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# Towards agricultural innovation systems: Actors, roles, linkages and constraints in the system of rice intensification (SRI) in Sierra Leone

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ABSTRACT

Despite success in parts of Southern Africa and Asia, the use of the System of Rice Intensification (SRI) has remained low in many parts of Sub-Saharan Africa (SSA). Alongside this, an Agricultural Innovation Systems (AIS) framework has been touted as a method to support innovation processes and enable a variety of agricultural innovations to be used by large numbers of farmers. However, very little is known about the linkages/interactions between stakeholders within such AISs and which are deemed important for the AIS to function. This study seeks to understand the perceptions of the agricultural innovation system actors regarding Sustainable Rice Intensification (SRI) usage in Sierra Leone. More specifically, it examines the key actors and their roles, the patterns, and strengths of the linkages among them, as well as the perceptions towards the innovation /potential constraints faced by the actors. The study draws on several workshops and key informant interviews with 49 actors consisting of research and extension professionals from governmental and non-governmental organisations and smallholder farmers involved in the rice innovation system. Using UCINET's NetDraw for social network analysis (SNA) among innovation actors, the study finds a high level of connectedness between key actors – the Ministry of Agriculture, NGOs and farmers. The eigenvector centrality (a measure of influence within a network) was highest among NGOs, the Ministry of Agriculture and farmers respectively, which shows that these actors had the strongest influence within the SRI network. Further exploration of these ties also showed that these actors play a critical role in facilitating knowledge, resources and information flows within the network. Despite a strong level of interaction between actors and positive perceptions of the innovation, SRI usage has been unable to reach scale for a variety of reasons. The key reasons identified include: (i) the lack of interaction across levels (e.g. provincial and local) thereby limiting locally adapted techniques from emerging relevant to all regions; (ii) farmers' limited technical skills in swamp development; (iii) a lack of funding opportunities (including private sector engagement) and (iv) the perceived labor-intensiveness of SRI techniques. Overall, this research has identified possible entry points for increasing the functioning of the innovation system and a useful methodological approach that can be applied to exploring the effectiveness of agricultural innovation systems. It also highlights the need to engage private sector actors to support the use of agricultural innovations as some services are

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sometimes beyond the purview of research and extension actors alone. The need for further research is also necessary to deepen the understanding of whether AIS approaches are enhancing farmers' capacity to innovate or impeding this by encouraging embedded norms related to a transfer of technology model to perpetuate.

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## Introduction

The increasing acknowledgement of the complexity and multi-faceted problems faced by smallholder farmers has necessitated the development and use of research and extension approaches with a potential to address these problems. The traditional approach in agricultural research and extension views the course of agricultural knowledge and information with a hierarchic flow where innovations come from the scientists to be diffused to farmers through extension services – a system characterised as top-down and linear [1]. The traditional approach views the change agent as a 'messenger' whose function is to transfer and disseminate the ready-made knowledge from research scientists to farmers. Among other criticisms, the approach has been largely criticized for making mono-disciplinary theoretical recommendations for what are, in fact, multi-faceted problems embedded in complex local agro-ecosystems and socio-cultural systems [2]. Others criticize it for not recognizing the roles of different actors beyond research and extension in the generation, dissemination and use of knowledge and information in agriculture. The many criticisms and shortfalls of the traditional top-down approach associated with the adoption and diffusion theory of agricultural innovations has gradually been replaced by a number of approaches, the most recent of which is the Agricultural Innovation System (AIS) approach.

The AIS approach is viewed as an inclusive and bottom-up approach that recognizes the role of various stakeholders in agricultural innovation processes. Given the myriad of complex, often multi-disciplinary problems faced by smallholder farmers, there has been an increasing demand for the use of an approach that can adequately and sustainably address these problems. The AIS approach views agricultural innovation as the result of a process of networking, interactive learning and negotiation among a heterogeneous set of actors [3]. These considerations and current thinking has led to the emergence and promotion of an innovation system thinking in the delivery of research and extension services. Previous research on AIS has found little recognition of the fact that interdependent actors may have different interests, goals and perspectives which are likely to diverge and conflict within the system. This needs to be taken into account when assessing participation, roles and behaviours of certain actors in the innovation process [4]. Hall [5] observed that there lies a challenge of selecting who to work with in agricultural innovation programmes, as selecting too few will miss the innovation system concept while too many may become unmanageable.

It can be deduced from this that although it is important to engage diverse actors in the innovation process, there is a need to consider the role that each actor may likely play in the process and whether or not their participation may influence the desired results. In fact, Hall [6] advanced key attitudes and practices that can affect innovation processes such as proactive networking supports knowledge flows and learning and participatory attitudes can improve the inclusiveness of poor stakeholders. Klerkx and Begemann [7] has argued for the need to understand networks and their drivers in AIS's. More recently, Kabirigi et al. [8] explored social networks and the diffusion of knowledge within innovation systems and the role played by different actors. Gaitan-Cremaschi et al. [9] further used social networks to explore how actors can stimulate/impede innovation. Schut et al. [10] adopted a framework which focuses on analysing the innovation support system, the innovation capacity of the actors in the innovation system and complex agricultural problems to provide specific and generic entry points for innovation. In particular, the framework indicated the importance of the attitudes and behaviours of the actors to be relevant in promoting agricultural innovations and development.

In Sierra Leone, the AIS approach is now the official approach taken for the design and implementation of agricultural development projects as specified in key policy documents of the leading and national regulatory institutions including the Ministry of Agriculture, Forestry and Food Security (MAFFS) and the Sierra Leone Agriculture Research Institute (SLARI). Given the importance of understanding the perceptions of various actors, their roles and behavior (e.g. [3]) and attitudes towards particular innovations (e.g. [6,10]) using the system of rice intensification (SRI) as a case study; this study explores the key actors and their roles, the patterns and strengths of the linkages among them, as well as the attitudes towards the innovation / potential constraints faced by the actors. The following provides an overview of AIS and SRI followed by an explanation of actors and linkages explored. Section 2 provides an explanation of the methodology employed. Section 3 presents the results and discussion, and Section 4 explores conclusions of the study.

### *Agricultural innovation system (AIS): a theoretical review*

The concept of the innovation system has evolved through various stages. Rogers [11] first defined innovation as an 'an idea, practice or object that is seen as new by an individual or other unit of adoption'; and those innovations, when diffused,

take a regular pattern of adoption evident in his [11] Innovation Adoption Curve. His-view of innovation was espoused in what he called the Adoption and Diffusion Theory. This theory perceives scientists as the only innovators, whose ideas or technologies need to be adopted by farmers, who are seen as adopters or laggards [4] – Extension Agents being the messengers or intermediaries. This became the prominent thinking for the development of programs intended to promote innovations in the National Agricultural Research Systems (NARS) and Training and Visit Systems [12]. However, this theory has been heavily criticised for a variety of shortfalls. It has been perceived as having a social application with no regard for institutional and policy factors and the difference between interventions and innovations [12]. Furthermore, this has been criticised for developing technologies that are inappropriate and for not being able to understand the complexity of knowledge generation and use, farming systems and the diversity of needs of smallholder farmers [13].

Following the criticisms of the Adoption and Diffusion Theory, the Farming Systems Research (FSR) theory subsequently emerged in the 70 s and 80 s. The FSR diagnoses constraints, needs within the farming system, and provides packages to increase efficiency using a multidisciplinary approach. It is strongly dependent on effective partnerships between key stakeholders including farmers, technical and social scientists and, more recently, Extensionists and policy makers (e.g. [4]). Despite the fact that this system involves on-farm testing and modification of technologies, decision-making remains largely with the scientists using information from farmers and farms to decide what to do or try [13]. The common key weaknesses identified with the FSR are – the lack of focus on resource poor farmers, poor dialog between researchers and farmers, difficulties associated with the coordination of multi-disciplinary teams and the difficulties in communicating the knowledge gathered [14].

The Agriculture and Knowledge Information System (AKIS) emerged as a more sophisticated and less linear approach in response to the shortfalls of the preceding approaches. AKIS boundaries are broader than Farming Systems Research, focussing on a wider set of information sources as well as the importance of strengthening systems that assist in the generation and dissemination of knowledge [15]. The AKIS has seriously been criticised for its disregard of the historical and cultural contexts in which innovation processes take place [16]. Additionally, the AKIS sees the agricultural research system as the center of innovation as opposed to the concept of multiple knowledge-bases, and that its capacity to analyze systems beyond the sphere of the public sector is limited, hence, lacks an understanding of the different kinds of actors involved [17]. The AKIS framework has a limited perspective of the heterogeneity among agents, the institutional context that conditions their behaviours and the learning processes that determine their capacity to change [1].

Subsequently, the Agricultural Innovation System (AIS) was pioneered by Hall et al. [6] in response to increased attention on demand for research and technology, and a shift in focus to improving capacity to innovate [13]. The Agriculture Innovation System (AIS) focusses on obtaining a better understanding of the innovation processes and looking at them as multidimensional and complex interactions, and consisting of novel and interdependent practices implemented by diverse actors [1]. Temel et al. [18], define an Agricultural Innovation System as a 'set of agents (i.e. farm organisations, input supply, processing and marketing enterprises, research and education institutions; credit institution, extension and information units, private consultancy firms, international development agencies and the government) that contribute individually or jointly to the development, diffusion and use of new agricultural technologies, and who influence, directly or indirectly the process of technological change in agriculture'. In other words, it is a system of interconnected institutions for the creation, storage and transferring the knowledge, skills, and artefacts that define new technologies (ibid). It is clear from these definitions that the agricultural innovation system approach recognizes the role and existence of a huge cadre of actors that can contribute in diverse ways toward technology development, transfer, use, adaptation and better knowledge flows to improve the performance of the overall system. The AIS approach has therefore emerged as the recent and sustainable approach in the provision of research and extension services among smallholder farmers in the developing world and beyond [19].

### *The system of rice intensification in Sierra Leone*

The System of Rice Intensification (SRI) is one of the prominent rice innovations that has been promoted in the country starting from the early 2000s to date. It is a lowland rice cultivation and management system that was first introduced in Sierra Leone by World Vision in 2001 among a group of farmers [20]. It was concurrently piloted by the Sierra Leone Agriculture Research Institute (SLARI) specifically at the Rokupr Agricultural Research Center (RARC) in the same year. It has recently been promoted by other NGOs (including Catholic Relief Services, Concern Worldwide) and the MAFFS among smallholder farmers in various parts of the country. The West Africa Agricultural Productivity Programme (WAAP) has also (in 2014) promoted SRI as one of its strategies to promote sustainable increase to smallholder farmers' lowland productivity [21]. The SRI is a lowland rice cultivation method (mostly suitable for Inland Valley Swamp cultivation) with features considered by research and extension professionals to be distinct from the conventional methods of rice cultivation in Sierra Leone, with a potential to sustainably increase agricultural productivity among smallholder farmers [20]. Key techniques include line sowing, the planting of one seedling per hill, transplanting seedlings between 8 and 14 days old, swamp development for water control, use of organic manure, planting seedling in a square pattern of 25 *25 cm, and the use of organic manure. Other techniques include the use of mechanical Weeders and the commencement of pre-planting operations such as brushing, digging and clearing of plots before nursery of seedlings. Commencing pre-planting operations before nursery is to discourage the long duration of seedlings in the nursery on one hand, and enhances farmers' ability to transplant seedlings within the prescribed one to two weeks of nursery.

The perceived benefits of SRI to smallholder farming have sometimes been questioned, (e.g. [22,23]), however, many studies have shown substantial improvements in the productivity of land, labor, and water with the use of SRI methods, (e.g. [24]). Barison and Uphoff [25] in a recent study found that rice plants cultivated with SRI methods produced more than double the average yields than those from the standard practice of rice cultivation in Madagascar. The SRI is therefore perceived as an innovative system of lowland rice cultivation with a promise to improve smallholder farmers' productivity per unit area and subsequently increase their incomes. This has been a key premise that motivated the promotion of the innovation in the country.

*Role of actors in an AIS*

Actors in an innovation system are the catalysts of the outcomes of that system. They largely represent the results of the innovation system. According to Temel et al. [18], a variety of actors contribute to an effective innovation system. These should include: famers, research institutes, farmers' associations, private consultants, training and education institutions, public services delivery organisations, credit organisations, input suppliers, NGOs, processors, transporters and policy and regulatory bodies. Moreover, Arnold and Bell [26], identified several actors in the innovation system. These include: (a) The Research domain (formal research organisations producing mainly codified knowledge, public and private sectors and NGOs); (b) The Demand domain (domestic and international markets for products, policy actors, and consumers); (c) Enterprise domain (firms and farmers using and producing mainly codified and tacit knowledge); (d) Intermediary domain (organisations that may not necessarily be involved in the creation and use of knowledge but plays a part in the flow of the knowledge from one part of the system to another). The number of actors and their involvement in a given innovation system can largely influence the success of the system. Too few actors in the design and development of an innovation can limit smallholder farmers' access to services and products, and the reverse is true.

Actors in an innovation system can play a variety of roles. These roles are classified broadly as facilitator, communicator, collaborator (e.g. [27]), coordinator [6], knowledge source and networking [2]. These roles are considered important in promoting an effective agricultural innovation system constituting of various actors including smallholder farmers.

*Linkages among actors in an AIS*

Linkages, mostly referred to as interactions by some academics [43] are an important conduit for innovation system (IS) actors' access to resources, services and knowledge. Acquisition or transference of knowledge and skills in an innovation system is an interactive process that requires extensive linkages among a wide variety of actors [6]. An understanding of the linkages among IS actors can therefore be useful in determining the effectiveness of the system. The linkages among innovation actors in a social network help understand the knowledge flows, identify central/key actors, and to see how farmers are connected to other actors in the system (e.g. [28]) Linkages are considered important in the spread of stocks of knowledge [29] and they play an important role in establishing partnerships and cooperation with other actors, sourcing external knowledge and information, and securing funding for innovation processes [30].

## Methodology

The study uses structured interviews (primarily qualitative approach) to gather qualitative and some quantitative data to help understand the various actors, their roles & linkages and the constraints limiting the effectiveness of the innovation system on SRI. As asserted by Biggs and Matsaert [28], it is important to elicit the views of stakeholders involved in an innovation system to understand needs and solutions. The study therefore conducted a social network analysis as recommended by Ekboir et al. [31] to understand information flows and the size, efficiency and connectedness of actors within the innovation systemThe study therefore conducted a social network analysis as recommended by Ekboir et al. [31] to understand information flows and the size, efficiency and connectedness of actors within the innovation system. The linkages among the actors were also studied following Hall et al. [6], who supports exploring partnership linkages in order to map specific roles and their strengths/weaknesses. The study further explored the perceptions of the innovation and potential constraints faced by the actors within the innovation system.

*The study area*

The target country of this study is Sierra Leone. Like most Sub-Sahara African countries, Sierra Leone is highly dependent on agriculture as a source of economic growth, and the sector employs more than half of the national workforce (about 75%). While the study is generally considered a national study, however, interviews were focussed mainly on farmers and institutions in the Northern Province, in addition to the capital city, Freetown. The Northern Province was considered most suitable compared to other provinces, because it constitutes the major rice growing districts and constitute the major actors in the rice sector in the country. Although agriculture is the main source of livelihood for the population in most districts in the North - Kambia (78.4%), Koinadugu (84.2%), Port Loko (80.5%) and Tonkolili (76.4%) - food insecurity in this Province is among the highest in the country [32]. The high prevalence of poverty/food insecurity in the study districts, coupled with the high dependence of the population on agriculture for their livelihood, has led to many actors in the agriculture

sector focussing their operations, particularly in relation to rice, in Northern Sierra Leone. In addition to Government line ministries, the study districts host the operations of many NGOs, both local and international, with most having an agricultural component [33]. The Northern Province hosts four of the seven constituent centres of SLARI. The Rokupr Agricultural Research center (RARC), whose primary mandate is to conduct research on rice and other cereals, is located in the Kambia District [34], one of the target districts of the study.

*Target respondents*

The study targets research scientists from the Sierra Leone Agriculture Institute – the key public institution with the mandate to conduct and coordinate agricultural research in the country - farmers and extension professionals from the MAFFS and Non-Governmental Organisations implementing projects on rice in the country. These are the key stakeholders in the promotion of the System of Rice Intensification in the country. For Research and Extension professionals, different categories were targeted including senior, middle and frontline staff as they have varying knowledge, skills and authority consistent with their professional hierarchies. Selecting the respondents from these cadres presented a unique opportunity to triangulate information and discern differences in the perceptions between staff with varying level of authority. Farmers who have participated in the SRI were specifically targeted.

*Sampling technique*

The quality of a research output is to a large extent a function of the sampling technique used. Factors such as cost, time and accessibility among others usually constrain researchers from interviewing the entire population in a given study area [35]. For this study, a non-probability sampling technique was adopted. Agriculture research scientists and extension personnel were purposively selected from the relevant institutions to participate in the study. This was to ensure that all cadres of staff including senior, middle and junior level staff are targeted. A list of all Agriculture Sector NGOs registered with the Ministry of Agriculture was obtained from the NGO Desk Officer. NGOs that are either currently implementing or have implemented programmes on rice in the past ten years were identified by the researcher with assistance from the NGO Desk Officer. These were then selected and invited to attend the workshops through the NGO Desk Officer of the MAFFS at both national (Freetown) and district (Kambia) level. Key Informant Interviews were then conducted from a cross section of workshop participants as well as other staff that were not present during the workshops but were identified by their colleagues as useful informants. Farmers were purposively selected based on their participation on SRI activities in their communities in the past ten years. Farmers from across the target districts were selected for participation in the workshops and KIIs.

*Data collection methods*

The data for this study was collected in from January to March 2016. The following methods were used.

*Workshops*

Workshops are group interviews that do not only constitute a spontaneous exchange of views but a careful questioning and listening approach with the purpose of obtaining a thorough and tested knowledge [36]. One was held in the city – Freetown and the other was held in Kambia District, Norrthern Sierra Leone. These were held in two different locations to allow participation of actors at national (Freetown) and District (Kambia) level in responding to the same research questions. The workshops were specifically used to elicit information from research and extension professionals and farmers on the key perceived benefits of SRI, the key actors involved and their roles, the linkages and constraints in the testing, dissemination and utilization of the SRI, as an innovative system of rice cultivation and natural resource management. The workshops contained all cadre of professionals in both locations. Both workshops in the

To obtain maximum contributions from participants, efforts were made to have groups containing exclusively one category of participants – researchers, farmers or extension professionals and the workshop divided into three sessions. Farmers were mainly members of the Farmers' Federation, so some were moderately literate. Extension professionals were further divided into NGOs and MAFFS and each workshop was divided into four groups. Before the start of the sessions, the researcher did a presentation explaining the objectives of the study and the emergence of the AIS perspective, as well as explaining the expected outputs of each session and the corresponding templates/matrices to be completed by participants in their various groups. In each session, participants from each group presented their findings and were collectively merged in a plenary with the participation of all present. A research assistant was hired to help with facilitating the workshops.

Findings from the workshops were complemented/triangulated through the Key Informant Interviews. Each session of the study elicited specific type of information. Session 1 elicited information on the key benefits of SRI, the actors involved and their roles. An Actor Sheet consistent with Gervacio [1] was provided to workshop participants for completion and presented in a plenary (Table 1).

In session 2, the key constraints associated with the SRI innovation were identified as well as the general constraints limiting the effectiveness of the innovation system on rice in Sierra Leone were also identified but are not reported in this

**Table 1**
Sample Actor Sheet matrix used in the study.

| Organization | innovation | perceived benefits | actors | key role of actors |
|---|---|---|---|---|
| | 1. | 1. | 1. | 1. |
| | | 2. | 2. | 2. |
| | | 3. | 3. | 1. |
| | | 4. | | 2. |
| | | 5. | | 1. |
| | | | | 2. |

**Table 2**
A sample constraints matrix used in the study.

| organization | innovation | constraints faced with this innovation | general constraints limiting innovation |
|---|---|---|---|
| | 1. | 1. | 1. |
| | | 2. | 2. |
| | | | 3 |

**Table 3**
Example of an Actor Linkage Matrix.

| Actors | A | B | C | D |
|---|---|---|---|---|
| A | ST*: | ST: | ST: | ST: |
| | P*: | P: | P: | P: |
| B | ST: | ST: | ST: | ST: |
| | P: | P: | P: | P: |
| C | ST: | ST: | ST: | ST: |
| | P: | P: | P: | P: |
| D | ST: | ST: | ST: | ST: |
| | P: | P: | P: | P: |

* ST: Strength of Linkage; P: Purpose of Linkage

article. A constraints matrix designed by the researcher was also presented to participants for their use. Similarly, the group outputs were presented in a plenary by each group and then merged through a consensus by all (Table 2).

In Session 3, information on the strengths and purpose of linkages among actors on the SRI as perceived by research and extension professionals were elicited. An Actor Linkage Matrix following that used by Gervacio [1] was provided to participants during this session for their use. Information that was generated in this process was complemented by KIIs to fill any gaps and triangulate the findings (Table 3).

*Key informant interviews (KIIs)*

Key Informant Interviews were conducted to deepen understanding of the perceived benefits, actors, roles, linkages and constraints associated with the SRI in Sierra Leone. A total of 49 KIIs were conducted among research and extension professionals and farmers. Also, audio recordings were also taken by the researcher and were transcribed and analysed and used to fill in information gaps that were not captured by the researcher during note taking. Key Informant Interviews were conducted beyond Freetown and Kambia District to include other Districts. This was to enrich the triangulation of the data and gives opportunity to professionals and farmers in other districts where the innovation is being promoted to share their views on the innovation. Key Informants included research, NGO and MAFFS professionals as well as farmers were identified and interviewed based on their involvement and experience promoting or implementing the SRI. Below is a table showing the number of Key Informant Interviews conducted during the study. Each of these interviews lasted approximately 30–40mins for each Informant. The key questions asked are included in the table below. The key data from these interviews helped shape information presented on the perceived benefits of the innovation, the actors involved and their roles, the linkages among the actors as well as the constraints faced in the promotion or implementation of the innovation as presented in the following section.

*Data analysis*

Qualitative data generated during the study was analysed using the following approaches including (1) transcription and translation from Krio and Temne into English (where applicable) especially for the KIIs with farmers (2) coding and categorization (using different colors) & condensation into various themes and (3) interpretation of meaning using Microsoft Word. These techniques were used in organizing texts emerging from the FGDs and KIIs and for making implicit meaning of what was said by respondents for each objective. As noted by Miriam (1988), qualitative data analysis is best done in conjunction with data collection, suggesting that the researcher should organize the information gathered immediately after the interview. A similar strategy was followed by the researcher during the data collection, and this helped the researcher to

**Table 4**
Details of participants of the workshop in Freetown and Kambia.

| Location | Category of participant | Designation | Gender (Male/Female) | Hierarchy |
|---|---|---|---|---|
| Freetown | SLARI | Research Coordinator | M | Senior staff |
| | | Senior Communication Officer | M | Senior Staff |
| | | Research officer I -Crop Breeding | M | Intermediate |
| | | Research officer II – Agriculture Extension | M | Intermediate |
| | | Research Assistant - Soils | M | Junior |
| | NGO | Project Director – ACDI/VoCA (SNAP) | M | Senior |
| | | Program Manager – Agriculture – BRAC | M | Intermediate |
| | | Country Director – ENGIM | M | Senior |
| | | Program Manager – Cotton Tree Foundation | M | Intermediate |
| | | Project Officer, Livelihoods - CRS | M | Junior |
| | | Program Assistant – World Vision | M | Júnior |
| | | Project Manager – Concern | M | Intermediate |
| | MAFFS | Senior Crops Officer | M | Senior |
| | | Crop Protection Officer | F | Intermediate |
| | | Director of Agriculture Extension | M | Senior |
| | | Deputy Director of PEMSD | M | Senior |
| | | Monitoring and Evaluation Officer – PEMSD | M | Junior |
| | | Crops Officer | M | Junior |
| Kambia | SLARI | Research officer II- Engineering | M | Senior |
| | | Research officer II – Agriculture Extension | M | Senior |
| | | Center Research Coordinator | M | Senior |
| | | Research Officer I – Agriculture Extension | M | Intermediate |
| | | Research Assistant Crops | M | Junior |
| | NGO | Project Officer – ABC Development | M | Junior |
| | | Project Manager, Agriculture – KADDRO | M | Intermediate |
| | | Project Manager – Concern Worldwide | M | Intermediate |
| | MAFFS | District Monitoring and Evaluation officer - | F | Junior |
| | | District Crops Officer | M | Intermediate |
| | | District Crop Agriculture Extension | M | Intermediate |
| | | Block Extension Officer | M | Junior |
| | FARMER | Representatives 1 | M | Senior member |
| | | Representative 2 | F | Senior member |
| | | Representative 3 | M | Junior member |
| | | Representative 4 | M | Midlevel member |


**Fig. 1.** MAFFS officials (left) and NGO professionals (right) preparing their presentation.

adequately record all relevant information emerging from the interviews. A social network analysis (SNA) program, UCINET, was used to organize linkages among actors as identified by research and extension actors during the workshops. Representatives from these key institutions were asked to indicate the number of ties they have with others and as well as the strength of the linkages. The freeware program contained in UCINET known as NETDRAW was used for visualizing networks into a sociogram. This helped in establishing the underlying patterns of social relations of actors in the SRI innovation (Table 4, Fig. 1, Fig. 2, Fig. 3).

**Fig. 2.** A cross-section of research professionals preparing their presentations in Freetown (left) and Kambia (right).

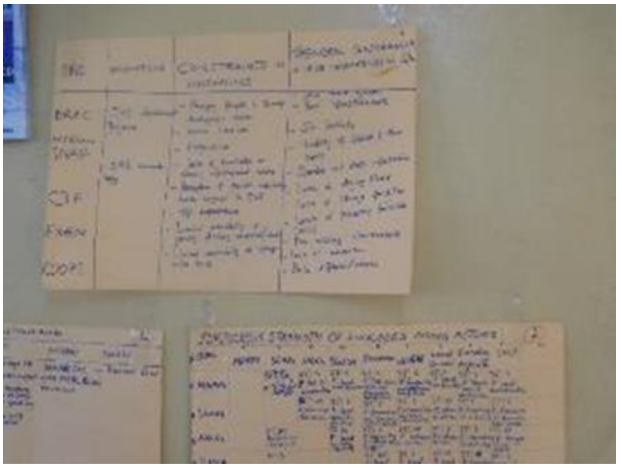

**Fig. 3.** Sample output of workshop discussions.

## Results

The key findings of the study are presented as follows. The first section explores the linkages/interactions among actors, the second section looks at the perceived benefits of SRI for farmers, and the third looks at the key actors and their roles in the innovation system. The fourth section looks at the strength of linkages among actors in the innovation system whilst the fifth examines the purposes of their linkages. Finally, the constraints associated with the innovation system from the key actors' perspective are presented.

### *The perceived benefits of SRI for smallholder farmers*

SRI is promoted among smallholder rice farmers for a number of reasons. Key among them are the perceived ability of SRI to increase rice yield, and subsequently, the incomes of rice farmers (Table 6). However, another key benefit that has been highlighted by respondents is the increase in input use efficiency i.e. lower inputs necessary needed to achieve the level of production. This belief is based on the principle of planting one seedling per hill with a reasonable spacing of 25*25 cm between seedlings i.e. less inputs, the use of organic manure – which are locally available and cheaper – as opposed to chemical fertilizers, and the low water requirement and ability to control its presence in a plot. The District Crop Officer, Koinadugu District at the MAFFS said:

> "…. *SRI techniques are beneficial to farmers and those that have been participating have seen the benefits. When we established the first demo plots in our target communities, participating farmers initially thought we are wasting our time cultivating one very young seedling per hill. But with time they noticed the seedlings doing well, tillering and growing well. Really, it was not easy at the start, because farmers were sceptical about the success of the method but after the first year*

**Table 5**
Total number of KIIs conducted from the target organisations.

| Location | Organization | Number of KIIs | Key Questions |
|---|---|---|---|
| Freetown | NGO | 5 | • What are the perceived benefits of SRI? |
| | Researchers | 6 | • Who are the key actors involved in its promotion? roles do each of them play in the promotion of the innovation? |
| | MAFFS | 5 | |
| Port Loko District | NGO | 1 | |
| | MAFFS | 3 | • What are the strengths of their linkages in promoting this innovation? |
| | FARMERS | 3 | |
| Kambia District | MAFFS | 3 | • Why do these actors interact and how strong are their interactions/linkages? |
| | FARMERS | 3 | |
| | Researcher | 6 | • What constraints do you face in the promotion/implementation of SRI? |
| Koinadugu District | NGO | 4 | |
| | MAFFS | 3 | |
| | FARMERS | 4 | |
| Tonkolili District | MAFFS | 3 | |

*Note:* In Tonkolili, only MAFFS officials were interviewed due to their experience with SRI in other districts before moving to Tonkolili District. No other categories of Informants were interviewed as the innovation was not prominent in the district at the time of the interviews.

*of demos some farmers are now using the techniques. They now use less seed compared to what they have been using before and are now transplanting earlier than they used to. Some are lazy though but most participating farmers have seen that SRI techniques can help them use minimum inputs. They have reduced their inputs considerably which ultimately contribute to their productivity…..you see. With SRI, farmers can now save some of the rice seed they have been using for cultivation before now…the saved seeds is the start of productivity……." (Interviewed, 3rd March, 2016).*

It is believed that adequate spacing of rice seedlings transplanted at a younger age will have a huge impact on its growth and tillering ability while at the same time reduces the amount of seeds farmers use for planting. This will in turn increase the overall yield and income farmers realize from their agricultural enterprises. The planting of single seedlings and spacing between them will also translate to the use of less seed inputs, thereby reducing the seed-related costs. Also, the use of organic manure is expected to boost farmers' savings as they no longer need to buy expensive (and sometimes scarce) chemical fertilizers, one of the respondents highlighted (KII-KAD-ExtN). The training they receive from research and extension actors on the preparation of these manures is also expected to increase their innovative capacity in this respect.

*Key actors and their roles*

The key actors include Government institutions (MAFFS and SLARI) and a few NGOs and smallholder farmers - the target beneficiaries of the innovation. NGOs, such as the Catholic Relief Services, Concern Worldwide, and World Vision, were identified by respondents as key NGOs promoting SRI as an innovative system of rice cultivation among smallholder farmers (see Table 7). Their roles, according to respondents, include: the mobilization of farmers at community level; provision of training to farmer groups on the key techniques of SRI through a variety of extension approaches, such as Farmer Field Schools; and, in some cases, provision of other inputs, such as rice seeds and tools. Some International NGOs, such as Japan International Cooperation Agency (JICA) were identified as providing funding to MAFFS and local NGOs for scaling out SRI activities. For instance, Concern Worldwide has funded Mankind Activities Development Accreditation Movement (MADAM) - a local NGO in Koinadugu to scale up SRI to smallholder farmers in the district. It was noted that certain NGOs are more prominent in certain districts of the country than in others. For example, the Agriculture Programme Manager of Catholic Relief Services said:

"*CRS work has been focused on three districts, that is, Kailahun, Kenema, and Koinadugu Districts for the past few years. We have only added other districts, such as Kambia and Port Loko etc., during the Ebola outbreak. For SRI, we have only been working with farmers in Koinadugu District*" (KII-FT-ExtN).

Similar statements were made during the workshops by presenters from NGOs, and during some of the KII interviews with NGO personnel. This suggests that the services of a particular NGO may be concentrated only in a part of the country. SLARI's role is linked more towards the conduct of research into the efficacy of the SRI compared to conventional methods of rice cultivation but has not been very active in reaching out to farmers with SRI techniques, according to respondents. This is possibly due to the fact that SLARI is more focussed on research activities to either develop innovations or to provide evidence on the merits and demerits of agricultural innovations but is not normally funded for scaling out innovations to smallholder farmers (WS-RK-Res). MAFFS is normally the major government institution responsible for scaling up and scaling out innovations certified by SLARI or other sources. MAFFS [37] joined NGOs in the promotion of SRI techniques to smallholder farmers through funding from the West Africa Agricultural Productivity Programme (WAAP). Its roles are not different from those of NGOs, except that it also responsible for certifying farmer groups at community level, thereby enhancing their eligibility to benefit from a range of agriculture sector interventions (KII-KOD-ExtM). Cornell University was

**Table 6**
The Perceived Benefits of the SRI identified by Research and Extension Actors and farmers.

| | Increases income and livelihood of farmers | Increased productivity | Enhances better water control, reduces weeding-related drudgery due to use of weeder | Facilitate soil aeration | Less costly due to use of organic manure | Increase in tillering of IVS seedlings | Organic crop production | Use less seed inputs and water | Increases yield through better growth and tillering of seedlings |
|---|---|---|---|---|---|---|---|---|---|
| KII-KOD-ExtM | xxxx | xxxx | x | x | xxx | xx | x | xxx | xxx |
| WS-RK-Res | x | x | | | x | | x | x | x |
| WS-RK-ExtM | x | x | | x | x | x | | x | x |
| KII- POD-ExtM | x | xxx | | | xx | | x | x | xxx |
| KII-POD-Fmrs | xx | xxx | xx | | x | | | xx | x |
| WS-FT-ExtN | x | x | x | x | | x | | x | x |
| KII-KAD-Fmrs | x | xxx | xxx | | | x | | xx | |
| KII-TOD-ExtM | x | xxx | x | x | xx | x | | x | xx |
| KII-FT-ExtN | xxx | xxxx | x | xx | xx | x | xx | xx | x |
| KII-KOD-Fmrs | xxx | xxx | | x | x | | x | xx | x |
| KII-KAD-Res | xx | xxx | x | | xx | x | x | x | xx |
| KII-KOD-ExtN | xx | xx | x | x | x | | x | xxx | xxxx |

Source: Field Research, 2016, Key: KOD – Koinadugu District; KAD – Kambia District; FT – Freetown; TOD – Tonkolili District; POD - Port Loko District; RK – Rokupr; ExtN –NGO Extension staff; Res – Research staff; ExtM – MAFFS Extension staff; Fmrs – Farmers; WS – Workshop; KII – Key Informant Interviews; x – number of respondents that mentioned the benefit; IVS= Inland Valley Swamp

**Table 7**
Actors and their roles in the Rice Intensification innovation system.

| Source | Actor | Role |
|---|---|---|
| WS-FT-ExtM, WS-RK-Res, WS-RK-ExtM | SLARI/RARC | • Determination of seedling age, spacing, density of released varieties<br>• Develop technologies on cereal crops<br>• Research services<br>• Source of certified rice seed |
| WS-RK-ExtM, KII-FT-ExtM | SLeSCA | • Seed certification |
| WS-RK-Res | SMP | • Dissemination of rice technologies<br>• Capacity building |
| WS-FT-ExtM,<br>WS-RK-ExtM,<br>KII-KOD-ExtM,<br>KII-POD-ExtM,<br>KII-POD-Fmrs; KII-TOD-ExtM,<br>KII-KOD-ExtN,<br>KII-KAD-Res | MAFFS | • Extension services – demonstration and multiplication of seed<br>• Training, monitoring and supervision of farmers<br>• Facilitates the registration of farmer groups<br>• Supporting farmers with seeds<br>• Provide seed support to NGOs at district level<br>• Capacity building of NGOs and farmers |
| WS-FT-ExtM, WS-RK-Res, KII-KAD-Res,<br>KII-TOD-ExtM, KII-KAD-ExtM, KII-FT-ExtN,<br>KII-FT-Res | NGOs (Local and International) | • Facilitate the dissemination of SRI technologies<br>• Documenting the advantages and disadvantages of SRI<br>• Enhance access to quality seeds of released varieties<br>• Provision of other agricultural inputs such as tools<br>• Mobilization of farmers and other stakeholders<br>• Providing training on marketing to farmers<br>• Funding for scaling up of SRI activities eg JICA |
| WS-FT-ExtM,<br>WS-FT-ExtN, WS-RK-Res, WS-RK-ExtM,<br>KII-KOD-ExtM, KII-POD-ExtM, KII-KAD-Fmrs;<br>KII-TOD-ExtM, KII-FT-ExtN<br>KII-KOD-ExtN, KII-KAD-Res | Farmers | • Feedback on the advantages and disadvantages of SRI<br>• Participation in field trials<br>• Use of SRI technology<br>• Participate in program activities<br>• Source of seeds for NGOs and colleague farmers |
| WS-RK-ExtM,<br>KII-KOD-ExtN,<br>KII-KAD-ExtM; KII-KAD-Fmrs | District Council<br>Agriculture Business Centers (ABCs) | • Monitoring of activities of MAFFS and NGOs<br>• Sale of farm inputs such as seeds, fertilizers etc |
| WS-FT-ExtN | WFP | • WFP buy milled rice from farmers; and do IVS rehabilitation |
| KII-POD-ExtN,<br>KII-KOD-ExtN | Community Leaders/Authorities (Paramount chief, section chiefs, youth leader, headman, Master farmers, | • Monitoring project implementation<br>• Approval/disapproval of intended activities by NGOs<br>• Assist in mobilizing farmers |

Source: Field Survey, 2016, Key: KOD – Koinadugu District; KAD – Kambia District; FT – Freetown; TOD – Tonkolili District; POD - Port Loko District; Fmrs – Farmers; RK – Rokupr; ExtN –NGO Extension staff; Res – Research staff; ExtM – MAFFS Extension staff; WS – Workshop; KII – Key Informant Interviews. IVS= Inland Valley Swamp

the only university mentioned that had provided technical backstopping to and sharing experiences on SRI activities with a local NGO (ENGIM) in Port Loko District (KII-POD-ExtN).

Farmers, being the ultimate target of the innovation, were mentioned by most respondents and in both workshops as key actors in the SRI. In addition to the farmers' roles of trying the innovation at farm level and providing feedback to research and extension agents, as perceived by respondents, farmers also act as a source of seeds of varieties suited to SRI techniques for use by other farmers. Furthermore, a few of the farmers (e.g., the community leaders) also participate by monitoring project implementation activities, assisting in the mobilization of colleague farmers at the community level and by acting as the primary point of entry/dialog with external actors (particularly NGOs, in their communities). The District Councils were also identified as performing similar functions, particularly the monitoring of activities of research and extension actors in their districts. As noted earlier, the district councils are in practice not being utilized, despite the importance of the roles they could play in the system.

**Table 8**
Purpose of linkages among Actors.

| ACTORS | Farmers | ABC Committees | Community Leaders | NGOs | MAFFS | WFP | SILC Groups | Funding Agencies (DFID, FAO, ADB, IFAD, etc) |
|---|---|---|---|---|---|---|---|---|
| **Farmers** | | Convening meetings/coaching sessions; Facilitating access to post-harvest facilities; Mediation; Facilitate marketing; Agro- information services exchange | Mobilization; Passing on information/messages; Mediation | Facilitate access to input support, Convening meetings and coaching sessions on use of machinery and governance of ABC | Coaching sessions; Formation of farmer groups; Monitoring of ABC activities | Facilitating purchases; Support with rice packaging; Information exchange | Loans; Dissemination of information about the ABC | Not clear |
| **ABC Committee** | Facilitating continuity of activities e.g. processing, marketing of input/outputs; Information exchange | | Governance of ABCs; Convening meetings | Funding; Facilitate access to input support; Convening meetings and coaching sessions on use of machinery and governance of ABC | Funding; coaching and mentoring; Monitoring; Facilitate marketing produce from ABC members | Facilitating purchase of milled rice; Provision of packaging materials; information exchange | Not clear | Not clear |
| **Community Leaders** | Participation in meetings and awareness raising activities; Sharing information | Convening meetings; Information sharing on ABC operations | | Collaboration (entry point); Raising awareness; Coaching sessions; information exchange | Coaching and mentoring opportunities; information exchange; Raising awareness | Mobilization of ABC farmers/committees | Mediation; Facilitating the settling of group dynamics | Not clear |
| **NGOs** | Participation in coaching sessions eg use of machinery in ABC, leadership etc; Facilitating sale of outputs in ABCs; Information exchange; | Promoting marketing activities of ABC; Participation in innovation programs; Providing information; Mediation | Facilitating access to farmers; Mobilization of farmers; Awareness raising; Participation in meetings, workshops and coaching sessions; Sharing of community level information | | Monitoring; Funding; Collaboration in project implementation; Provision of technical advice; Coordination of activities | Partnerships in rice purchases, information exchange | Seeking technical advice and support; reporting; Participation in meetings and coaching sessions; sharing of information | Funding of programmes; Monitoring |
| **MAFFS** | Participation in meetings; Registration of Farmer Groups; Seeking technical advice | Funding opportunities; Reporting; Participation in meetings, workshops and coaching sessions; Facilitating sale of inputs/seeds; Information exchange; | Facilitating access to farmers; Mobilization of farmers; Awareness raising; Participation in meetings, workshops and coaching sessions; Sharing of community level information; Advocating for farmers | Funding; Reporting; Experience sharing | | Collaboration in coaching sessions with ABC members; information exchange; Seeking approval; Reporting of activities | Facilitating sale of seeds; Information sharing; participation in meetings | Funding of programmes; Monitoring |
| **WFP** | Facilitating marketing of outputs; Attending coaching sessions on rice processing/value addition | Facilitating the purchase/sale of milled rice; Participation in coaching sessions | Coordinating marketing of milled rice; Sharing of information; Raising awareness | Not clear | Facilitating interface with ABCs | | Facilitating the purchase/sale of milled rice; Participation in coaching sessions | Not clear |
| **SILC Groups** | Facilitating loans availability for members; Seeking funds/loans | Information exchange; Raising funds | Mediation among members | Coaching sessions, Funding of activities | Coaching sessions; Provision of improved seed varieties | Facilitate the buying of rice from members; Conducting coaching sessions on value addition | | Not clear |
| **Funding Agencies** | Information exchange on ABC innovation | Not clear | Not clear | Seeking funding opportunities; Reporting | Seeking funding opportunities; Reporting on progress; | Not clear | Not clear | |

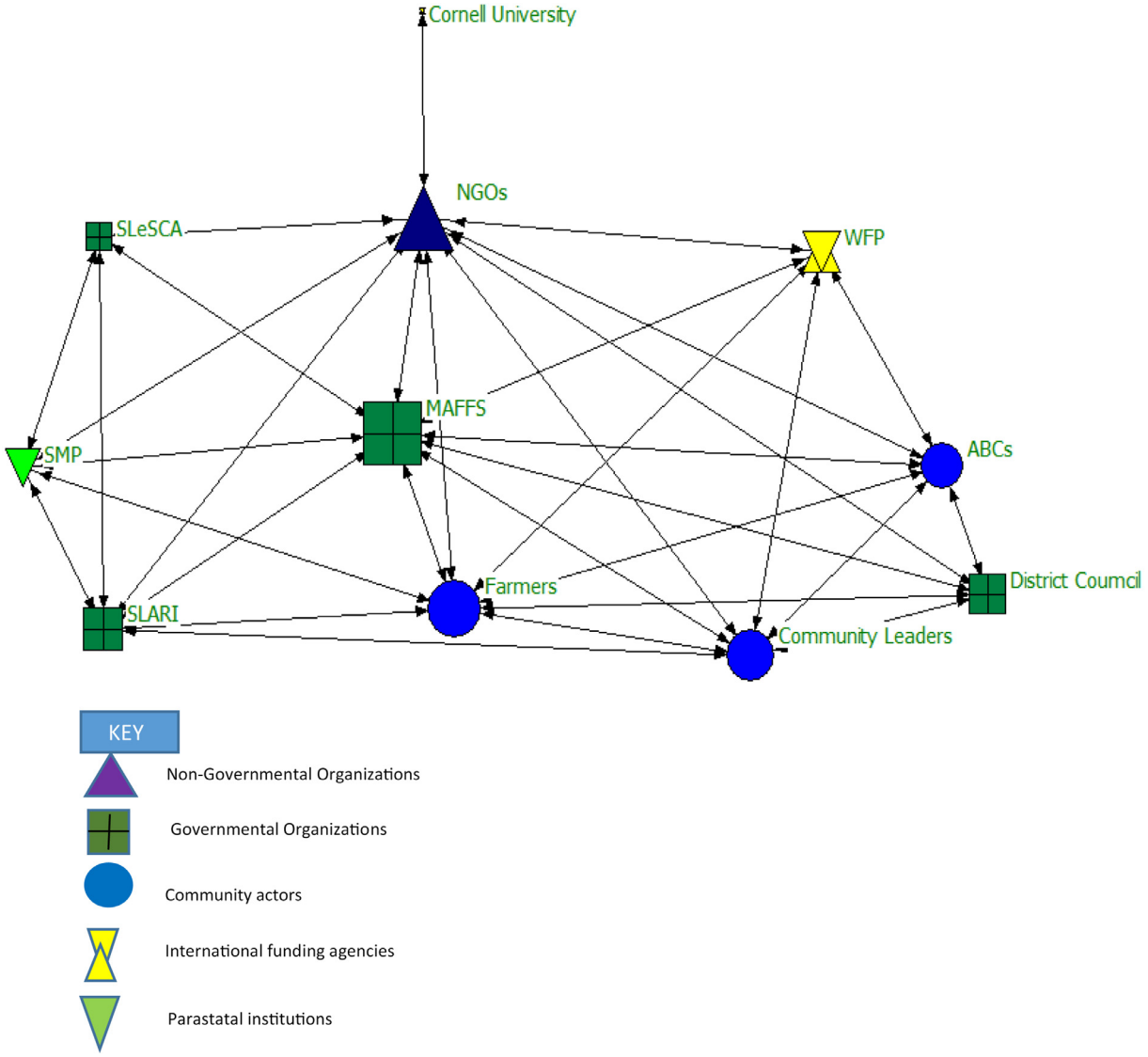


**Fig. 4.** Patterns of linkages/interactions among actors in the Innovation System (Node size: eigenvector centrality value).
*Note:* Arrows indicate ties.

**Table 9**
Actor Linkage Matrix in SRI*.

| ACTORS | MAFFS | Farmers | SLARI | District Councils | NGOs | SLeSCA | ABCs | Community Leaders | WFP | SMP | Cornell University |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MAFFS | – | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | – | |
| Farmers | 3 | – | 3 | 3 | 3 | 1 | 3 | 3 | 2 | 2 | 1 |
| SLARI | 3 | 3 | – | 1 | 2 | 3 | 1 | 3 | 1 | 2 | 1 |
| District Councils | 3 | 3 | 1 | – | 3 | 1 | 2 | 2 | 1 | 1 | 1 |
| NGOs | 3 | 3 | 2 | 3 | – | 2 | 3 | 3 | 3 | 3 | 2 |
| SLeSCA | 3 | 1 | 3 | 1 | 2 | – | 1 | 1 | 1 | 3 | 1 |
| ABCs | 3 | 3 | 1 | 2 | 3 | 1 | – | 3 | 3 | 1 | 1 |
| Community Leaders | 3 | 3 | 3 | 2 | 3 | 1 | 3 | – | 2 | 1 | 1 |
| WFP | 2 | 2 | 1 | 1 | 3 | 1 | 3 | 2 | – | 1 | 1 |
| SMP | 3 | 2 | 2 | 1 | 3 | 3 | 1 | 1 | 1 | – | 1 |
| Cornell University | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | – |
| **Average score/actor** | **2.8** | **2.4** | **2** | **1.8** | **2.7** | **1.7** | **2.1** | **2.2** | **1.6** | **1.8** | **1.1** |

* The numbers in the matrix indicate strong (3) and weaker linkages (2 and 1). Blank (–) means does not know or not applicable. Reads from left column to row cell, i.e. type of actor in the column provides their view on the actor on the adjacent row. This is consistent with Lalani et al. [48].

**Table 10**
Constraints associated with the SRI innovation system.

| SOURCE | CONSTRAINTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Human Capacity**: Lack of adequate experience and skills, Lack of knowledge on swamp development works, high initial cost due to swamp development requirement, poor land preparation, Inadequate number of extension workers – the ratio of farmers to extension workers is very high | **Financial**: Lack of funding sources, Lack of fertilizers and the related cost, Late disbursement of funds by the District Council to MAFFS | **Infrastructural**: problem of ivs leveling/water control, inadequate perennial ivs, poor water control structures, too many undeveloped swamps, poor road network, lack of adequate logistics for extension workers at maffs, limited availability of quality planting materials, limited availability of appropriate tools, insufficient availability of organic manure lack of equipment for weeding (rotor, manda river etc) | **Labor**: labor intensive (collection of organic manure and 3 times of weeding) high labor requirements in generating organic manure, line sowing, swamp development | **Attitudes of farmers**: perceptions of people associating health hazards to IVS, high expectations; Difficulty of farmers to adopt improved technology; farmers never-ending dependence on 'outsiders' for development and rehabilitation of swamps | **Interactions and Collaboration** Unwillingness of farmers to work as a group; Difficulty in cooperation of agric. Partners eg INGOs and LNGOs; | **Institutional:** Poor remuneration for MAFFS staff, Devolving funds to the District Councils slows implementation of activities in the MAFFS; | **Natural:** Infertile soils/lands; Heavy rainfall – washes away seedlings; |
| WS-FT-ExtM | x | | x | x | x | | | |
| WS-RK-Res; KII-KAD-Fmrs | x | x | x | | | | | x |
| WS-RK-ExtM | | x | x | x | | | | |
| WS-RK-ExtN | x | x | x | | | | | |
| WS-FT-ExtN: | x | | x | | x | | | |
| KII-KAD-ExtM | x | x | xx | | | | | |
| KII-KOD-ExtM; KII-KoD-Fmrs | x | | | | x | x | | |
| KII-POD-ExtM: | | | x | | x | x | x | |
| KII-FT-ExtM: | x | | x | | | | | x |
| KII-TOD-ExtM: | | | xx | x | | | x | |
| KII-POD-Fmrs | x | x | x | | | | | x |
| KII-POD-ExtN | | | | | | | | |
| KII-POD-ExtN | | x | xx | | | | | |

Source: Field research 2016 Note: x – number of respondents that mentioned the constraint IVS= Inland Valley Swamp

Other actors, such as WFP, Agriculture Business Centers (ABCs), and SMP, were also mentioned by respondents as actors in SRI in that they provide services such as Inland Valley Swamp rehabilitation (specific to WFP), and the uncoordinated sale of seed and other inputs to farmers and other actors, including NGOs.

*Linkages/Interactions among actors in the innovation system*

Fig. 4 below shows a sociogram, consisting of the stakeholders in the SRI innovation system in Sierra Leone. The size of the nodes represent the eigenvector centrality (i.e. how well the actor is linked to other influential actors in the network) determined using NetDraw, which shows the level of influence of each actor in the whole network. The node shapes and colours represent stakeholder type. A high overall network density was found (i.e. 60%) which indicates that knowledge exchange and information flows are able to move quickly within the network [38]. In addition, the MAFFS and farmers (including community leaders) had a strong level of influence and interaction with many other actors (second only to NGOs) with eigenvector centrality values 0.398 and 0.372 respectively.

The subsequent sub-sections discuss further the strengths and purposes of the linkages, which exist among these actors as perceived by respondents (researchers, extension staff and farmers) who participated in the study.

*Purpose of linkages/interactions among actors*

The identified purpose of linkages among actors in the innovation system as perceived by research and extension professionals are shown in Table 8. While some actors share a common purpose of linkages between each other, for instance, convening and participating in meetings and coaching sessions, there are also distinct purposes for linkages with certain actors. MAFFS was identified as linking with most other actors for funding, coordination of activities, and mobilization.

*Strength of linkages among actors in the SRI innovation system*

In Table 9 below, the strength of linkages among actors in the rice innovation system, as perceived by research and extension professionals and farmers, is shown. Unsurprisingly, MAFFS was identified to have very strong links with most of the actors, with the exception of Cornell University and WFP, which were each identified to have weak linkages because neither had interacted with MAFFS on SRI issues at the time of data collection.

Moreover, it can be seen that a few actors were identified to have weak linkages with the majority of the actors in the innovation system, they were: SLeSCA; WFP; SMP; and Cornell University. These findings are consistent with those of the social network analysis (section 3.1), which shows the MAFFS and NGOs having a strong influence among actors in the SRI system.

*Constraints associated with the SRI*

The key constraints associated with the SRI are classified into a number of categories as shown in Table 10 below. These include the lack of technical skills by farmers for swamp development, lack of adequate extension staff, lack of funding sources for NGOs, lack of appropriate tools for swamp development, the labor-intensiveness of SRI techniques. The high dependency rate of farmers on development organisations, farmers' unwillingness to use innovations, unwillingness of smallholders to participate in group work, climatic disturbances and poor motivation of public sectors staff (MAFFS and SLARI) are also key. It is worth noting that these constraints were highlighted by research and extension professionals, however, some of them were identified as factors affecting smallholder farmers themselves (e.g. the labor intensiveness of the innovation, lack of appropriate tools, lack of technical skills on swamp development, climatic disturbances etc). This points to the fact that research and extension professionals are the key promoters of the innovation, but aware of the constraint's smallholder farmers face in the use of the innovation at farm level.

## Discussion

*The perceived benefits of SRI*

The study has largely found that farmers and Research and Extension professionals involved in rice innovations viewed SRI practices positively (e.g. Table 5). These perceptions are supported by a number of studies on SRI, including in Sierra Leonne that highlight the benefits including improvements in yield, reduced input requirements and costs of production (e.g. [39,40]). These benefits have been the key drivers for the promotion of SRI practices by research and extension professionals and their use by farmers.

*Key actors and their roles in the promotion of SRI*

Exploration of the key actors and their roles revealed the Ministry of Agriculture, NGOs and farmers as key actors in the innovation system (Table 6). Though the patterns and strengths of the linkages among the actors revealed a dense network

(See Fig. 1). which usually can be interpreted as one which is a conduit for higher levels of knowledge exchange; Isaac et al. [41] has argued that high-density networks may result in high levels of interaction which are important for scaling but which are limited in developing new information (essential for innovation). Likewise, low density networks may result in lower ability to scale due to low levels of exchanges, but which may be able to generate new information (essential for innovation).

It is interesting to see that NGOs have the highest influence (signalled by the node size i.e. eigenvector centrality value of 0.405). This highlighted that NGOs interacted with all other actors identified in the innovation system. NGOs including Catholic Relief services, Concern Worldwide and World Vision have played a key role in the promotion of the SRI in Sierra Leonne and have ties that exist with the public/private sector and farmers. (See Fig. 4) However, these are mostly INGOs and little or no participation of local NGOs was reported (See Fig. 1). NGOs are independent entities which usually strive to increase their visibility through networking and partnerships with other actors beyond the agriculture sector. Ng and Thiruchelvam [30], who found that innovation actors in Malaysia established links with other firms in order to increase their technological advancement, or to sustain their existence. Suchiradipta and Raj [43] made a similar finding in India.

Similarly, MAFFS, in addition to its role in the promotion of the innovation, also serves as the primary government institution overseeing the coordination of activities of the many actors in the sector. Therefore, other actors find it necessary to link with MAFFS for visibility of their activities, and also for protection, when necessary. Although SLARI and District Councils, had fairly high eigenvector centrality value (0.289 and 0.269 respectively) (See node sizes in Fig. 4), which suggests they seem to have played a central role in the dissemination and promotion of SRI after NGOs, MAFFS and farmers; however, they are not effectively utilized during the process. They have likely been mentioned because they are government institutions that offer services to other actors especially NGOs and the private sector in agricultural innovation processes. For SLARI, it is probably because they have also tested and promoted SRI. Interestingly, Cornell University had the lowest eigenvector centrality value (0.060) meaning their role in the promotion of SRI is not seen as central to the network as they seemed to have interacted only with one actor in the network (Fig. 4). Information from a key informant who happens to be Director of ENGIM, an INGO based in Port Loko District, reveals that Cornell University has been providing mentorship on SRI activities through exchange visits. Since Cornell has only been interacting with this single NGO, it is shown to have linked only with NGOs.

*Strengths of linkages/interactions among actors in SRI*

The perceived strong linkages between MAFFS and the other actors could be due to their reliance on each other's services (Table 8). For example, MAFFS depends on SLARI, SLeSCA, SMP, and NGOs for obtaining certified seeds, mentoring, and information sharing that could be important in their SRI activities. Similarly, farmers are perceived to have strong to medium linkages with the majority of the actors identified, with the exception of Cornell University and SLeSCA, with whom they are seen to have weak linkages (Table 8). Farmers, being the target beneficiaries of SRI, ultimately experience some strong interactions with the majority of actors on SRI for a variety of reasons. For instance, farmers would have repeatedly interacted with MAFFS, NGOs, SLARI, and district councils, for coaching on SRI techniques; accessing improved rice seed varieties; developing IVS; and forming Farmers' Groups at community level. They do not seem to have interacted with Cornell University or SLeSCA directly, hence the perceived weak linkages between farmers and these actors (Table 8). This is because these institutions often interact at the "macro" level with institutions such as MAFFS, NGOs, SLARI, and district councils for service provision and information sharing, amongst others, but do not deal with farmers or their collectives directly on SRI issues.

Other studies have shown that systems which are more linear will reinforce the top-down transfer of innovations approach rather than encouraging innovation to occur from interactions of stakeholder groups across different levels [42]. Similar research in Burundi, Democratic Republic of Congo and Rwanda found an absence of local and provincial levels in knowledge and influence networks [44]. Kabirigi et al. [45] argues that farmers' networks are more predictive of extension delivery than proximity which also suggests the importance of local knowledge networks. As Gaitan-Cremaschi et al. [9] has shown innovation processes can be hampered/blocked by different actors and thereby it is important to identify these constraints/issues. Kabirigi et al. [8] further highlighted that particularly at the local level social and cognitive proximity are increasingly important factors that are needed to improve knowledge exchange and stimulate innovation.

Klerkx and Begemann [7] have also recently advocated for the exploration of networks and governance in order to understand how AIS's evolve and to determine their impact. As suggested by Jiren et al. [46], most actors in innovation systems are targeted due to the powers they possess. For example, the MAFFS, NGOs and farmers have been playing lead roles in the system due to the various powers they possess – positional power (e.g. MAFFS), sociological power (e.g. farmers) and formal power (e.g. NGOs and MAFFS). It is clear that though there are positive perceptions of SRI practices and strong information flows/connectedness of key actors in the rice innovation system, the AIS at present has limited capacity to enhance innovation processes related to SRI practices at any meaningful scale.

*Constraints associated with the SRI*

There exists several constraints faced by the key actors in Sierra Leone that could negate the use and effectiveness of SRI in the country such as related to financial constraints, human capital and challenges with infrastructure (Table 9). This

is reinforced by Foster and Heeks [47] who identified that inclusive innovation systems need to be centred around local needs and demand-centred. Contrary to the tenets of an effective AIS as suggested by Klerkx et al. [4], there has not been any conscious effort in facilitating the participation of other actors (e.g. the private sector, local NGOs/organisations) in the system, hence, limiting the effectiveness of the innovation system and thereby limiting locally adapted/context specific practices from emerging. Farmers have little or no access to services (finance, transportation, inputs etc) that can enhance the use or practice of techniques associated with the innovation. As noted by Jiren et al. [46], the effectiveness of an innovation system should encompass a governance network that harnesses stakeholder collaboration across sectors and levels. This is yet to happen in Sierra Leone especially in relation to the SRI.

One option as proposed by Lamers et al. [49] is the use of multi-sector platforms at various scales. These have been found to improve connectivity among stakeholders across levels and through the use of contracted 'innovation champions' at different levels joint agenda setting and participatory action research/problems solving can occur [49]. Altering the 'innovation sequencing', (e.g. more focus on local organisations/the private sector as an entry point) including the configuration of stakeholders at different levels may also be necessary to improve the inclusivity of the AIS [49,50]. For example, Álvarez-Mingote et al. [51] tracked changes over time where activities to strengthen stakeholder platforms were initiated in Malawi. The authors found tangible improvements in platform functionality in these districts compared to districts without such an intervention. Improvements in farmers' voice and responsiveness to their needs as well as overall improvements in the formation of farmer networks/problem-solving were found. Moreover, more recently McNamara [52] has found that adjustments/strengthening of innovation platforms at the meso-level have similar benefits for farmers at the village level.

This aligns with the suggestion made by Klerkx and Begemann [7] for mission-oriented agricultural innovation systems (MAIS) approach which can help understand how AIS's develop at different geographical scales and the specific catalysts/barriers to transformative change. 'Missions' can be either demand-pull orientated (e.g. certain social movements) or supply led (e.g. business or science). Hoffecker et al. [53] recently explored inclusive innovation processes in agricultural systems, looking at cases in South America, Southeast Asia, and Africa which found. in each case that social learning, social capital strengthening and factors such as consensus formation were all 'causal mechanisms' responsible for outcomes at different levels i.e. technical, institutional and organisational. Notwithstanding this Ziegler et al. [54] has further asserted that social innovation in changing land use has seldom explored unintended and negative consequences and deserves more focus. McGuire et al. [55] also noted that gender considerations need to be more explicitly made when thinking through the scaling of innovations and that among other important considerations such as the communication aspects regarding innovations; scale models e.g. entrepreneurship and business development are important and reinventing and changing technology.

Similarly, Wigboldus et al. [56] have cautioned against the scaling of a set of practices given differing impacts under a variety of conditions. Rather it is important to view scaling as an 'integrative and iterative process' with the need to find out 'what fits' and 'what is responsible' rather merely what works/fits well. Thus, the focus shifts from how to scale new cultivation practices to 'addressing organisational and institutional prerequisites for sustainability' [56]. Additionally, Pigford et al. [57] has put forward the agricultural innovation and ecosystem approach which goes beyond innovation systems thinking and considers multifunctionality at the 'ecosystem' level [58]. An innovation ecosystem therefore 'simultaneously support niches' and interactions (e.g. across innovation systems) which are more explicitly cross-sectoral (e.g. agriculture and fisheries such as rice-fish systems but also forestry, water, conservation and energy) [57]. There is also a need to consider the variety of ecosystem functions (e.g. [59]), potential health implications (e.g. [60]) and the power dynamics that exist in innovation platforms/communities [57].

## Concluding remarks

This study sought to understand the perceptions of the actors within the SRI innovation system in Sierra Leone by exploring the key actors and their roles, the patterns and strengths of the linkages among them, as well as the attitudes towards the innovation /potential constraints faced by the actors. The study has largely found that Research and Extension professionals involved in rice innovations viewed SRI practices positively. The key actors identified in the innovation system include the Ministry of Agriculture, NGOs and farmers; functioning as facilitators, funders, knowledge conduits, coordinators, implementers and collaborators. The Ministry of Agriculture and a few NGOs have been playing a key role in promoting the innovation though constrained by the level of funding, poor coverage, and the limited role of the extension services.

Overall, this study brings to light the tensions that exist from the existing TOT models and AIS approaches that seem to be promoted at least in theory (e.g. a lack of consideration for local needs and existence of a demand centred approach). Future studies, in a similar context, that examine the extent to which AIS approaches have been integrated in the promotion of rice innovations such as SRI would also help to examine whether existing ToT models are pervasive or whether innovation systems are successfully transitioning to an AIS; able to stimulate innovation processes and thereby the contextual adaptation of agricultural innovations that fit well and are responsible at a wider ecosystem level.

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