST scaling reveals that complementary carbon payments, learning by doing and building social capital are key for sustained, accelerated scaling.

Keywords: amplifying feedbacks, climate change resilience, smallholder farmers, sub-Saharan Africa, Regenerative agriculture, scaling, agroforestry

Introduction

Agriculture in sub-Saharan Africa is highly vulnerable to climate change effects. The International Fund for Agricultural Development estimates that 70% of the total food supply in the continent is from smallholder farms (IFAD, n.d.). Most of these farms are rainfed, have highly degraded soils and extremely low capital to invest in improving production systems (Nezomba et al., 2017) thus limiting their adaptive capacity. The Intergovernmental Panel on Climate Change Working Group II report states that most smallholder farmers in the global South, including Africa, have already reached their soft limits for human adaptation to climate change(IPCC, 2022). Implying that, while adaptation options still exist, they remain inaccessible to smallholder farmers due to financial, governance, institutional, and policy constraints. Nevertheless, the impacts of climate change continue to worsen across the region. Most climate models agree that, across most parts of sub-Saharan Africa, dry seasons will become longer and hotter while wet seasons will become shorter with more intense rainfall (Ayugi et al., 2021; Dosio et al., 2021; Wainwright et al., 2021), putting already vulnerable smallholder farmers at a higher risk of food and livelihood insecurity. Despite these challenges, there is compelling evidence that the adoption and effective implementation of regenerative agriculture (RA) could enhance the resilience and productivity of smallholder farming systems in the face of growing climate change pressures (Rehberger et al., 2023). For instance, it is estimated that with just 50% adoption of RA, African smallholder farmers could potentially see a 30% reduction in soil erosion, 60% increase in water infiltration rates (reducing run-off and increasing soil water storage), 24% increase in nitrogen content and 20% increase in soil carbon content, which could add approximately $70bn gross value per year to African farmers (IUCN, 2021). Despite these potential benefits, most interventions promoting RA practices struggle to

40 attain and sustain scale. Here, scaling means expanding, adapting, and sustaining successful initiatives in

41 different places and over time to reach a greater number of beneficiaries (Jagadish et al., 2021).

42 There is general agreement that rapid adoption of RA practices is essential to cope with growing climate

43 change pressures on the food system (LaSalle & Hepperly, 2008; Rehberger et al., 2023; Strauss & Chhabria,

44 2022). Definitions of what constitutes RA and how it differs from other good practices in conventional

45 agriculture have been debated (Giller et al., 2021; Newton et al., 2020; Schreefel et al., 2020). However,

46 despite this contention, almost all definitions recognise the importance of soil conservation and a systems

47 approach to defining RA. In this paper, RA is defined as '*farming practices that improve soil, water and*

48 *overall ecosystem health, increase carbon sequestration, increase biodiversity, maintain or improve farm*

49 *productivity and improve social and economic wellbeing of the farming community*' (Newton et al., 2020).

50 Examples include minimum tillage, maintaining soil cover, fostering plant biodiversity including agroforestry

51 and integration of livestock (Giller et al., 2021; Newton et al., 2020). However, for practical purposes, Giller

52 et al.,(2021) suggests that for any given context RA champions need to ask five key questions: (1) What

53 problem is RA meant to solve? (2) What is to be regenerated? (3) What agronomic mechanism will enable or

54 facilitate regeneration? (4) Can the mechanism be integrated into economically and socially viable agronomic

55 practices for the specific context and (5) What political, social, and/or economic forces can drive use of the

56 new practice? Concerning scaling, these questions could relate to Why scale? What to scale? How to scale

57 quickly? Here, we focus on the question of how to scale quickly.

58 Moore et al., (2022) identify three dimensions of scaling: scaling out, scaling up, and scaling deep. Scaling out

59 involves expanding an initiative to more people, more places or promoting organic spread(Mills et al., 2019).

60 Scaling up entails engaging with higher institutional levels to change the rules, logics, incentives (Moore et

61 al., 2015) or leveraging existing ones to facilitate uptake (Geels, 2002). Finally, scaling deep involves shifting

62 attitudes, norms, knowledge, and values to accelerate adoption (Moore et al., 2015). The magnitude of the

63 challenges facing smallholder farmers in Africa necessitates rapid and exponential scaling out of RA. While

64 most studies on scaling within the agricultural sector identify the importance of a clear vision and suggest

65 strategies (Gillespie et al., 2015; Millar & Connell, 2010; Nicol, 2020), many of the scaling frameworks used

66 do not explicitly explore the factors and processes that might catalyse such desired rapid and exponential

67 growth. A better theoretical understanding of these could help in the design of interventions that leverage

68 positive feedback processes for rapid and non-linear scaling of RA.

69 Here, we draw on the framework for operationalisation of positive tipping points proposed by Lenton et al.,

70 (2022) to explore enablers and processes that could accelerate scaling. It proposes that under certain enabling

71 conditions, some actions can trigger or strengthen amplifying feedback processes that drive rapid adoption of

72 new technologies or behaviours in social-technological systems (Lenton et al., 2022). If the amplifying

73 feedback processes are strong enough, adoption could be rapid and self-propelling as the system reaches a

74 tipping point. In this paper we combine theories of scaling and positive tipping points to explore the adoption

75 of RA in sub-Saharan Africa. Specifically, we examine Moore et al.'s three dimensions of scaling to identify

76 the potential role of feedbacks between the spread of adoption between individuals, changes in governance

77 and institutions, and changes in culture, values, and behavioural norms. We draw on literature from various

78 regenerative farming interventions across Africa, using The International Small group and Tree planting

79 programme (TIST) in East Africa as a case study.

80 **Conceptual Framing**

81 A social tipping point is reached when a critical mass of adopters triggers the mass adoption of a new idea,

82 technology or innovation leading to social system transformation(Lenton et al., 2022). In the case of adoption

83 of RA practices, expansion to new sites, recruiting more program participants, and promoting organic spread

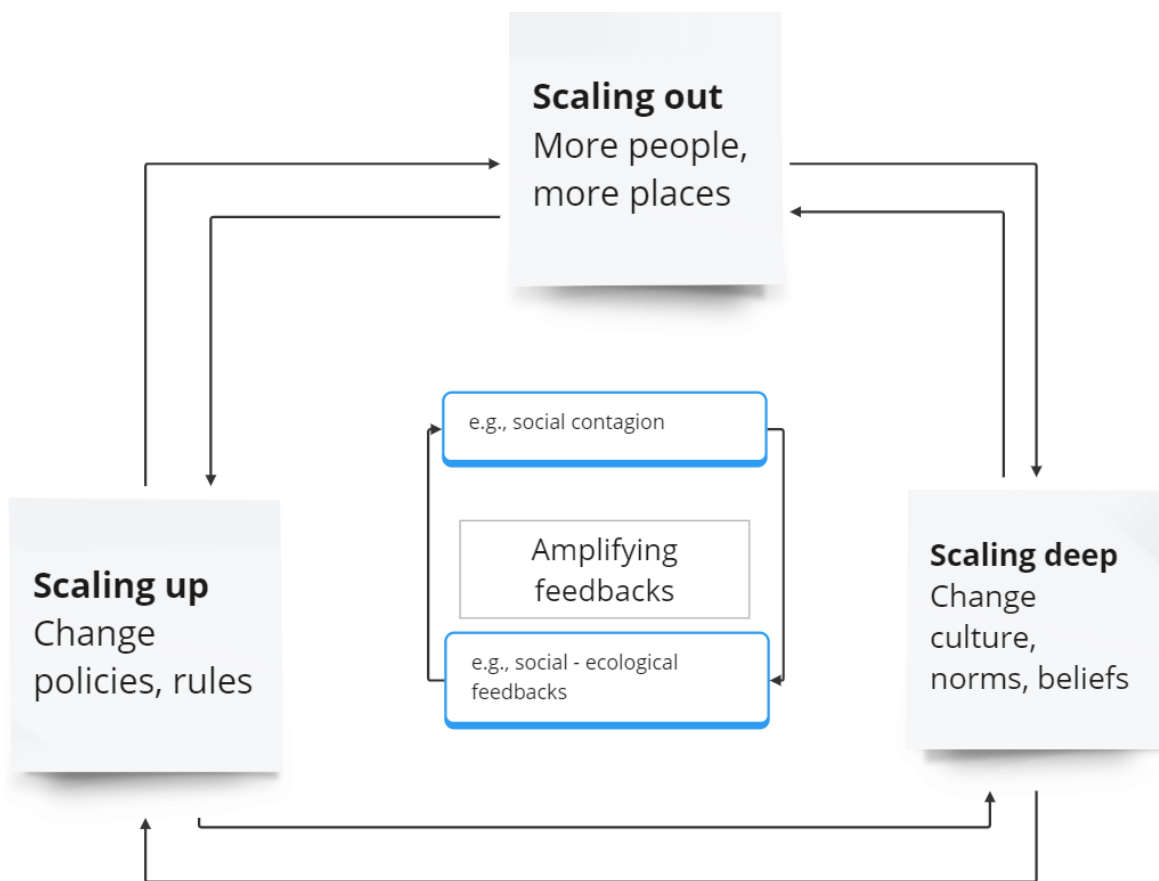
84 (scaling out) accompanied with complementary changes in policies, institutions (scaling up), and cultural

85 norms and beliefs (scaling deep) could provide the necessary leverage for achieving such a tipping point. The

86 different dimensions of scaling interact through feedback processes, often complementing each other and

87 amplifying the resultant changes in scale (Figure 1). For instance, policies that create synergies between

88 behavioural and technological changes could lead to virtuous political feedback loops (Fesenfeld et al., 2022),

89 which in turn influence social norms and potentially adoption of certain ideas and interventions.

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91 *Figure 1: The interaction between the different dimensions of scaling driven by amplifying feedback*

92 *processes. The amplifying feedback processes act within and across multiple spatial scales (from local,*

93 *national to international) and influencing changes to the scaling within and across those levels in the process.*

94 Several feedback processes could be involved at any time and identifying these processes is key in positively

95 influencing scaling. These feedback processes could include social contagion; information cascades;

96 increasing returns to adoption; learning by doing; social-ecological effects; and network effects(Lenton et al.,

97 2022). Insights into these interactions could help to identify the most effective actions to accelerate adoption

98 in a particular context. Just like the dimensions of scaling, these feedback processes are not mutually

99 exclusive and act across multiple spatial scales. For instance, the adoption of agroforestry at the community

100 level could result to landscape-level social-ecological impacts (Buxton et al., 2021) driven by social-

101 ecological amplifying feedback processes. The scaling dimensions and feedback processes often compliment,

102 antagonise, or even balance one another and affect the impact of any given intervention. The same scaling

103 interventions could have varying effects across scaling levels. For instance, while agricultural subsidies could

104 increase real household incomes at small scale, once scaled up for the same group, the average welfare effects

105 could drop (Bergguist et al., 2023). At small scales, the land-rich experience larger income gains from

106 subsidies at the expense of the land-poor. However, at scale, input prices might decrease for input-intensive

107 crops while the cost of labour increases, hence, increasing income benefits to the land poor over the land rich.

108 Activation of these feedback processes requires certain enabling conditions to be in place. Some of these

109 conditions relate to the innovation itself and can be partly addressed at the design stage, such as price and

110 quality. Others such as complementarity and performance, desirability and symbolism, accessibility and

111 convenience, information and social networks depend on how the innovation fits within the environment it is

112 to be implemented (Lenton et al., 2022). These conditions are highly dynamic, continuously adjusting in

113 response to the actions taken and the feedback processes triggered, modifying the intervention environment.

114 To keep up with these dynamics, implementors have to be highly proactive and adaptive in their response.

Enabling conditions and feedback processes for successful adoption of RA in Africa

116 Innovation adoption is a complex process with multiple possible outcomes; adoption (continued use of an

117 innovation) (Ainembabazi & Mugisha, 2014; Amadu et al., 2020), partial adoption (using part of the

118 innovation) (Zulu-Mbata et al., 2016), adoption intensity (using more or less of the

119 innovation)(Kunzekweguta et al., 2017; Mujeyi et al., 2022), non-adoption (not using the innovation) (Khoza

120 et al., 2019), dis-adoption (stopping use of the innovation) (Alpizar et al., 2022; Grabowski et al., 2016), and

121 adaptation (editing the innovation) (Bouwman et al., 2021). Here, an innovation is any intervention new to a

122 given location or context. It could be a product (e.g., a new plant variety), a practice (e.g., cover cropping,

123 governance approach) or knowledge (e.g., a planting technique). The individual attributes of an innovation

124 (e.g., price, quality) as well as how well it integrates with existing systems (e.g., complementarity,

125 accessibility, symbolism, performance) would affect its scalability and readiness to scale. Here adoption is

126 used to mean the same as scaling out.

Cost, performance, and capability: The cost of an innovation is often evaluated in terms of a farmer's

128 available resources (can I afford it?) either in terms of capital or labour, how it fits with existing systems (does

129 it complement what I have?), or perceptions of performance (can it make things better?). For instance, for a

130 farmer who already has oxen, buying an ox plough could be cheaper than hiring a tractor. However, the

131 converse may be true for a farmer without oxen. Perceptions of performance may motivate initial investment,

132 however actual performance drives future investments. To fully experience the benefits of an innovation,

133 farmers need to have the capability to effectively use the innovation. In most cases, farmers must meet the

134 innovation's effective implementation requirements (i.e., the requirements to maximize the benefits of an

135 innovation), such as labour (Habanyati et al., 2020), time (Bouwman et al., 2021), and land requirements

136 (Kurgat et al., 2020) to fully experience the benefits. Therefore, interventions that increase the affordability of

137 an innovation, the capability of farmers and optimize performance would most likely increase the scalability

138 of the innovation.

139 The interaction between cost and performance could trigger certain amplifying feedbacks and lead to virtuous

140 rapid scaling cycles. For instance, if the cost of implementation decreases while the performance increases,

141 increasing returns could be achieved (Takeshima, 2017). Increasing returns could also result from farmers

142 changing their enterprise mix (Li et al., 2023), specialisation (Takeshima, 2017) or mechanisation (Takeshima,

143 2017). As farmers learn through practice, they get more efficient and potentially obtain higher benefits from

144 the intervention. These benefits from increasing returns or learning by doing could trigger mass sequential

145 adoption through social contagion as farmers learn from, listen to, observe and mimic successful peers in their

146 social networks (Centola, 2021). At programme level, learning by doing could lead to reduced barriers to

147 entry and better intervention benefits, thus, increasing the likelihood of successful scaling.

148 **Desirability and symbolism:** Cultural beliefs, norms and traditions shape what is acceptable within a given

149 society. Changing social norms and beliefs (scaling deep) often precede and could drive political (scaling up)

150 and technological changes and if the amplifying feedbacks are strong, this cycle of changes could potentially

151 tip social behaviour. In the RA adoption space, such norms could relate to livelihood strategies for a given

152 group (Agundez et al., 2022); gender roles and associated resource access rights (Kehinde & Adeyemo, 2017;

153 Khoza et al., 2019); and social-cultural beliefs (myths about certain practices) (Agundez et al., 2022;

154 Assogbadjo et al., 2012). For instance, in northern Malawi, Bambara groundnuts (*Vigna subterranean*) had

155 been promoted for its high nutritious value, drought tolerance, and soil-enhancing qualities. However, certain

156 groups culturally associated this plant with death thus limiting its cultivation, distribution, and marketing

157 (Forsythe et al., 2015). Resistance to the adoption of potentially beneficial interventions could, in principle, be

158 mitigated through educational campaigns through communities of practice (Page & Dilling, 2019). However,

159 there can be important ethical considerations around changing beliefs and practices in ways that could change

160 the identity of a people.

161 Social norms and behaviour can be moulded and shaped through actions of third-party entities such as the

162 government, intergovernmental and non-government organisations, academics, and faith-based organisations,

163 who may have competing motivations (Fehr & Fischbacher, 2004; Halevy & Halali, 2015). It is therefore

164 crucial that communities, whose cultural beliefs, norms, and traditions are impacted, are provided with

165 adequate information about interventions, enabling them to independently assess their options and make

166 informed choices. In the smallholder setting, this often involves intensive and consistent agricultural

167 extension, characterised by active farmer participation, practical demonstrations of RA practices benefits, and

168 working with common interest groups (Reed, 2007). Groups particularly provide a space for consultation

169 between peers and leverage the power of social influence towards adoption of group norms (Alexander et al.,

170 2022). In practice, agricultural extension services and community groups are often affiliated to certain entities

171 whose viewpoints and norms they champion. Utilising existing extension and community structure therefore

172 risks playing into preexisting power dynamics and potentially contributing to processes with unintended and

173 often undesirable outcomes.

174 **Accessibility/Convenience:**   For a product or process to be considered accessible, it must be available,

175 farmers must be able to reach the point of supply with ease, and they need to have the rights to use it.

176 Availability refers to the physical presence, for instance, of land (Kehinde & Adeyemo, 2017;

177 Razafimahatratra et al., 2021), water for irrigation (Maindi et al., 2020) and essential inputs (Murindangabo et

178 al., 2021) in case of most RA interventions. However, just because a resource is available does not guarantee

179 accessibility due to infrastructural barriers or issues associated with resource use rights. For example, distance

180 from markets/point of supply (Abdulai et al., 2021; Kifle et al., 2022; Kunzekweguta et al., 2017; Mujeyi et

181 al., 2022), inadequate road infrastructure (Maindi et al., 2020; Wafula et al., 2016), and ownership of transport

182 assets to reduce the relative distance (Mujeyi et al., 2022), land tenure (Murindangabo et al., 2021; Owombo

183 & Idumah, 2017; Teklu et al., 2023) and rights to protect and own trees in agroforestry schemes (Kouassi et

184 al., 2021) could limit access, and capability of potential user and thus adoption.

185 Addressing the various dimensions of accessibility could improve farmer interaction, increase their likelihood

186 of experiencing innovation benefits and potentially adoption. On the other hand, by taking steps to address

187 these challenges, it is likely that certain amplifying feedback processes could be triggered resulting to virtuous

188 scaling cycles. For instance, addressing the issues of rights could involve both addressing certain social norms

189 linked to gender roles (scaling deep) and reviewing policies around land rights (scaling-up). On the other

190 hand, infrastructural investments such as road networks and markets often come after policy changes (scaling

191 up). The latter could lower the cost of investment creating opportunities for increasing returns and potentially

192 network effects. Network effects occur when the benefits offered by a product or service increases with the

193 number of users (Tucker, 2018).

194 **Information/social networks:** While mechanisms like persuasion, regulation and incentives have often been

195 used to bridge the adoption gap for most interventions (Ajayi et al., 2008), positive perception of performance

196 of a RA practice plays a key role in driving both the initial engagement with and continued use of an

197 innovation. Exposure to the innovation forms an essential part in enabling the potential adopters to understand

198 the innovation, its performance and their own capability to effectively use it. For interventions whose benefits

199 could take long to be realised, increasing duration of exposure (Alpizar et al., 2022) while providing technical

200 support (Habanyati et al., 2020) is an essential step. However, it is important to manage expectations or else

201 risk potential dis-adoption if the innovation does not deliver as expected (Chinseu et al., 2019). Access to

202 complete information is crucial in shaping potential adopters' experiences with an innovation, thereby

203 influencing its likelihood of adoption or non-adoption.

204 The impact of all the enabling conditions discussed above is information dependent. Therefore, the type of

205 information, how to present it, to whom, when, how often, and where are all key questions when creating

206 conditions for successful adoption. The level of access, perception, and trust of any particular information

207 source could vary from group to group. Thus, to effectively communicate, one must understand the most

favoured sources of information for any particular group (Djido et al., 2021; Muriith et al., 2021). 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, extension approaches that prioritise farmer participation and practical demonstration of the RA practice benefits are likely to be more effective in improving farmer perception and adoption (Reed, 2007).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, to strengthen and leverage the social capital in farmer networks, it makes sense to work with groups of people near each other. For highly complex behaviours like adoption of a new innovation, the strong social networks cultivated in a group environment can play a powerful role in propelling behavioural contagion(Centola, 2021). Groups also provide secondary services that could improve the ability of individual group members to address resource limitations that could affect adoption such as providing access to affordable credit.

Most of the amplifying feedback processes linked to scaling leverage the power of information and social networks. For instance, network effects rely on the benefits of being part of a large network (Tucker, 2018), social contagion is driven by farmers getting information from, observing and imitating influential members of their social networks (Herrando & Constantinides, 2021; Randall et al., 2015). For information cascades, agents are most likely to act on information from trusted contacts and then only evaluate these reactions later (Tokita et al., 2021). Some of these feedback processes could result in the reconfiguration of social network structure, impacting the scaling processes that are reliant on these social network structures. For instance, in the event of undesirable outcomes, agents would likely change their trusted contacts to avoid going through a similar experience in the future (Tokita et al., 2021). Therefore, it is worth ensuring that expectations are managed, the information shared is authentic, and multiple points of the network are targeted to minimise chances of information loss in case of a network reconfiguration.

Learning is an essential step in the adoption process and in its absence, the capability of the user could be greatly diminished and along with it the benefits drawn from an innovation. While information cascades can be highly effective in recruiting large numbers of participants in a short time, there is a risk that social learning could be blocked as agents conform too quickly, not allowing time to aggregate information and update personal beliefs (Bikhchandani et al., 2021). It is therefore essential to create a balance between having rapid scaling and ensuring that individuals learn enough to explore and experience the benefit of an innovation.

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 is currently running in Kenya, Uganda, Tanzania, and India (Benjamin et al., 2018). The programme also promotes reforestation, conservation farming, entrepreneurship and operates in small groups of 6-12 farmers within walking distance from each other (Reid & Swiderska, 2008). Since its launch in 1999, TIST has reached over 216,812 farming

households in 33,911 small groups, maintained over 25 million trees, and offset over 7 million tonnes of carbon (https://programme.tist.org, *accessed on 20/07/2024*). In East Africa, Kenya (15,529 groups) has the highest number of groups enrolled followed by Uganda (5,976 groups) (Figure 2).
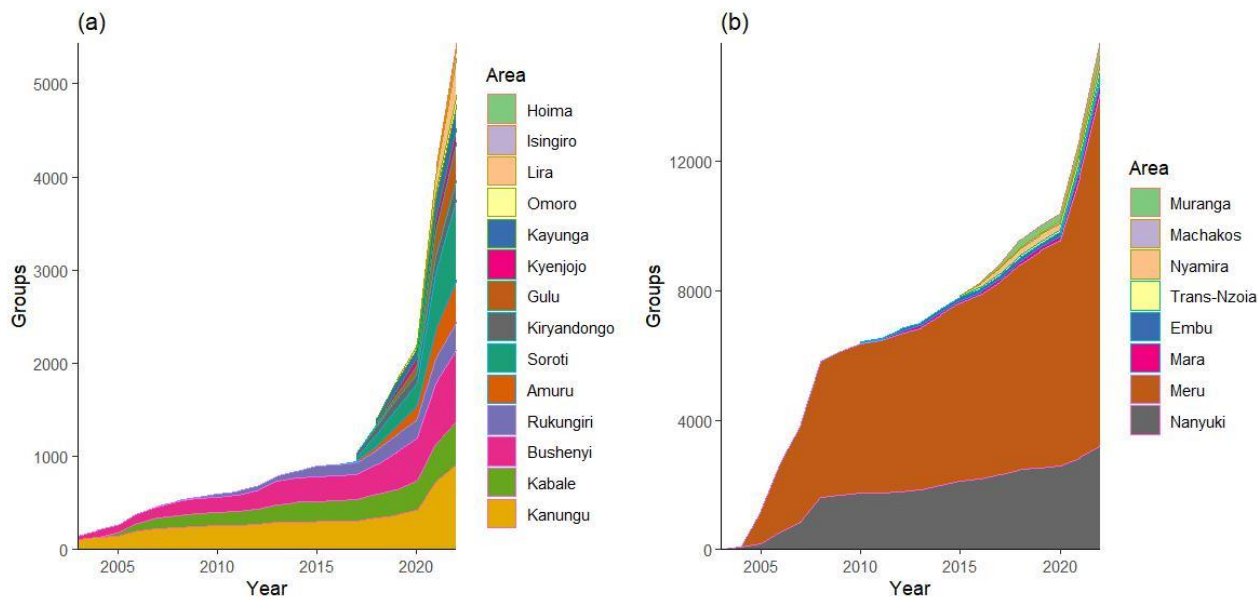
Figure 2: Enrolment of TIST participants in Uganda (a) and Kenya (b) between 2003 and 2022. Enrolment varies between countries and sites within each country thus highlighting the context specificity of scaling processes.

Figure 2 above shows variation in enrolment across different sites thus highlighting the contextual nature of scaling and hinting on the need to address each scaling challenge on a case-by-case basis. In Kenya, participant enrolment rates in the Meru and Nanyuki project areas overshadow all the other sites in the country and shape the national enrolment picture while in Uganda, the programme expanded to several new project areas after 2015, with some (Soroti, Gulu, Amuru, and Lira) achieving high rates of enrolment comparable to the older sites. For instance, of the five sites with the highest number of groups in Uganda, three sites are less than seven years old as of 2024, and among these Soroti has the second-highest enrolment rate of all the sites in the country.

Scaling of TIST

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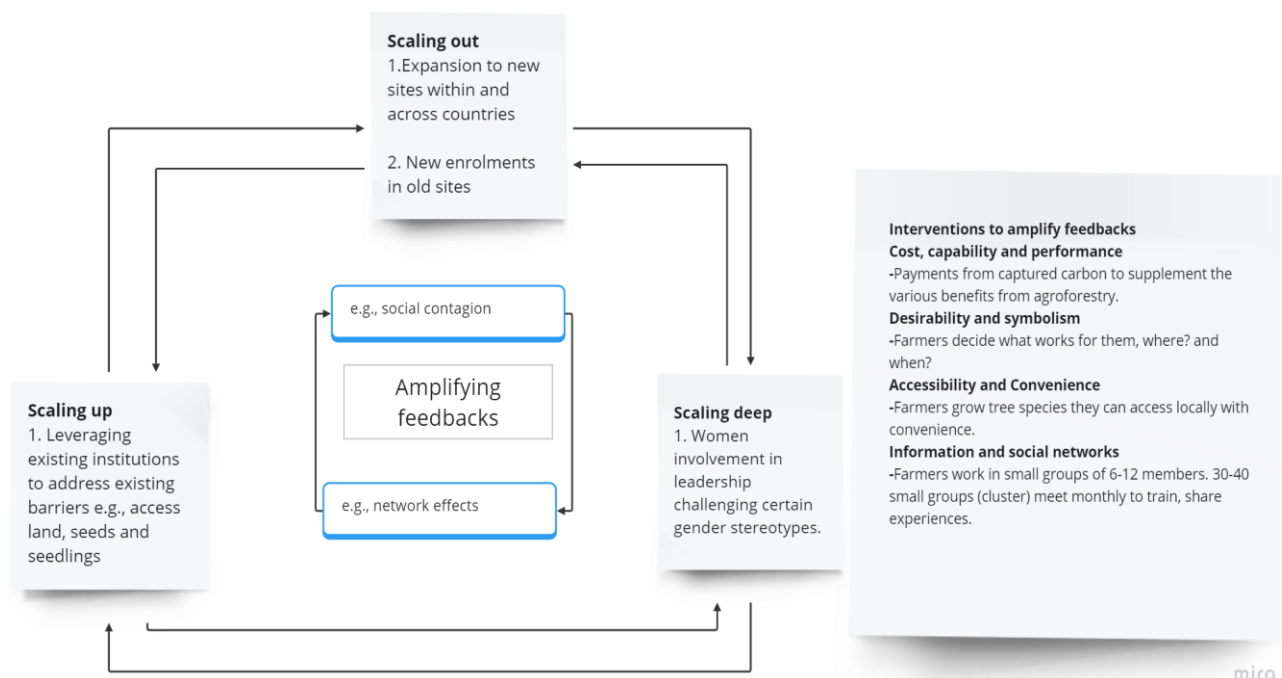
Figure 3: The different forms in which TIST scales up, deep and out. The various interventions activate and contribute to the amplification of certain feedback processes that drive the various forms of scaling and the interaction between them.

Enabling conditions and amplifying feedback processes in the scaling of TIST.

Cost, capability, and performance: While the promise of supplemental income from captured carbon is a key incentive for initial enrolment in the program, the additional diverse benefits and the low cost of participation gives participants multiple reasons to join and stay involved with the program. By design, TIST prioritises maximisation of the benefits from participation in the programme while increasing the capability of the farmers to engage with the program through minimisation of involvement costs. On the benefits side, the programme supports its participants to access payments for the carbon captured by their trees to supplement the other benefits the trees already provide or may provide in the future. Such benefits include soil improvement, erosion control, wind breaks, firewood, fruits from fruit trees, fencing material, timber, medicine, bee habitats, natural insecticides, and fodder (Reid & Swiderska, 2008). The programme also offers secondary benefits to participants such as better access to credit (Benjamin et al., 2016), improved social capital, gender equity (Benjamin et al., 2018), and various livelihood diversification opportunities. On the cost side, farmers in the program are encouraged to establish their own tree nurseries at group levels and grow locally available tree species. This localisation of supply and flexibility of choice aims to improve affordability and the contextual appropriateness of tree choices. Secondly, TIST does not restrict participation based on land size or location. Therefore, interested farmers do not have to incur any extra costs to access land in order to participate. This cost reduction, while increasing the benefits, also increases the returns to participation potentially igniting social contagion as farmers observe and imitate successful peers, network effects as the increase in the number of adopters results into stronger social support systems and a build-up of social-ecological feedbacks leading to greater social-ecological impacts (See Figure 4).

Social contagion & network effects

Social processes
Ecological processes
Economic processes
Agronomic processes
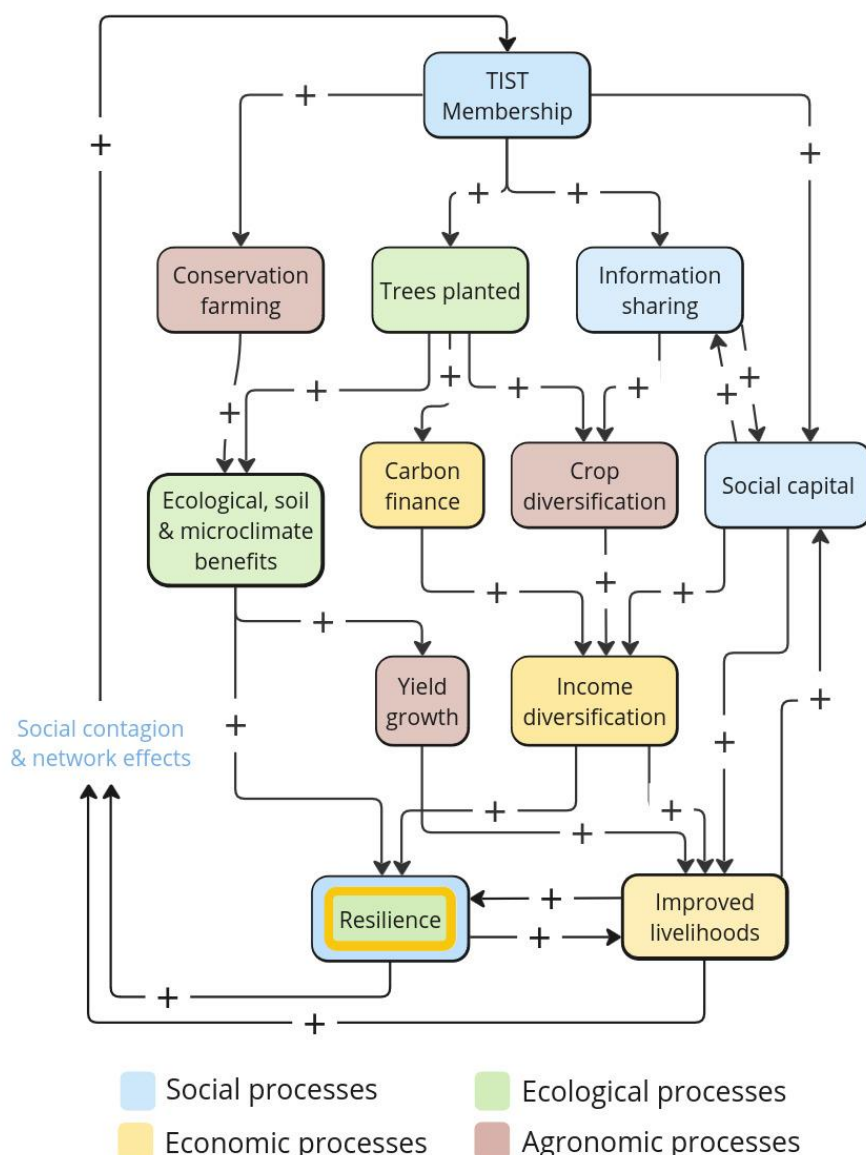
Figure 4: Reproduced from Figure 4.3.11 in Powell et al. (2023 p.43). Amplifying feedback processes drive adoption of TIST at community level. Conservation agriculture and agroforestry improve the soil ecological functioning hence contributing to improved and more stable yields, while the various tree 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. The various pathways contribute to improved resilience and drive social contagion in TIST.

Desirability and symbolism: Since TIST is farmer-centred and farmer-led, the farmers' own beliefs, norms, and value system are integrated within program participation decisions like what tree species to plant, where, and how to plant. With farmers driving decisions, they are also able to drive appropriate local policy changes from the grassroots. To aid this, TIST employs 'cluster servants' to provide extension services, supporting farmers in making such context-relevant changes without compromising program operational principles. The cluster servants are appointed from the community of farmers and so are familiar with both the local context and the programme's operational dynamics. In the absence of external support, farmers often promote their innovations among peers (Reed, 2007). Under TIST, various groups in the same cluster (30-40 small groups)

meet monthly, thus creating a platform for peer-to-peer innovation promotion. These monthly cluster meetings also strengthen the social support networks that play a key part in dealing with the more nuanced and personal adoption challenges.

Accessibility and convenience: Enrolment in the TIST programme is open to all interested smallholders within the different project areas. Participation is not restricted by farm size (Benjamin & Blum, 2015) implying that even farmers with access to very small pieces of land are capable of participating. Groups source their seed and seedlings. For instance, groups are encouraged to establish and manage the nurseries but could also obtain seeds through other preferred local sources. This ensures that farmers only grow species they can obtain locally and with convenience. TIST cluster servants are recruited from the local community where they remain and work. Most are group members within the same communities where they operate. This ensures that the much-needed extension support is easily and conveniently accessible by the beneficiary community. TIST offers farmers contracts of 10-30 years along with regular training 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). These various factors minimise the barriers to entry into the program, increasing the potential value in the benefits from participation and making the program highly scalable.

Information and social networks: Perception of performance is dependent on what is known about the impact of the program. To introduce new entrants to the program impacts, TIST adopts a 'come and see' approach where representatives from a potential project area are invited to visit and directly engage with actual beneficiaries from older sites. For example, TIST started in western Uganda with representatives of the south Rwenzori Diocese visiting active farmers in Tanzania and experiencing the impact of the project there, then returning and initiating it in their region. This approach creates an opportunity for potential participants to witness the benefits, learn, gauge their capability to participate, and build networks for support during implementation.

TIST also adopts a highly participatory approach in its activities with farmers. For instance, farmers are involved in the monitoring, verification, and reporting of the trees' carbon content along with quantifiers (Benjamin et al., 2018). Individual farmer experiences are often shared during the cluster meetings, which are always open to other community members who might be interested in the program. Since the members of the cluster are often from the same geographical area and the same or closely related communities, the experiences shared are relatable and shared by people already known to the community. Through the group structure and these regular meetings, newly enrolled participants get to engage with participants who have been in the programme longer. This creates more opportunities for validation of knowledge and farmer-to-farmer support during the adoption process.

The interesting experiences from the different cluster meetings held across the country are captured and compiled into monthly newsletters, which are freely distributed by cluster servants to the different stakeholders in their areas of operation. The newsletters are also accessible to the public on the TIST website (www.tist.org), creating an opportunity for other non-program participants in the reported areas to learn about

339 the program activities, successes, and opportunities to get involved. The program also maintains an open

340 policy to research, actively seeking collaborations with researchers and providing access to essential program

341 datasets, which has enabled higher-level impact evaluations.

342 Through the various processes described above, TIST creates diverse opportunities for learning by doing,

343 laying the foundation for social contagion as participants have access to numerous opportunities to observe

344 impacts and peers to learn from and imitate. The social-ecological amplifying feedback processes potentially

345 lead to landscape impacts such as increased greening of the landscape in Kenya (Buxton et al., 2021) along

346 with the demonstrated social impacts such as economic empowerment (Benjamin et al., 2018) have increased

347 the value of carbon credits sold by TIST thus commanding some of the highest prices for forest-based

348 initiatives in the market, currently USD $46 per tonne (https://program.tist.org/buy-carbon-credits, *accessed*

349 *on 26/7/2024*). TIST has also received various recognitions and awards attesting to its contribution, drawing in

350 more collaborators and partners, consequently increasing the value of being a member of its network and

351 potentially leading to network effects.

Conclusion

353 RA practices have been lauded as a potential solution to the growing food insecurity and declining

354 smallholder farmer resilience to the growing climate change pressure, and their rapid and mass adoption an

355 essential step to addressing some of the key climate change targets (IUCN, 2021; Marrakech Partnership,

356 2022). However, except for a few programs like TIST, most interventions promoting these practices struggle

357 to attain the desired levels and rates of adoption. In this paper, by combining 'the positive tipping points and

358 Moore et al.'s scaling dimensions' we propose a conceptual framework for rapid and mass scaling, apply it in

359 the evaluation of TIST scaling success, and draw three key lessons;

360 (1) To achieve rapid and sustained scaling and potentially a positive tipping point in the adoption of RA, it is

361 essential to scale out (reach more people) while at the same time scaling up (impacting policy and institutions)

362 and deep (impacting beliefs and norms). One of the ways TIST achieves this is by empowering smallholder

363 farmers to lead not only in the mobilisation and recruitment of peers through group formation but also in the

364 decisions around what tree species to plant, where? and how? Through this process, the choices made are not

365 only contextually relevant, but the smallholders can also influence local policies and norms to complement

366 their adoption choices.

367   (2) These different dimensions of scaling (scaling out, up, and deep) continuously interact, often reinforcing

368 each other. For instance, as more farmers in a particular location enrol in the program, they attain a critical

369 mass to trigger changes in local policy, beliefs, and norms. Such changes could in turn trigger further

370 adoption.

371 (3) Feedback processes mediate interactions between and across scaling dimensions. For instance, when a

372 TIST group receives carbon payments, other groups, and community members are encouraged to enrol,

373 triggering greater complementary changes in policy, norms, and beliefs. As members learn and gain

374 experience in implementing the various program practices, they can reap even greater benefits from

375 participation. By leveraging the social network and social capital cultivated through working in groups, new

376 members are supported to achieve similar benefits including carbon payments. All these events amplify

377 feedback processes for further scaling. If such feedbacks are strong, scaling can be rapid and self-
378 perpetuating.

379 Although the reasoning behind the proposed conceptual framework provides a compelling structure for
380 systematically thinking about and addressing the rapid scaling challenge for RA in sub-Saharan Africa, in its
381 present form it lacks strong empirical backing and its practical utilisation will depend on the availability of
382 highly context-specific data associated with the relevant variables and parameters (enabling conditions,
383 amplifying feedbacks, and scaling goals). While monitoring and evaluation processes in existing programs
384 could be an important resource in bridging the essential data gaps, it would be worth re-orienting the
385 monitoring targets to meet the data needs for accelerating scaling. Secondly, most resource-limited grassroot
386 organisation may not have the capacity to invest in robust data collection yet they are best placed to initiate
387 certain grassroot actions. For such organisation, relevant regional-level or country data sets could provide a
388 starting point for narrowing down relevant actions and processes. Hence, as a next step, future research could
389 investigate creating such data sets.

390 **Open Access Statement**
391 For open access, the author has applied a Creative Commons Attribution (CC BY) licence to any Author
392 Accepted Manuscript version arising from this submission. Data and code used for figure 2 can be accessed in
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394 **Competing Interests**
395 The contact author has declared that none of the authors has any competing interests.

396 **Author Contribution**
397 **Antony Philip Emenyu** conceived the paper, worked on the conceptual framework, developed figures 1,2,3,
398 and structured and wrote the paper with input from the various co-authors. **Tom Powell** drew Figure 4 (TIST
399 feedback diagram) and contributed to the conceptual framing of feedback interactions in the conceptual
400 framework section and TIST case study along with **Tim Lenton. Thomas Pienkowski** contributed to
401 conceptualisation of the link between feedback processes and the dimensions of scaling. **Andy Cunliffe**
402 oversaw the coding for Figure 2 and the development of the GitHub repository and Zenodo in the open-access
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