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Innovation systems and Affordances in Climate Smart Agriculture

Abstract

There is significant international investment and effort in the development, piloting and upscaling of climate smart agriculture (CSA), with particular emphasis on delivering benefits to smallholder farmers through programmes of CSA interventions. However, there is poor understanding of how smallholder farmers access beneficial outcomes from changes in agricultural practices, beyond narrow and simplistic metrics, such as adoption rates and yield increases. Furthermore, binary notions of adopters and non-adopters provides a poor basis for understanding innovation within complex farming systems. By integrating an innovation systems perspective with the theory of affordances, we explore how agricultural innovation happens in the context of two CSA interventions in the Tanga Region of Tanzania, to examine who has access to, and is able to benefit from interventions, who does not, and why. Drawing on ethnographic and interview data involving over 200 participants, we demonstrate how innovation processes in this context are diverse and non-linear, and discuss how potential outcomes derived from programmes are shaped by farmers' affordances. We argue that common programme reporting metrics fail to account for the dynamic and nonlinearity of innovation processes and risk overlooking unintended outcomes of interventions. We propose that interventions should be conceived with an appreciation of context and affordances from the outset, to support how they engage with the least capable from the very beginning.

Keywords: Climate change, agriculture, agricultural innovation systems, smallholder, affordances theory, agricultural research and development

1. Introduction

To transform agriculture into a climate-resilient sector, the international research and development community is focusing significant effort and investment in achieving and upscaling climate-smart agriculture (CSA) (Perez et al., 2019; Schaafsma et al., 2018; van Wesenbeeck et al., 2019). CSA holds the promise of simultaneously improving agricultural production, whilst also enabling adaptation to, and mitigation of climate change (Lipper et al., 2014). CSA discourse re-brands a set of existing practices and technologies as ‘climate-smart’, and in doing so, it brings together a new configuration of actors, generating new opportunities for investment alongside a rise of ‘new’ initiatives to demonstrate the viability of agricultural practices (Clapp et al., 2017). CSA is therefore an emerging space for innovation. However, the operationalisation of CSA has far outpaced academic enquiry (Wood et al., 2016). Multiple social, institutional, environmental and economic complexities pose significant challenges to effective upscaling of CSA (Long et al., 2016; Senyolo et al., 2018; Steenwerth et al., 2014), many of which remain unidentified (Lipper et al., 2014). Developing nuanced understanding of these complexities is critical for transforming agricultural systems (Suleman, 2017).

CSA success stories are often narrated on the basis of incomplete evidence about the contextual dependencies of CSA technology performance, or the lived experience of CSA interventions by individual farmers (Sumberg et al., 2012). Through this approach, they support broader endeavours towards ‘scaling up’ practices and technologies that ‘work’, but may simultaneously mask the ways in which these technologies and practices are unequally experienced across time and space (Whitfield et al., 2015). Socially disaggregated outcomes of CSA interventions remain unclear (Taylor, 2018); limited understanding who is rendered vulnerable and how, means that implementation of CSA may overlook those most in need and instead risks exacerbating inequalities. In contributing to efforts that provide grounded insight into the embedded experiences of CSA innovation (Glover et al., 2016) – embedded both in place and in a multi-level innovation system –, in this paper we examine how innovation happens in the context of two CSA interventions in Tanga Region of the United Republic of Tanzania (henceforth Tanzania). Through exploring innovation processes, this paper highlights the diversity of actors, approaches and outcomes of interventions, who does and does not benefit, and raises questions about the viability of, and challenges with global ambitions to upscaling CSA.

Multi-lateral partnerships are typical in programmes of CSA intervention (Taylor, 2018). Often, these are implemented through local agricultural service providers and local government authorities in partnership with international non-governmental research and development organisations, themselves funded through a constellation of bilateral and multilateral donors. There is an inevitable multiplicity of motivations and norms, as well as power asymmetries that exist across these levels, which ultimately shapes programme design and implementation. These typically manifest in the demonstration and promotion of technologies and practices through models such as farmer field school, ‘lead farmer’ or demonstration plot approaches. Through these, knowledge spreads and technologies diffuse, becoming adopted beyond the immediate site of training and demonstration (Neate, 2013; Sala et al., 2016).

There are however concerns that CSA implementation exists in an apolitical space, where implementation is restricted to identifying technocratic solutions to fix field-level problems (Taylor, 2018). This is reflected by operational language in programme documents that revolve around ‘toolkits’ and ‘pathways’ (Newell & Taylor, 2017). Critiques of CSA interventions also highlight concerns around the tendency to implement in a technocratic top-down and linear manner, which can serve to de-legitimise and limit alternative opportunities for novel, relevant and appropriate change. This is well illustrated in the literature, where studies tend to focus on the scientific and technical practices in CSA, often at the farm-level, with few including off-farm activities in their evaluations, such as institutional arrangements, policies and knowledge generation (Chandra et al., 2017; Hermans et al., 2020). Until recently (Andrieu et al., 2017; Mwongera et al., 2017), the participatory mandate of CSA has been lacking (Wood et al., 2016). This has not only reduced space for farmer-driven change (Whitfield, 2015), but also raises questions about how vulnerable stakeholders have been (in)-excluded from decisions that affect their livelihoods (Karlsson et al., 2018). Better understanding of farmers' responses to CSA technologies and practices is therefore required (Totin et al., 2018) in order to understand who does and does not benefit, and why.

A focus on technical solutions and outcomes fails to address the complex social structures and dynamics in rural communities (Friis-Hansen & Duveskog, 2012) and does not sufficiently recognise farmers' disposition towards certain practices, nor their abilities to employ them (Glover et al., 2019). As such, CSA implementation is criticised for failing to prioritise farmers' rights and knowledge (Sugden, 2015) and emphasising a control of, rather than promoting access to, technologies (Newell & Taylor, 2017). Furthermore, evaluation of CSA interventions often focusses on reporting adoption rates, classifying farmers in a binary way, as adopters and non-adopters (Khatri-Chhetri et al., 2017; Senyolo et al., 2018), in part to evidence success and report impact-at-scale metrics. Such measures simplify processes of innovation and provide a poor basis for understanding innovation within complex farming systems (Glover et al., 2019).

In this study, we extend evaluation of CSA, and development interventions more broadly, beyond the more common focus on adoption rates, or technologies, practice and production, to focus on the innovation processes that support smallholder livelihoods. Our study has the following objectives, to: a) examine how agricultural innovation happens in the context of CSA programmes, and b) explore differentiated experiences of innovation within and across the two case studies. From our analysis, we draw lessons to inform future design, implementation and upscaling of CSA interventions.

2. Materials and methods

2.1. Conceptual framing

In this paper, we conceive innovation as an ongoing process of change. Progressing from a linear model of innovation, where innovation is created by 'experts' and 'new' knowledge is hierarchically transferred to end users, we draw on an innovation systems perspective. This views innovation as a complex, non-linear process-based approach and allows the conceptualisation and examination of how knowledge is generated and used (Hall et al., 2003; Spielman et al., 2008). An innovation systems perspective recognises how multiple actors, markets and policy regimes may shape innovation processes (Spielman et al., 2009). In agricultural innovation systems, knowledge exchange incorporates a diverse range of stakeholders, inclusive of farmers, scientists, educators, supply chain actors and government officials. Supporting services, such as research, extension and education, play a pivotal role in innovation processes (Hermans et al., 2017).

Innovation is therefore not simply a piece of technology (for example see Senyolo et al., 2018), or the adoption of said technology. Rather, as Smits (2002) notes, innovation can be described as the integration of a range of interconnected processes distinguished into three broad components: *orgware, software* and *hardware*. *Orgware* concerns the institutional conditions and forms of organisation, including the ordering of formal and informal institutions and organisations, such as farmer field school or financial groups; *software* relates to knowledge (including tacit knowledge), modes of thinking and communication and sharing of knowledge, such as through teaching and learning processes in both theory and practice; *hardware* denotes the physical equipment and tools, as well as the skills, techniques and practices involved, such as genetic modification, biochar, fertiliser and irrigation (adapted from Smits, 2002; Leeuwis and Aarts, 2011; Klerkx and Leeuwis, 2009; Hermans et al., 2017).

Innovation may reflect diverse combinations of these three components and is best understood as complex interactive processes where scientific, technological and societal systems coevolve (Smits 2002), hence technologies and knowledges are socially constructed. Whilst the framing of Orgware software and hardware (OSH) covers the key components of innovation, as Smits (2002) remarks, this definition of innovation has limitations. Certain limitations are perhaps particularly pronounced in the context of programmes of development interventions, where smallholder farmers are often the intended beneficiaries of innovation. By promoting the use of alternative agricultural practices and technologies through farmer field schools, for example, programmes of CSA interventions seek to modify pre-existing innovation processes, and fundamentally change agricultural systems to generate positive outcomes for smallholder livelihoods. Yet, in this context the OSH framing may fail to capture the complex dynamics of smallholder agriculture, and interactions with smallholder farmers' agency.

In their critique of conceptual innovation theories, Glover et al., (2019) demonstrate how there is much to learn from social constructivist perspectives of technological change, to enhance the more well established innovation approaches commonly used by practitioners, such as diffusion theory (Rogers, 2010) and agricultural innovation systems (Clark, 2002; Sumberg, 2005, as cited in Glover et al., (2019)). Social constructivist approaches bring a more actor-oriented lens that recognise spatial and individual variability, whereby technologies and practices are made and remade, rather than received and adopted. Glover et al., (2019) also note that it is more important and revealing to understand broad changes as a result of a programme or intervention (such as outcomes in food security and nutrition, gender equality and environmental sustainability), than to identify instances of adoption, as this may overlook both positive and negative unanticipated outcomes.

In the context of technological change in smallholder agriculture, Glover et al., (2019) explain the theory of *affordances,* where "an affordance is an opportunity, perceived by an agent, to put an object or material to some use" (pp.173-174); these perceptions are "subjective, situational and relational" (pp. 174). The theory of affordances has been applied elsewhere in agricultural innovation systems, particularly focussed on technology affordances, for example to enhance participatory design of agricultural systems analysis tools (Ditzler et al.,2018), and in understanding access and barriers to digital and mobile technologies (Wyche and Steinfield, 2015; Macharia 2020).

Affordances place smallholders' agency at the centre of innovation processes, whereby affordances stem from both the property of an object or environment (i.e. innovation components (OSH)), and from the characteristics of an individual, including their intrinsic capacities (e.g. their knowledge, intelligence, physical strength etc.) and their resources (e.g. financial, land, labour etc.). These interactions are diverse and dynamic, conditioned and shaped over time and by social and cultural norms (Arora & Glover, 2017; Ramstead et al., 2016). Consequently, innovation components (OSH), an agent and their affordances are embedded into broader and situational contexts. Affordances are relational – they emerge from the interactions between users (in this case smallholder farmer) and innovation components (Ditzler et al.,2018). The key insight, Glover et al.,(2019) note, is recognising that affordances of agricultural technologies are unique to different people in different situations - though we would argue that this understanding should be expanded to all innovation components (OSH), rather than limiting this recognition to only a technological component. Affordances therefore reflect the dynamic interactions between the characteristics of an agent and the attributes of varied innovation components (OSH), within a given context.

Drawing on the theory of affordances (Glover et al., 2019) and of innovation components (Smits 2002), we present an innovation-affordance framework (Fig 1). In smallholder agricultural systems, innovation is an ongoing process of change that an external programme may seek to influence. The framework highlights how affordances emerge from the interactions between innovation components (OSH) and an agent, and illustrates the cyclical feedback nature of outcomes. Embedded within and shaped by the situational context, these interactions reflect dynamic and diverse farm-systems and farmer livelihoods and recognise that innovation pathways draw on a range of resources and may lead to a variety of expected and unexpected outcomes.

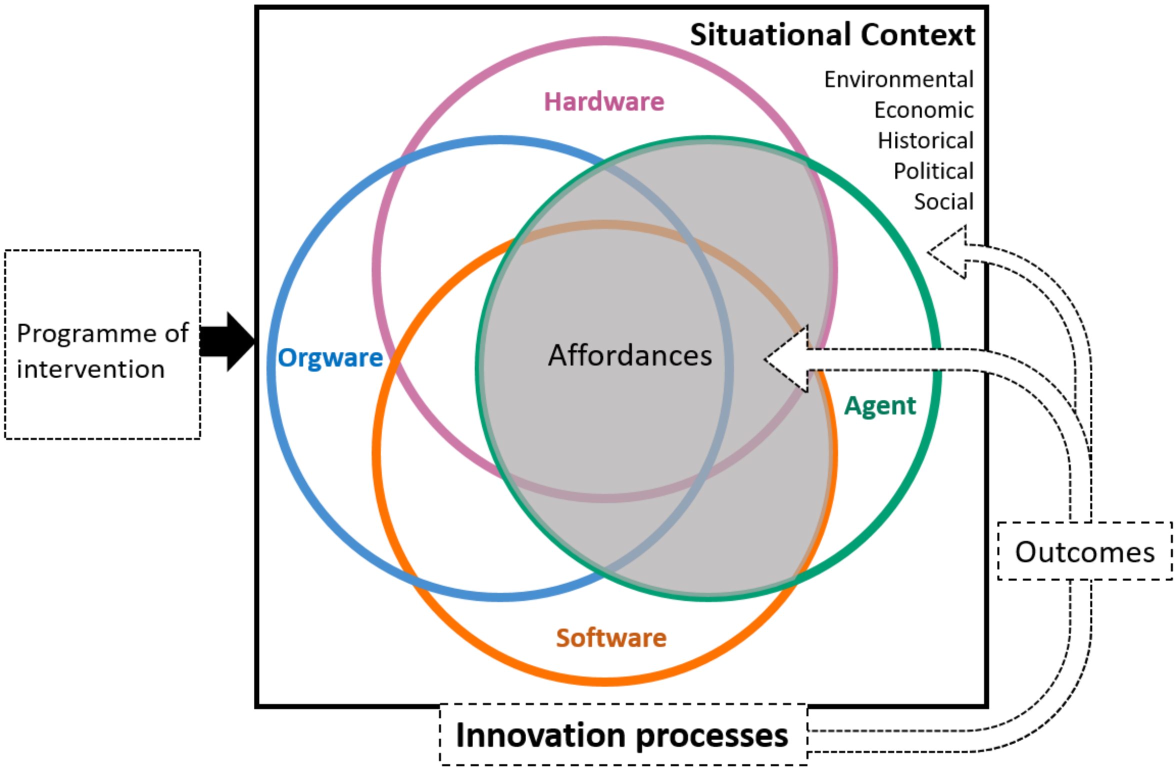

Fig. 1: An innovation-affordance framework. External programmes of intervention may seek to modify innovation processes, change agricultural systems and generate positive outcomes for smallholder livelihoods. When thinking about change in these systems, the framework illustrates how *Affordances* (shaded in grey) -perceived opportunities to use or engage with innovation components- arise from the interactions between interconnected innovation components – *Orgware* (blue), *Software* (orange), *Hardware* (pink) – and an *Agent* (green). These elements, and the interactions that emerge between them, are embedded within and shaped by the *situational context* – including environmental, economic, historical, political and social factors. The arrows in the framework highlight how innovation processes are cyclical in nature, creating *outcomes* that feedback and may alter the context or the circumstances of an agent and their affordances, which in turn may lead to novel innovation processes and outcomes.

2.2. Study site

The Usambara Mountains located in Tanga Region, north-east Tanzania, form the eastern most ranges of the Eastern Arc Mountains. The Usambara Mountains are divided into the East Usambara (EUM) and West Usambara Mountains (WUM) intersected by the Lwengera valley, located across

Muheza, Lushoto and Korogwe Districts (Fig. 2). The Usambara mountains typically experience high annual rainfall (ranging between 600-1300 mm across both the EUM and WUM) and moderate temperature variation (13-27°C) compared to the lowlands (Ambaw et al., 2020; Msuya et al., 2010; Ogada et al., 2020; Vigiak et al., 2005, 2006; Winowiecki et al., 2016). Rain falls in a bimodal pattern, with a longer rainy season (Masika) expected from March – May and a shorter season (Vuli) from October – December; a third season (Mchoro) occurs July-August in some locations. There are differences in rainfall across the montane region, dependent on elevation and aspect, with the south-eastern (coastal facing) side typically experiencing higher rainfall levels (Conte, 2004). Variability and climate uncertainty is however high (Chapman et al., 2020), with delayed rainfall onset and unusually heavy rainfall becoming increasingly prevalent.

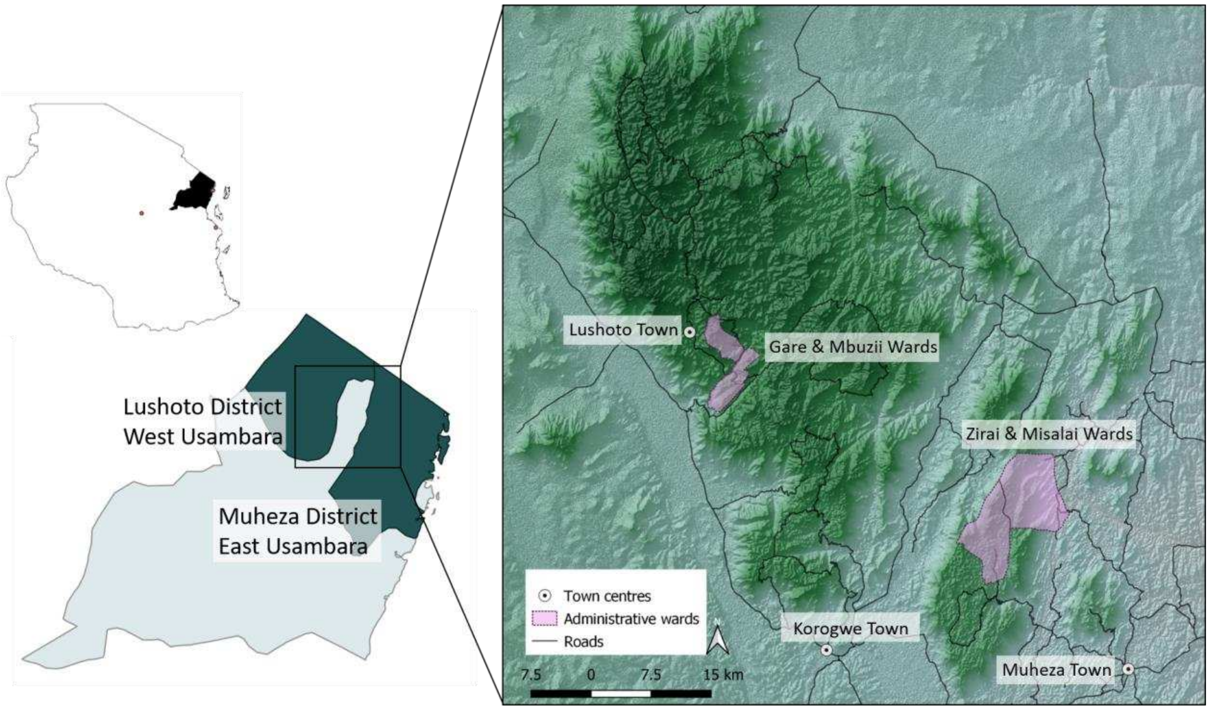

Fig.2: Locations of the CSV-WUM and IACCA-EUM programme areas.

Across the Usambara Mountains, landscapes, livelihoods and farming systems are diverse. Highland communities predominantly depend on low-input mixed cropping, livestock (primarily zero-grazing dairy cattle and poultry) and agroforestry systems. Households produce subsistence food crops including maize, beans, yams, banana and cassava, and commercially grow a range of produce, where spice (cardamom, cinnamon, clove and black pepper) and horticultural (e.g. potatoes, cabbage, carrots, tomato and peppers) production dominates in the EUM and WUM, respectively.

Both the EUM and WUM carry historical legacies of externally defined agriculture and forestry-focussed interventions, dating back to the colonial period and still in living memory of residents. In the EUM, past emphasis has been placed on environmental protection and biodiversity conservation efforts, with intended benefits for local livelihoods largely considered as a means through which to achieve conservation objectives; interventions were largely funded by international donors. In contrast, past projects in the WUM have largely focussed on increasing incomes and agricultural production alongside an emphasis on food security, through the promotion of soil conservation measures, irrigation and natural resource management practices.

The two interventions examined in this study – the European Union's Global Climate Change Alliance (GCCA+) funded 'Integrated Approaches for Climate Change Adaptation in the East Usambara Mountains' (henceforth IACCA-EUM), and the Consultative Group for International Agricultural Research (CGIAR) research program on Climate Change, Agriculture and Food Security (CCAFS) implementation of Climate-Smart Villages (henceforth the CSV-WUM) – are located in the neighbouring EUM and WUM.

IACCA-EUM was a four-year programme implemented 2015-2019 by two non-governmental organisations (ONGAWA and Tanzania Forest Conservation Group) in partnership with Muheza District Council. The overall objective of IACCA-EUM was to demonstrate effective and efficient strategies that support poor, rural households in Tanzania to adapt to the negative impacts of climate change and to alleviate poverty. The project set out to support eight communities living near to high biodiversity forests in the EUM to increase and diversify incomes, strengthen resilience and reduce vulnerability to climate change-related impacts; villages were located in Zirai and Misalai Wards, Muheza District. An integrated ecovillages model guided implementation of a suite of activities, including training and promotion of CSA techniques and associated financial mechanisms (loan and savings groups), alongside community-based forestry and alternative income-generating activities (e.g. beekeeping, butterfly farming, tourism), improved cooking stoves, watershed conservation and sanitation. The project also aimed to build institutional capability to assess, plan and implement climate change strategies.

The CSV-WUM was a partnership between CCAFS, Tanzania Agricultural Research Institute and Lushoto District Council that has been in operation since 2011 (and still was, at time of publication). The overall goal of CSV-WUM was to reduce hunger, ensure food and nutritional security and improve household incomes, by enhancing communities' understanding of climate risks for improved agricultural decision-making (Ogada et al., 2020). Using action research approaches, the CSV-WUM focussed on CSA activities, facilitating the testing and scaling up of improved crop and livestock production practices, promoting integrated land and water management practices, weather forecasting and building local institutions. In 2012, three community-based organizations were initially established in seven villages from Gare and Mbuzii Wards. In 2014, these transitioned into savings and credit cooperative organizations (SACCOs) covering 29 villages in Lushoto. Tanzania's Ministry of Agriculture, Food Security and Cooperatives, and the Lushoto District Council partnered with CCAFS to build the capacity of the SACCOs in the use of improved agronomic practices and livestock management. At the time of writing, the SACCOs were still in operation, providing services including village savings, table banking, and loaning and acquisition of farm inputs.

2.3. Data collection and analysis

This study draws on data from two separate field studies, conducted between March 2018 – September 2019. The first drew on ethnographic approaches (i.e. through observing participants' daily practices and activities) and interviews, to gauge an overview of the wider programme activities conducted under the IACCA-EUM programme, and collated broader community perspectives of the programme (quoted data from this study is noted as S1 IDXX EUM). The second focussed explicitly on the innovation dynamics of farmers living in communities where the two programmes operated (quoted data from this study is noted as S2 IDXX EUM/WUM).

To collect a range of voices 20 informal, unstructured conversational interviews and 60 semi-structured interviews were conducted with community members from villages participating in the IACCA-EUM programme. Interviews explored topics related to programme activities, including the participant selection processes, group organisation, and perceived project benefits and expectations. Interviewees represented a range of community perspectives, inclusive of men, women, village leaders, committee members, active IACCA-EUM programme participants and individuals who either had no involvement in programme activities, or who had subsequently dropped their involvement. Data were collected in the period March – September 2018. Ethnographic observations of IACCA-EUM programme activities were also undertaken from March – September 2018. This involved attending and observing meetings and training sessions of the IACCA-EUM programme. Data were recorded as notes, audio recorded and transcribed into English by two native Kiswahili translators.

To capture innovation dynamics, a participatory timeline approach was embedded within a structured interview, in a similar approach used to investigate livelihood dynamics (e.g. Biddulph & Amberntsson, 2017; Cottyn, 2018; Etzold, 2017; Sallu et al., 2010; Tittonell, 2014; West, 2013). Interviews combined participants drawing and verbal description of periods of learning about, and implementation of different agricultural practices. Key past events (for example the start of programme implementation, or a drought year) were identified by participants and used as reference points for the formulation of the timeline. Additional occurrences mentioned by participants, for example in reference to programme implementation, or events of particular importance, were subsequently situated along the timeline. The interview comprised a set of open-ended questions and prompts to explore the following:

- Participants' histories of innovation; including sources of knowledge, methods of learning and their experience and participation in programme activities, technological, social and institutional aspects of innovation, participation in community and programme groups, and changes to the interviewees' farming practices.
- Occurrence and impacts of shocks and stresses (e.g. climate change and/or weather events, personal or social circumstances) on programme and farming activities, prompting for changes in the timing of farming activities, any challenges or opportunities incurred, and consequential impacts on farming and livelihood outcomes.
- Costs, benefits and trade-offs incurred, as well as direct and indirect impacts from on- and off-farm activities
- Interactions between mentioned activities, events, challenges, opportunities and impacts.

Interviews were conducted with 148 farmers from two IACCA-EUM programme villages and two CSV-WUM programme villages between July and September 2019. Due to the closed-nature of the farmer groups through which CSA training was provided, and the relatively short running of the IACCA-EUM programme, we sampled from 180 listed members of the farmer demonstration groups in the EUM. Due to on-going inclusive training (sessions were open to anyone, rather than a select group) and longer running of the CSV-WUM programme, we selected participants from village lists in the WUM. Participants were selected by stratified random sampling from each Programmes' target populations, stratifying for an equal representation of men and women. Interviews were conducted with 75 people who participated in the IACCA-EUM farm demonstration groups and 73 people from the villages in which the CSV-WUM programme operates.

All interviews were conducted in Kiswahili and recorded by two trained enumerators; recordings were subsequently translated and transcribed into English by a team of five native Kiswahili translators. To ensure data validity and accuracy, translators underwent training prior to transcribing and a random sample of the translated transcripts were checked and verified by the field enumerators. Interview transcripts and field notes were explored and thematically analysed using Nvivo and Microsoft Excel software. An integrated approach of both deductive, based on the innovation-affordance framework in Fig.1, and inductive thematic analysis was conducted, where recurring elements were matched to create categories and collapsed to form themes (Fereday & Muir-Cochrane, 2006). Data from the two study sites were compared; subsequent analysis to search for relationships across and within themes was conducted, to draw relevant meanings and identify collective and unique narratives. Programme documents were also consulted to confirm and clarify information gleaned from interviews.

3. Results

Following the conceptual framework, the results are structured into three sections focussed on the innovation components: Orgware, Software, Hardware. Integrated throughout each section, we highlight how agents and their affordances (perceived opportunities to use or engage with innovation components) interact with innovation components, highlighting how this may lead to different innovation processes and outcomes for individuals. Concurrently, we elaborate on the roles that programmes of interventions play in these processes, and the implications of varied situation contexts on innovation processes and outcomes.

3.1. Orgware: Institutional conditions, membership and participation

Creation of formal groups, particularly farmer demonstration groups and village savings and loans associations, were central to both programmes. Demonstration groups ran for four years from 2012-2016 in the CSV-WUM programme, and for one season in 2017 in the IACCA-EUM. The IACCA-EUM additionally created a number of groups and committees in each programme village, including community based-trainers (a voluntary sub-group of the farmer demonstration groups), community owned water supply organisations, land use planning committees, river committees for catchment protection, and alternative income generating groups for butterfly farming, beekeeping and eco-tourism, and livestock husbandry. In the CSV-WUM programme, tree nursery groups were initially established and later evolved into the savings and loans groups.

Membership requirements for certain groups provided perceived opportunities for some, but not all respondents and inevitably exacerbated notions of group exclusivity. For example in both programmes, village savings and loans groups were anticipated to provide financial opportunities to support farm investments alongside other household activities such as investments into small business, housing developments and education costs. However only farmers with sufficient economic resources required for initial and continued deposits and repayments were afforded the opportunity to join, thus participation in these financial institutions was limited. Insufficient funds, perceived prospects of failure to commit payments or potential to lose capital, expressed as anxiety over repayments and lacking trust in other members' ability to repay, were common reasons for interviewee's non-participation.

Membership formation and selection criteria of the farmer demonstration groups was central to their functioning and shaped different experiences for group members. There were marked differences between the IACCA-EUM programme, in which people volunteered to group membership, and the CSV-WUM programme, which took a randomised approach to membership selection. This randomised process, whereby twenty farmers were selected from each participating village from a list (sampling frame) that had been compiled by CCAFS and partners, and were each required to donate a small portion of their own land to function as a demonstration plot, created a particular dynamic of impartiality. Training sessions were open to all community members. In contrast, the IACCA-EUM programme prescribed gender-equal representation for the farmer groups, with particular requirements for group volunteers to be from more vulnerable and marginalised backgrounds - particularly those from poorer households, the elderly and women. Small plots were volunteered by a few group members and used as the demonstration farms (up to four plots per group). Only group members were permitted to attend training sessions.

Interview responses highlighted how social and political dynamics had implications on individuals' perceived opportunities for group involvement. Despite the voluntary nature of the IACCA-EUM programme, where groups were formed during sub-village meetings, experiences of group exclusivity and favouritism in the membership selection process were reported by some respondents. In several interviews, respondents referenced particular challenges with 'volunteer selection', whereby some perceived the opportunity to join a group being attributed to an individual's social and familiar connections. For one respondent, such preferential treatment led them to abandon the group entirely:

> *"There was selfishness and nepotism at the farm demonstration sessions. I decided to drop [from the group] as there was selfishness and clannish behaviour" (S2 ID37 EUM).*

In the IACCA-EUM programme, farmer demonstration group byelaws determined membership rules and expectations, stipulating fines for non-attendance and subsequent group dismissal for repeat no-shows. Alongside timetabled training sessions, members were expected to continuously maintain demonstration plots (e.g. through weeding and watering seedlings). These conditions, alongside discrepancies between groups and apparent inflexibility in the enforcement of punitive rules, limited opportunities for some to attend and engage, leading to their dismissal - despite desire to be a member. Ensuring full and active participation posed continual challenges, predominantly as a responsibility for group leaders. Yet, limited resources to support full member participation was available through the programme. Indeed all group activities were voluntary in nature and members' time unaccounted for. Without adequate preparation and resources, it proved challenging for the programme to manage members' expectations and ensure full group attendance.

Interview responses highlighted numerous challenges in session involvement, particularly for labour-intensive activities such as the construction of terraces and general farm upkeep and maintenance. A perceived lack of incentive, such as financial compensation for members' time and labour, alongside competing household priorities meant that several respondents perceived little to no opportunity to benefit from their involvement and hence chose not to attend sessions:

> *"When I am there [at the demonstration farm] I don't work for money, I don't even know what I get. So how can I come back at the end of the day to my family with nothing? I can't, so I do my own things" (S1 ID65 EUM).*

The personal circumstances of participants also highlighted multiple incidences where individuals' affordances -their perceived opportunities to attend and actively participate in group activities- were diminished. Those with caring responsibilities for example, felt they were less able to participate in group activities (Box 1; a) or had fewer opportunities to attend sessions (Box 1; b). Livelihood activities such as attending livestock (Box 1; c) or running a business (Box 1; d) similarly conflicted with session attendance or commitments to maintenance activities. Elderly members found their age to be particularly preventative, especially for the more physically demanding activities (Box 1; e).

Box 1: Example challenges in attending training sessions

a) I have got a small child and once I reached there [at the farm] I could not participate fully like others. Sometimes I missed the sessions to take my child to the clinic (S2 ID69 EUM)
b) Most of the time when the training was going on I was not around as I was travelling to my children due to funerals and helping my children who are either having babies or nursing their sick children in town (S2 ID14 EUM)
c) I could not attend the sessions comfortably as there was no one to care for my cows, like feeding and milking them. My children are already grownups, they live far away and have their own homes and households so they cannot help (S2 ID7 EUM)
d) There was conflict of activities between attending the sessions and frying mandazi [fried dough snacks]. You are required in the same morning to go and water the seedlings. I had to stop making the mandazi and go to water the young plants, or send some of my grandchildren (S2 ID33 EUM)
e) Now due to my old age it is difficult for me to be part of any other group as I cannot participate effectively (S2 ID14 EUM)

Providing incentives and support may help to foster farmers' affordances and consequently maintain their engagement in programme activities. Over four consecutive years 2012-2015, the CSV-WUM programme supported baseline farmers through donations of improved maize and bean seed varieties and fertiliser, where any yields were kept by the farmers. This was later extended to the wider community through the three local savings and credit cooperative societies (SACCOS) for improved bean seed varieties, on the condition that farmers returned the initial seed amount for three subsequent seasons, when the bean seed was still viable for planting. Perceived opportunities from the free allocation of inputs and retention of yields were considered positive outcomes and facilitated engagement, however the exclusive membership requirements for the SACCOS ultimately meant that not all community members (particularly those with limited financial resources) had the opportunity to participate in the scheme.

However, the provision of incentives are not a straightforward solution, particularly where perceived opportunities are solely for short-term gains, which may misalign with programme objectives. Upon initiation of the IACCA-EUM farmer groups, members were assured a range of inputs, including spice-tree seedlings, improved seed varieties and a share of crop yields from the demonstration farms. Spice seedlings were the most coveted input, with several participants explaining they were the principal reason for joining the project. However there were several instances reported where once members had received seedlings, they stopped attending training sessions, or only attended the sessions where inputs were distributed.

3.2. Software: Diverse knowledges and learning experiences

"I grow PANA [improved maize variety] in all the seasons, in the valleys and in the uplands. I first learnt something in growing these seeds from my colleagues and my friends whom I heard praising the seeds. My friend showed me how to plant, by deploying the seeds in my farm and showing me all the instructions on how to grow this type of seed. I have also learnt from the company that sells these seeds, and then something from some Kenyan facilitators [CSV-WUM programme] in 2017, who taught me how to grow the improved seed varieties, including the interval to skip from one stem of crop to another. They also put some signs up at my farm" (S2 ID104 WUM).

As the above quote demonstrates, programmes did not exist in a knowledge vacuum. Multiple knowledge sources and learning opportunities exist in, influence and reinforce innovation processes.

However such diverse sources were found to also create conflicting messages and confusion around the use of technologies and practices, especially when instructions or advice differed.

Knowledge sources ranged from more informal actors and interactions, such as friends, family and neighbours, to more formal arrangements, including advice and instruction from input shops, at school, and engaging in training sessions and farm visits provided by agricultural extension services and external interventions. Such diverse sources provided multiple opportunities for farmers to learn new knowledge. Indeed, farmers were active learners, although opportunities to learn were heterogeneous across both case study sites with implications on the type of knowledge shared and obtained. Practices more frequently learnt through informal routes for example (i.e. from friends and family rather than from extension services or a programme of intervention), tended to focus on low-investment practices, such as crop rotation and intercropping, field preparation and planting methods and the production and use of compost. In contrast, knowledge on chemical inputs in the WUM, was more often gleaned from input shops and extension services.

Interviews with several respondents suggested that not all knowledge sources were perceived equally robust or trustworthy, thus sources carried differential affordances. For example, unconditional trust in 'experts' contrasted with knowledge gleaned from alternative sources, such as fellow farmers. Perceptions of the external 'expert' provided confidence in promoted technologies and practices:

The skills were taught by experts, which means every method has been tested and approved (S2 ID23 EUM).

Despite such assurances however, the origins of practices and training were not always clear, especially for farmers not directly engaged in programme activities. Some respondents identified external projects through their affiliation to specific individuals, though demonstrated limited knowledge about the donors and implementing organisation supporting them. Indeed during interviews many farmers did not differentiate between external interventions and actors, especially in the WUM where there had been a prolonged history of external agricultural interventions. A few individuals, typically government staff working both in partnership with 'external' interventions and as part of government extension services, were well known and respected amongst participants. This rapport served to build trust between farmers and the new knowledge promoted by programmes, especially amongst farmers directly engaged in programme activities.

Significant learning was also garnered through independent experimentation, whereby farmers frequently trialled new technologies or practices on small plots of land (Box 2; a, b, d), either purposefully or for lacking resources (Box 2; f), between seasons (Box 2; c) or by comparing techniques used by other farmers (Box 2; e). Experimentation required the ability to carry risk, i.e. of a failed harvest or lost investment, thus the affordances and opportunities to learn through experimentation was limited to those with sufficient resources, and typically initiated on a small scale. However, through the free provision of costly inputs, such as improved seed varieties or inorganic fertiliser, programme incentives deliberately provide opportunities for member farmers to experiment, thus reducing risk from potential failure.

Box 2: Example descriptions of farmer experimentation

a) I chose a small portion of the farm and grew some beans using manure on sowing the seeds and applied Urea fertilizers when they had germinated. The results proved that those in a small portion for experiment performed better than those in the large portion of the farm (S2 ID107 WUM)

b) I did an experiment of improved seeds by some planting with manure and the other half of the farm I did not plant with manure. I found out that improved seeds planted by using manure are more productive than those where no manure was used during planting (S2 ID141 WUM)

c) I tried experimenting once with DECA seeds in my farm in 2008 up to 2009 but the results were not good enough due to low yields. Since 2010 I have started to use PANA the production has improved comparing to DECA production in my farm (S2 ID140 WUM)

d) I have done an experiment in some of the areas to observe the results, but it is in some of the areas of my farms. The result are obviously clear, that the crops upon which there has been manure […] are greenish [and] healthier than those grown without (S2 ID10 EUM)

e) I have learnt from my neighbour who did not grow crops by using manure, but I did. Then, I observed the consequences he suffered. Apart from that, if you use a labourer for the task and if he puts insufficient manure, you'll come to realize when reaping the crops. There is a variation to be observed (S2 ID1 EUM)

f) Once I am tired of working in my farm, I sometimes decide to rest and plant the crops without manure in a small part of the farm, for the reason of being tired. […] The crops grow healthily and produce good yields opposite to the place where I grew the crops without manure. Here produces poor yields (S2 ID 11 EUM)

In contrast to the innate experimentation reported in many interviews, some respondents perceived no opportunity to adapt 'expert' knowledge. Instead there was a sense of duty towards certain technologies, linked to their perception of being underpinned by 'expertise'. Concern of deviating from the 'correct' implementation was voiced, and experimenting with or altering a practice, particularly those learnt from an 'expert', was deemed unthinkable:

"I have not dared to make any experiments on changing those terraces. I work on them according to the way we were instructed there during farm demonstration (S2 ID23 EUM)".

3.3. Hardware: Variable uses of technologies and practices

Whilst Table 1 summarises the technologies and practices promoted by the two programmes, the uptake and use of these technologies and practices were far from ubiquitous across the two study areas.

Table 1: Practices and technologies promoted by the IACCA-EUM and CSV-WUM programmes

Promoted technologies and practices	**IACCA-EUM**	**CSV-WUM**
Nursery establishment and techniques for raising tree seedlings [a]	**X**	**X**
Water [b] and soil conservation (*Fanya juu* terracing, contouring, mulching, reduced-till, stabilising plants [c] - also promoted for their use as fodder)	**X**	**X**
Timing of farm activities (e.g. preparing fields ahead)	**X**	**X**
Spacing of seeds	**X**	**X**
Making and application of compost and manure	**X**	**X**
Improved seed varieties [d]	**X**	**X**
Homemade organic pesticide	**X**	
Triple layer hermetic PICS storage sacks	**X**	**X**

Chemical farm inputs		**X**
Indigenous and scientific weather forecasting		**X**

a) In the IACCA-EUM seedlings were for spices, including cloves, cardamom, cinnamon and pepper, in the CSV-WUM seedlings were primarily for timber

b) The IACCA-EUM programme additionally discouraged against planting in riparian and wetland areas

c) Such as elephant grass (*Pennisetum purpureum)* and Guatemala grass (*Tripsacum andersonii)*

d) In the IACCA-EUM improved seed varieties included maize, beans and cassava. In the CSV-WUM, improved seed varieties included maize, beans and potato.

Farmers' applications of promoted technologies and practices were nonlinear and cyclical and in some cases a few voiced no desire to change practices at all. Participants' unique affordances –their perceived opportunity to put innovation processes to use– and resultant changes to their farming practices were diverse, temporally variable and in part shaped by each individual's personal circumstances and situational contexts.

For the majority, crop and livestock agriculture was the primary income generating activity, where profits were primarily used to purchase inputs and pay for labour. Remittances, small businesses, casual labour and loans from community groups were also common funding sources. Personal resources -particularly economic- were intrinsic to many decisions around farm management practices. Economic resources were the most commonly reported limiting and enabling factors, particularly for high-investment inputs such as chemicals, manure, improved seed varieties and labour-intensive activities; the receipt of free inputs did not necessarily induce their continued usage:

The major challenge is money if you don't have money you cannot farm more efficiently because improved seeds, fertilizers and pesticides they all require money so that you can start to farm (S2 ID 99).

The only time I used chemical fertilizers was during that time they provided free beans. They provided us with urea for planting beans also for free, but I never again used chemical fertilizers as they are expensive (S2 ID78 WUM).

The continuation of capital-intensive hardware required resilient resource generation, larger re-investments were often dependent on consecutive successful harvests. However, reliable harvests were highly vulnerable to numerous conditions and events, such as weather variability (drought, heavy rain and delayed rainfall onset), crop pests and diseases, market fluctuations (especially for horticultural produce in the WUM and spices in the EUM), theft, issues of fake inputs (only in the WUM), death and ill-health. In response to changing circumstances, those lacking funding explained how they would switch between high and low cost inputs, or temporarily stop or reduce certain activities:

I have never stopped using fertilizers, because there are no harvests without them. However, once I do not have money to buy [inorganic] fertilizers I proceed on using manure in other seasons, as I can use manure alone to grow my crops as an alternative (S2 ID110 WUM).

Labour resources also affected farmers' ability to use certain practices or technologies. Farmers with larger households had the ability to draw on labour resources more easily, those without would either pay for labour in cash or in kind, or were unable to do certain practices due to high costs. Creating terraces, carrying manure and precise measurements between planting were described as particularly time and labour-intensive activities. Without the ability to pay for labour implementing some practices were unfeasible for the less physically-able, such as the elderly:

I have understood well the training, but my old age was a challenge to implement most of the practices. […] For those who have money and energy they use inorganic fertilizer or manure. I tried last week but I was able to carry only two buckets of manure to my farm as I was tired […] I wish to dig terraces and plant by precise measuring spaces on my farm, but the challenge is I am old now and I don't have the money or the energy to dig terraces (S2 ID 14, EUM).

Issues around market availability of inputs were particularly pronounced, which reduced farmers' opportunities to access and use technologies. Fake inputs were a recent and particular challenge in the WUM, which created distrust in sellers. Instead, the opportunity to access improved seed varieties arose through farmers' social connections with a programme facilitator, who bought seeds direct from suppliers on behalf of some farmers. In the EUM, limited local availability of improved seed varieties and PIC bags reflected their low use but high desire amongst participants. Timing of the availability of seeds was also a critical challenge*:*

I am so eager to use these improved seed varieties. I haven't used a large amount, which is due to the availability of those seeds. It can occur that the planting season is at hand, while the seeds aren't available (S2 ID57, EUM).

I am not yet eager to use any of them [hardware taught in demonstration farms] in my farm because I would like to have ample time to observe this first one of growing the improved seeds varieties I am using now [of maize], and learn the impacts. From there, I then shall try the other ones (S2 ID9, EUM).

As is evident from the above quote, it can take time for opportunities to be perceptible and appreciated. Timing therefore matters in building affordances, in terms of the necessary time taken to obtain outputs and perceive reliable and beneficial results from a change in practice. Time was similarly important in terms of farmers' cost-benefit evaluations, such as in the time and effort required to prepare or undertake a practice and the resultant outcome. The timing of an intervention in relation to other social, economic and environmental dynamics also proved to be influential in shaping farmers' perceptions of particular technologies. For example, farmer groups ran for only one season in the IACCA-EUM programme. Here, groups planted improved varieties of beans and maize designed to cope with drought conditions, however that particular season was characterised by unusually heavy rain, which led to poorer than expected yields and created uncertainty amongst participants in the suitability of the promoted seed variety. In contrast, the successive years of the CSV-WUM programme meant that farmers' were afforded time to perceive sustained beneficial results, regardless of short-term fluctuations in a technology's performance.

The Usambara topography and climate created different micro-climates and micro-habitats, suitable for a range of crops. Such agrodiversity was reflected by the complex cropping strategies employed across both areas. Farm locations as well as their distance from homesteads influenced the perceived suitability and opportunities of different on-farm and cropping practices. For example, farms closer to forests in the EUM provide optimal growing conditions for cardamom (i.e. cooler conditions under-canopy shade). Similarly, wetland areas in both the WUM and EUM provided the most suitable conditions for horticultural produce, owing to the high irrigation requirements of these crops. However, this particular practice was restricted in the EUM by institutional conditions set by the IACCA-EUM programme, due to envisaged impacts on the watercourse. The biophysical conditions of individuals' farms also created unique innovation processes. For example, households across both areas typically farm multiple small plots, where soil fertility across the region is a persistent challenge. To manage such challenges, and irrespective of fertiliser application, several respondents in the EUM described traditional rotation practices for food crops, where maize is planted in the most fertile plot, then as fertility drops farmers switch to less nutrient-dependent crops like cassava, then to beans and finally plots are left to fallow.

Diverse biophysical conditions, pre-existing production practices, and variable resources or intrinsic capacities, rendered some innovation processes obsolete for farmers. For example, respondents explained how manure becomes increasingly challenging to apply to farms located further from homesteads, due to rising transportation costs. In the EUM specifically, changes in farming systems towards increasing spice production and reductions in food crops resulted in reluctance to invest in and create terraces. A few respondents considered terraces redundant altogether, as they were considered almost impossible to construct on spice farms, due to the presence of trees. They also argued that the presence of trees functioned similarly in stabilising soils, so did not see the need for additional terraces. Even if innovation components collectively present an option, the perceived opportunity to apply the innovation components may not exist for that individual. Consequently, farmers may choose not change their agricultural practices as expected, based on a subjective, situational and relational decision.

4. Discussion

Substantial emphasis has been placed on scaling up CSA across Asia, Africa and Latin America, with significant focus on supporting smallholder farmers within these contexts (Lipper & Zilberman, 2018). Despite the benefits of various technologies and practices, widespread uptake amongst smallholder farmers, especially in sub-Saharan Africa, has not happened (Andersson & D'Souza, 2014). In certain cases dis-adoption has succeeded (Chinseu et al., 2019; Habanyati et al., 2018). The emphasis for CSA to be implemented at the local level means that the pressure to operationalise CSA has been shifted to ill-equipped, rural, often poor households (Karlsson et al., 2018) and under resourced local authorities (Pilato et al., 2018).

In their recent evaluation of CSA assessment tools, van Wijk et al., (2020) point out the significant focus on biophysical evaluation, and ignoring of social and economic aspects of CSA outcomes. Climate adaptation is also highlighted as the weakest area for assessment, where evaluations rely on household-level data in order to develop "a robust 'adoption' indicator" (van Wijk et al., 2020, pp.3). Focussing on simplistic metrics, such as yields and adoption rates, risks a reductionist understanding of technological change (De Roo et al., 2019). Similarly, binary notion of 'adopters' or 'non-adopters' fails to reflect the non-linearity of innovation processes, as illustrated here and in the work of others (Glover et al., 2016; Sumberg, 2016). Scaling CSA typically focusses on the characteristics of technologies and adopters that determine adoption (Wigboldus et al., 2016). However, such approaches are overly simplistic. The complexities highlighted in this study ultimately challenge the viability of scaling CSA programmes in smallholder farming systems. Understanding innovation in a way that represents the realities of smallholder farmers, through an affordance lens, is therefore a necessary step in understanding progress in CSA implementation.

4.1. Differentiated experiences of innovation processes

Institutional contexts can be conflicting, formed of varying formal and informal institutions that represent diverse interests (Cleaver, 2002; Hounkonnou et al., 2012). Our findings provide insight into how the properties of orgware may create differential affordances -the perceived opportunities to use of engage with innovation components- where, depending on an individual's social connections or financial resources, institutions may be inclusive or exclusive. Reports of nepotism within the IACCA-EUM farmer group selection process and of financial prerequisites to join and participate in savings and loans groups highlight how social inequalities generate differentiated affordances, pathways and outcomes of innovation processes (Cullen, Lema, et al., 2014; Cullen, Tucker, et al., 2014). Even when efforts are made for inclusivity, such as the request for gender representation and of members from more vulnerable backgrounds in the IACCA-EUM, failure to consider how existing social and power dynamics influenced the process through which members were selected and were able to engage, led to membership formation that reinforced prevailing power hierarchies (Cooke & Kothari, 2001). This leads to the further exclusion of marginalised groups, and ultimately shapes innovation processes (Eidt et al., 2020).

Taylor & Bhasme (2018) show that farmers who typically engage have "the requisite access to productive inputs to be successful and who exercise a degree of social authority in the locality" (pp. 9). Likewise De Roo et al., (2019) present cases where projects work with 'more serious' farmers, who are already more receptive. They further demonstrate how purposeful exclusion of more marginalised farmers (i.e. those with limited affordances) from farm trials and demonstration groups risks compromising the scalability of CSA interventions. In a similar vein, our findings highlight how vulnerable farmers with fewer resources, limited capacity and less perceived opportunities to engage with programme activities i.e. the elderly, women, and the resource-poor, struggled to engage with programme activities or promoted technology (e.g. attend training sessions or invest in farm inputs). Whilst perhaps not intentionally excluded from the programme (indeed the IACCA-EUM programme stipulated their inclusion), limited resources available to support these farmers (such as through financial compensation for their time) and inflexible group membership requirements, ultimately led to their unintentional exclusion.

In the CSV-WUM, membership selection was random. Whilst this approach aimed to circumvent some of the challenges found in the IACCA-EUM programme, as Jabeen (2018) notes, "bypassing the elite and giving key positions to the poor might create friction (even if transitory) in a community" (pp.264), and damage social cohesion. Social cohesion and livelihood opportunities are closely linked (Suti et al., 2021; Jensen, 2019) and have been shown to be critical for building livelihood resilience (Mitra et al., 2017; Townshend et al., 2015). Some argue that institutional arrangements cannot be transferred, such as with technologies, but that they should emerge from the context in which they operate (Biggs, 2007). Arguably therefore, the formation of inclusive institutions that provide equitable opportunities for engagement with innovation processes cannot ignore nor evade social dynamics, but rather necessitates careful understanding and navigation of social inequalities.

Many farmers interviewed in this study were active learners, seeking solutions from peers to solve pest infestations, or testing different seed varieties over consecutive seasons, for example. Our findings complement more nuanced understandings (see also Mtega, 2012; Zossou et al., 2017), whereby the many differentiated learning experiences identified highlight variable access to knowledge and learning. Such differences may be better understood through an affordance lens. Affordances stem from an individuals' personal capacities and resources, and the properties of innovation components. Respondents who voiced challenges in attending and participating in training sessions may not have had the capacity to do so, for example due to old age and low physical strength. Or, individuals may not have had the resources to attend, in terms of available time, due to unavoidable household responsibilities, which are often complex and gendered (Vercillo, 2020). The properties of the innovation components, in terms of group membership rules and expectations for plot maintenance in this example, may likewise not have aligned to an individual's existing commitments or livelihood activities. Any combination of these could diminish perceived opportunities to attend and engage with the farmer groups, and access the learning experiences. Similarly, some innate learning experiences were associated with the level of capital and risk afforded to an individual, where farmers with more financial capital had the opportunity to carry more risk (Wolgin, 1975), and thus experiment more.

Information and knowledge are critical to perceived opportunities that may emerge from an innovation component, as they reduce uncertainty (Adolwa et al., 2012). As reflected by levels of unconditional trust and confidence in promoted hardware in both our study sites, programmes carry authority, legitimising shared knowledge and perceived properties of promoted technologies or practices. The legitimisation of promoted technologies and practices highlights the social construction of knowledge, where knowledge is embedded in people's perceptions and shaped by an individual's lived experiences (Leeuwis, 2013). Glover et al., (2019) elaborate on how the dimensions of politics and power (in this case the authority given to the programme 'expert') shape how the use and value of an innovation component is understood and evaluated by a farmer. Depending on the associated legitimacy of a knowledge source therefore (i.e. a programme 'expert' verses a neighbour), innovation components may present different opportunities to different people.

Adoption and adaption of new agricultural innovations is key to improve the productivity and sustainability of farming (Wheeler et al., 2017), as sustained uptake is more likely when farmers are able to adapt hardware to be locally relevant (Mekoya et al., 2008). However, programmes of intervention may inadvertently reduce farmer affordances, as unquestionable trust and reverence towards the 'expert' may serve to diminish the relevance of inherent experimentation and local knowledge. Although there is growing recognition for farmers to become innovators and co-designers of new knowledge (Sewell et al., 2017), narratives of farmers not perceiving the opportunity to adapt a learnt hardware reflects concerns around the effectiveness of agricultural extension models to support co-produced transformations (Sewell et al., 2017). This also highlights the persistence of imbalanced knowledge hierarchies in development programmes and agricultural innovation systems (Arora, 2012; Girvan, 2007; Taylor & Bhasme, 2018). Indigenous knowledge is considered a critical component of both climate adaptation (Nkomwa et al., 2014; Nyong et al., 2007) and in scaling CSA (Makate, 2019). However, there is a risk that such veneration of 'expert knowledge' may ultimately undermine innovation processes and CSA programme objectives.

Our findings add nuance to recent reports demonstrating widespread uptake of CSA technologies in the WUM (Ogada et al., 2020), as we find multiple incidences of short-term application of technologies and practices across the Usambara. We also observed incidences where farmers reduced their use of a particular technology or temporarily 'dis-adopted' and switched to lower-costing practices. Continuous application of hardware often relied on resilient resource generation. In many incidences practices to enhance yields were not able to be sustained, largely owing to insufficient or fluctuating resources (often linked to finances and labour), reducing farmers' opportunities for sustained use of technologies and practices. Such limitations are well documented in the literature (Liu et al., 2018; Long et al., 2016; Myeni et al., 2019; Senyolo et al., 2018).

Similarly to Röling (2010), we also found that farmers may be knowledgeable and motivated to use a certain practice or technology, but if opportunities are lacking (for example the opportunity to purchase inputs, or sell at a good price to reinvest in hardware), then expected innovation processes may not arise. Resultant application of hardware is therefore transient and dynamic, emerging alongside, and in response to the varied context and conditions of farmer livelihoods that shape farmers' affordances. However, re-adopters, along with pseudo-adopters, (i.e. farmers who use a practice in order to receive benefits from projects) are infrequently recognised in studies, which oversimplifies the dynamism of innovation (Kiptot et al., 2007). The use of agricultural technologies and practices, is evidently non-linear (Glover et al., 2016).

4.2. Fostering innovation through programmes of CSA intervention

More often than not, farmers who 'succeed' i.e. engage with programme activities, employ promoted hardware and reap higher yields, are endowed with affordances. In other words, these farmers already have opportunities to engage with innovation components, regardless of a programme of intervention. There is therefore need for more nuanced recognition of what success looks like for more resource-poor farmers, which may be different to programme-defined measures and the degree to which CSA programmes engage with and support the more vulnerable and marginalised. As our findings highlight, success for resource-poor farmers may be nuanced and marginal, but yet these experiences are often underreported in recording programme objectives because they don't adhere to more standardised and observable measures, such as adoption and yields. Consequentially, tensions exist between programmes engaging with communities, but wanting to demonstrate impact by highlighting 'success stories'.

CSA programmes do not exist in a knowledge vacuum, as evidenced by the wealth of diverse formal and informal sources of knowledge, information and learning experiences described in this study (Jain et al., 2011; Lwoga, 2011; Mtega et al., 2016; Munyua & Stilwell, 2013; Zossou et al., 2017). Accordingly, external interventions play a role in innovation process but are seldom the sole determinants of how innovation plays out over time, as there are multiple and often competing sources that bring new knowledge, reinforce, and update existing understandings. Furthermore, as our findings highlight, innovation processes and the realisation of outcomes can take time, and often requires continued investment. Yet, given the typical short-term nature of interventions, like the IACCA-EUM, and the possibility that more than one intervention may be operating in a given space, in the case of both programmes, consistency between successive programme messaging is important. Conflicting messages can create confusion, destabilise affordances, and may undermine innovation processes. A certain level of coordination at regional level may therefore help navigate and avoid such conflicts. However, limited capacity in local government authorities within the study areas highlight challenges for regional planning (Pilato et al., 2018), though also identifies opportunities to engage with and support local authorities, as part of broader programme activities.

Trust between implementers and target beneficiaries is of paramount importance in project implementation, yet there remains a lot to learn about its role in shaping the efficacy of programme implementation (Glover et al., 2019). In both our case study sites, responsibility to implement lay with a few key actors from government research and extension services. The familiarity and respect between participants and implementers corresponds with a study by Eidt et al., (2020), who highlight the important leadership role that practitioners and extension services play in innovation processes. However, several additional authors (Mdee et al., 2019; Scheba, 2017) also note how community's trust can be eroded if expectations, particularly of immediate returns, are mismanaged, which can have implications for the success of future interventions. Our findings highlight how it is fragile and easily eroded - particularly in programmes externally conceived and implemented. In the IACCA-EUM programme, issues arose during farm maintenance activities and participants' unrealised expectations for financial compensation, which for some individuals failed to provide them with a perceived opportunity to attend farmer group activities. This particular challenge highlights the need for greater consideration and dialogue around farmers objectives, and of the co-creation and design of programmes with communities to reflect due consideration of the context and of pertinent affordances (Massarella et al., 2018).

Ignoring the context, or identifying it as an 'external constraint', ultimately limits innovation (Sumberg, 2005a). Due consideration of context, whether that be of local government capacity, existing social and power dynamics in the formation of new institutions or market access and the availability of inputs, is critical. Context, and how it shapes affordances, are intrinsic to innovation, not separate from it, and should be considered as such (Taylor & Bhasme, 2018). This is a persistent challenge for practitioners, seeking to create fair and sustained change (Cullen, Tucker, et al., 2014). Programmes should therefore meaningfully engage with existing power dynamics to support inclusivity (Tschakert et al., 2016) and intervention design should ultimately be shaped with communities (Massarella et al., 2018) and local governments to reflect and actively engage with the broader context.

When operating in complex socio-ecological systems, unintended outcomes, as a result of agricultural development programmes, are perhaps inevitable (Hunt, 2004; Ramankutty et al., 2006; Sheahan et al., 2016). Jabeen (2018) goes so far as to suggest they are a natural by-product of programme implementation in complex systems. Failure to consider the context risks undermining programme objectives and creating unintended outcomes. Indeed, multiple unintended outcomes were highlighted during interviews, although as far as the authors are aware, none have yet been accounted for in programme reporting:

- The provision of incentives, such as the successive donations of farm inputs through the CSV-WUM programme, undoubtedly supports initial participation. However, this risks creating an expensive legacy of expected handouts for future programmes, can misalign farmer and practitioner objectives, and may create 'dependency syndrome' – the belief that problems cannot be overcome without outside support (De Roo et al., 2019). In this respect, farmers' affordances -their perceived opportunities to engage with innovation components- may become increasingly reliant on the presence of external interventions.
- The use of chemical inputs, such as inorganic fertiliser promoted by the CSV-WUM programme, dramatically increases yields, with anticipated benefits for food security and income generation. However, the environmental sustainability of this approach is questionable at best, as environmental trade-offs are to be expected (Koen et al., 2009; Rasmussen et al., 2018; Zhang et al., 2018).
- Planting of crops in upper watershed was promoted as a climate-smart strategy by the CSV-WUM programme. However, this practice was banned through rewriting of bylaws in the IACCA-EUM programme, in order to protect the local watershed. Yams, in particular, were grown in these areas and used as a key staple, particularly in times of drought. Yet the new byelaws inhibited this practice, thus eradicating pre-existing climate resilient strategies.
- Stipulations for balanced gender representation and inclusion of 'vulnerable groups' in the IACCA-EUM programme were made to increase inclusivity. However, inconsideration of how existing dynamics shaped group member selection reinforced prevalent power dynamics. Furthermore, limited additional support to sustain 'vulnerable' members' participation in group activities led to their exclusion and further marginalisation.
- Programmes may bring new knowledge to farmers. Yet, unconditional trust in 'expert' knowledge can undermines innovation processes and conflicting messages may lead to confusion around existing practices.

Whilst the unintended outcomes highlighted here are largely negative, with several of the above examples undermining innovation processes, positive outcomes, often beyond the scope of programme objectives, also exist. For example, Pant & Hambly Odame (2009) present cases of 'positive deviance': unusual strategies or behaviours that challenge the status quo and enable individuals or organisations to find superior and inventive solutions. Much broader consideration of programme outcomes is evidently necessary, as outcomes are diverse and go far beyond the scope of traditional programme evaluation (Jabeen, 2018). Combining quantitative and qualitative methods, including ethnographic approaches, may better support more holistic and nuanced understandings of programme outcomes and innovation processes.

4.3. An innovation-affordance framework

Innovation in smallholder agricultural systems, and the way in which it happens, is often perceived as technical, a-personal and a-political, which is reflected by studies' poor consideration of the broader settings in which farmers are embedded (Kiptot et al., 2007; Ensor et al., 2019). Such oversight does not sufficiently account for the cyclical, non-linearity of change in these systems and fails to recognise how different people are more or less able to engage with, and benefit from innovation processes (Glover et al., 2016, 2019; Shikuku, 2019). These omissions highlight a need to focus at the scale of smallholder farms, with due consideration of the context that shapes farmers' lived experiences, in order to better understand their priorities and the systems that support smallholder livelihoods (Chandra et al., 2017).

The innovation-affordance framework presented in this paper (Fig. 1) helps us to think through the somewhat messy innovation processes that occur in smallholder farming systems, and broadens our thinking beyond that of just a focus on technologies. Acknowledging that an agent, and their affordances, are integral to innovation processes helps to understand differentiated experiences of innovation processes. In other words, why some people engage and derive benefits from them, and why others do not. Bringing together thinking around innovation components (OSH) and affordances therefore places smallholder at the centre of understanding change in smallholder agricultural systems.

Whilst we draw heavily on the concept of affordances, as presented in the work of Glover et al., (2019), we acknowledge a slight detachment and perhaps interesting tension with our presentation of innovation and theirs. In their paper, Glover et al., (2019) adopt a technographic approach to present an thoughtful and considered framing for understanding deliberate technological change in smallholder systems. Their framework narrates progressions of *Propositions* (i.e. new ideas, technologies or alternative ways of working) and *Encounters* (i.e. incidences where farmers become aware of a proposition), further highlighting how *Dispositions* (receptive agents are disposed to react or respond in diverse ways) shape farmers' *Responses* (agents' (re)configuration the technological design) to the initial proposition.

Accordingly, Glover et al.,'s (2019) propositions are a combination of 1) biophysical resources, 2) methods, techniques and practices, and 3) a proposed mode of engagement. They note that the first two "correspond approximately to the hardware and software dimensions of technology that are recognised in other theoretical approaches" (pp.174). The classification and examples of innovation components (OSH) presented in our paper reflects diverse thinking from a range of scholars, thus differs slightly from that of Glover et al., (2019). Of particular difference, is our categorisation of hardware and software. Following Leeuwis and Aarts (2011), the former combines both the physical (e.g. equipment and tools) with the methods, techniques and practice (i.e. the act of doing), whereas the latter focusses more on knowledge and modes of knowledge sharing (i.e. through communication, teaching and learning). Picking up on Glover et al.,'s use of 'approximately', suggests that fuzzy boundaries might exist between innovation components and the ways in which they may be interpreted and defined. These fuzzy boundaries are perhaps better reflected by the overlapping innovation components depicted in our framework, emphasizing the multiplicity of definitions and fluidity of collective innovation processes.

We also depart from the work of Glover et al., (2019) by extending our focus beyond deliberative technological change, to broader innovation processes. As such, and reflected in our findings, our focus incorporates the more deliberate changes brought about by programmes of intervention, and extends to those that emerge through farmers' own invention, experimentation and learning, inclusive of the spectrum of innovation processes between these extremes. The innovation-affordance framing therefore forces us move beyond thinking simply about technological change, but also to societal, political, cultural and economic change, among others. In the context of evaluating CSA and development interventions more broadly, it helps to progress beyond the more common focus on the adoption of technologies, practice and production, to focus on how innovation happens in the context of smallholder agriculture. This approach encourages us to recognise that individuals may interact with and experience these interventions, and the innovation component (OSH) they influence, in various ways.

5. Conclusion

The diverse contexts and affordances presented here, from a relatively small study area, illustrate the considerable complexities integral to innovation processes and in scaling CSA in smallholder farming systems. By exploring the diverse innovation processes of smallholder farmers, this study also reminds us that programmes of intervention are just one of the many pathways through which innovation in smallholder farming systems occurs. Rethinking innovation, and the way in which change in agricultural systems happens and why, can support farmers, including those that are less-able, engage with innovation processes. The innovation-affordance framework helps us to understand why some people engage with, and derive benefits from programmes of interventions, and why others do not. It enhances our understanding of innovation, as it broadens our thinking beyond a focus technological change, considers individuals and their affordances within innovation processes, and acknowledges that the affordances of innovation vary between people in different situations. If programmes of interventions are to effectively engage the most vulnerable and be truly impactful and scalable, then the heterogeneity of farmer affordances, and appreciating how these shape innovation processes needs to be meaningfully engaged with. Programmes of intervention should therefore be conceived with an appreciation of context and affordances from the outset, to support how they engage with the least capable from the very beginning.

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