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Using an analytical model to explore potential gendered dimensions in agricultural innovation systems

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Abstract

Although technological development is increasingly recognized as a key driver of socio-economic benefits in the agriculture sector, innovation with or without adaptation has yielded uneven adoption results in Africa. Moreover, despite the great potential for multiple actors participating in agricultural innovation systems (AIS), some stakeholders – particularly women and other marginalized groups – continue to face innumerable challenges in relation to their participation in the overall innovation process. Yet, gendered relationships are part of the social relations that make up the linkages that in turn, constitute the AIS process. In theory, engendering AIS may be associated with outcomes benefitting both men and women equally and equitably. In practice, however, how and where to engender AIS remains a mystery, as it is unclear what or where the gender gaps are within the innovation process. This paper attempts to answer this question by identifying what the potential gender gaps are, where they are situated in the AIS and the magnitude of their impact on the innovation process. In this endeavour, the paper uses a combination of the Social Relations Framework (SRF) and the Social Network Analysis (SNA) to investigate and simulate gendered patterns emerging from the social interactions among AIS actor categories. The analysis leads to different conclusions. Firstly, a better understanding of the gender dynamics within the AIS processes should be well-articulated around the dimensions of power, people, resources, activities and rules. Secondly, a simulation of an actor network map showed that the category of policy/decision makers is likely to be the most connected and exerting the greatest influence on the other actor groups. Thirdly, a simulation of the centrality of the actors showed that the end user category appears to be the most central in terms of gendered relationships. The assumption is that intervening at the policy maker and end user levels is likely to significantly contribute to the engendering process of AIS. We recommend implementing measures that increase awareness of gender issues (at the policy maker level) and that are predominantly transformative (at the end user level) so as to optimize participation and inclusion of disadvantaged groups in the innovation process while ensuring significant positive impact on their livelihoods.

Introduction

Agricultural innovation[1] has the potential to offer promising prospects for economic growth in Africa (Juma 2011; Larsen, Kim and Theus 2009). Moreover, technology is increasingly becoming a key driver of social change and economic development across the continent (Juma 2011). However, agricultural innovation with or without adaptation has yielded uneven results to date. These results range from resounding success in adoption of some technologies, occasional success, to total failure for other technologies (Adekunle and Fatunbi 2012; Van Rijn, Bulte and Adekunle 2012). Researchers and developers have promoted technologies that result in varying adoption rates in different contexts. Context constitutes the circumstances that form the setting for an event -in this case agricultural innovation- and is dynamic over time and space. The variability in technology adoption has attuned the consciousness of technology developers that technologies can neither be delivered nor scaled up in an *ad hoc* manner. To ensure relevance of technology to context and the appropriateness of its delivery, agricultural research has gradually converged towards a more holistic and integrated stakeholders' approach: Agricultural Innovation Systems (AIS) which are viewed as a significant "*policy instrument for African agriculture*" (UNCTAD 2010:34; AUC and NEPAD 2003). Basically, an AIS perspective stresses the need for closer linkages between initiators of innovation (*technological actors*) and promoters/users (*socio-economic actors*) either in the search for and validation of agricultural knowledge or for technology application/use within an enabling environment (Clark 2002). The performance of AIS processes is thus determined by the strength of the linkages among actors/actor categories and how enabling is the context within which the AIS are situated, formed and maintained (Daane 2010).

Despite the great potential for multiple actors participating in the AIS, some stakeholders- particularly women and other vulnerable groups in society- continue to face innumerable challenges in relation to their participation in the innovation process (Ajadi 2013; Kingiri 2013; Kabeer 2000). Indeed, these social groups often have a considerable fund of tacit knowledge about appropriate technologies for enhanced production possibilities for their specific contexts, but are rarely in a position to act as innovators, entrepreneurs or decision makers within the innovation system (Blake and Hanson 2005; Doss and Morris 2001; Osuala 1987). Yet, social relations significantly affect the linkages that constitute AIS processes and are gendered in the sense that, such relationships can contribute in (re)producing stereotypes, attitudes and norms (Perrons 2004; Elson 1999, 1998) that, in many instances, can constrain opportunities for collaborative action in technology development, diffusion and use.

Multiple linkages constitute networks and through networks, resources like information are introduced and transmitted between actors, and new linkages are built among actors (Blake and

[1] I*nnovation* entails the search for development, adaptation, imitation and putting to use technologies, approaches and methodologies that are new to a specific context and have social and economic significance (Hall 2007). Innovation can be classified into two broad categories: product versus process and incremental versus radical innovation. In the case of agricultural innovation, examples include new agricultural technologies (*product*) and organization/planning of innovating entity (e.g., farm or firm) to motivate change (*processes*). Besides, product and process innovation can be incremental or radical. Incremental innovation entails improvement or change of an existing product, whereas in radical innovation, a new product is completely different from any previous versions (Blake and Hanson 2005).

Hanson 2005). Networks, therefore, play an active role in the development of individual and group identities by positioning individuals/groups relative to each other through their social relations. These relations, like context, are dynamic over time and space. Because social relations are gendered, networks through which they are formed are also gendered. Clearly, though, in the AIS context social linkages between actors might also be influenced and shaped by different gender issues, reflecting varying aspirations of different actor categories. From the foregoing, AIS processes do not only lead to efficient knowledge flows among and between key players, but also provide an arena where vested interest in social and transformative approaches to innovation can be implemented. Evidently, the influence of socio-economic characteristics (including gender) on the potential of AIS to deliver improved well-being and sustainable livelihoods of all groups, especially those of women and other marginalized populations, cannot be disputed (World Bank, FAO and IFAD 2009). In this paper, the authors elected to approach AIS as having the problem of not being engendered.

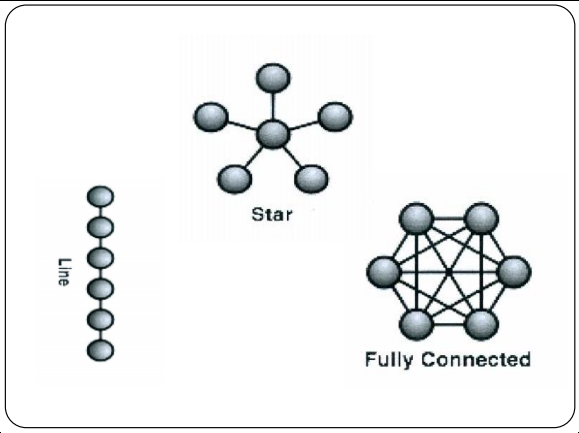
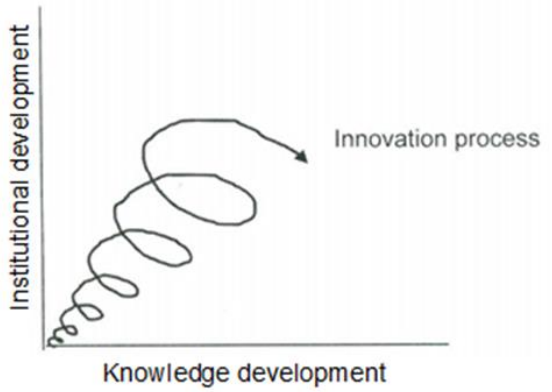
In theory, engendering AIS has been associated with desirable outcomes and impacts such as increased food security, poverty alleviation and overall wellbeing. In practice, however, how and where to engender AIS remains a mystery as it is unclear what or where the gender gaps are within the AIS. This paper attempts to identify what the potential gaps are, where they can be situated and the magnitude with which they might affect AIS processes. With this understanding, actors within the AIS will be able to identify and prioritize response opportunities in terms of gender-neutral, gender-specific or redistributive interventions. Specifically, the paper maps out gender gaps within and between the AIS actor categories based on existing literature; weighs the potential gender gaps and estimates their influence on the strength of agricultural systems.

I. Why a systemic approach to agricultural innovation?

Agricultural development has undergone transformation since its inception (Klerkx, van Mierlo and Leeuwis 2012; Edquist and Hommen 1999). Research describes this transformation process as resulting from multiple approaches[2], beginning with the linear pipeline technology delivery model, to a less linear knowledge exchange model characterized by a feedback system and eventually to the AIS, which integrates all actors equally in an exchange platform (Figure 1a).

[2] Several approaches to technology delivery have yielded diverse results. For example, the typically top-down linear model has had minimal impact, which has often been associated with the fact that agricultural innovation is embedded in the socio-cultural and economic realities of the intended beneficiaries. In other instances, the knowledge feedback model has not always worked, especially when the feedback from the potential technology users was not accounted for. This could be explained by the fact that innovation processes are often fragmented, focusing on one or a few aspects, and sometimes, defeating the intended purpose of the innovation in the system (Sanginga et al. 2009).

Figure 1: Evolution of agricultural technology delivery and the innovation process

a) Evolution of technology delivery processes	b) The innovation process
	

Source: Röling (2009)

Furthermore, the innovation process represents a paradigm shift in the way things are done (Figure 1b). According to Malton (2009), each step in technology development expands analysis and interventions; makes the framework dynamic by acknowledging the non-linear and iterative nature of change processes; and introduces a larger scale and a set of economic, socio-cultural, institutional and political factors. In this regard, researchers have emphasized the need to forge collaborative (co-development) processes to generate new agricultural technologies while also creating value from these innovations in agriculture (Sanginga et al. 2009; Hall et al. 2006). Situating the AIS as the latest form of evolution, Malton (2009) noted that such an approach can contribute to agricultural research and development by systematically incorporating functional linkages between stakeholders within the broader institutional and policy environment and incorporating internal organizational changes necessary for effective linkages. Bringing a systemic-oriented perspective to the innovation process, therefore, calls for multiple social interactions between actors through reciprocity and feedback mechanisms that take place within the context of existing institutions which shape the relationships among these actors (Hall 2007; Hall et al. 2003; Edquist and Hommen 1999).

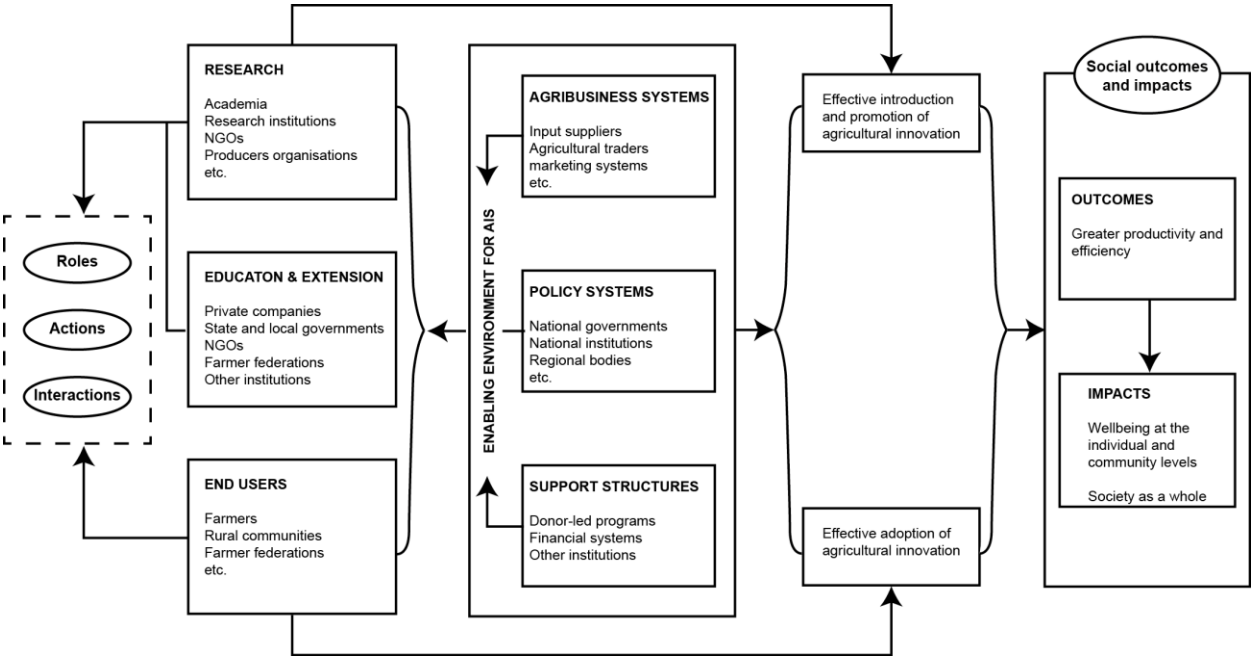
2. Major actor groups in the AIS process

AIS can be perceived as a network of stakeholders in agriculture interconnected with vertical (hierarchical between individuals/entities wielding different levels of power) or horizontal (collegial between individuals/entities wielding equal power) linkages of social and other relations (Blake and Hanson 2005).

The simplified conceptualization of AIS is based on a harmonization of actor categories from various sources (Figure 2). It identifies three broad actor groups: i) actors introducing and promoting agricultural technologies and hence initiating the innovation process; ii) actors intended to adopt, use and promote these agricultural technologies; and iii) actors providing an

enabling environment for the AIS to function effectively and efficiently. Each actor in the system has defined roles, actions and interactions. Effectively functioning AIS are associated with greater productivity and efficiency outcomes and impacts for each actor group and the whole society in terms of improved wellbeing.

Figure 2: Main actor categories involved in the AIS process



Source: Authors (adapted from Spielman and Birner 2008; Rajalahti et al. 2008)

2.1. Key players initiating the innovation process

Actors in this category initiate and catalyse the innovation process. They are primarily involved in agricultural research and extension systems.

- ***Agricultural research systems*** are primarily tasked with developing and providing research services that can sustainably contribute to addressing the priorities and needs of the most vulnerable social groups. This actor category encompasses a cross-section of stakeholders (e.g., universities/other tertiary institutions, research organizations, civil society organizations, farmer groups, etc.) involved in the public and/or private sectors and also, operating at national or international levels.
- ***Agricultural extension systems***, both public and private, are mainly responsible for promoting new agricultural knowledge/technologies while also facilitating use and adoption by population groups through non-formal learning, communication, and other varied activities aiming to support contributions to agricultural production, improve problem-solving skills, and increase market linkages for enhanced livelihoods. Actors in this category mainly comprise extension agents from the state and local governments, farmer federations and non-governmental

organizations. They are also from private companies and various other organizations involved in providing advisory and extension services.

2.2. Actors using -adopting/adapting- agricultural innovation

Agricultural innovation and its underlying processes are of greater benefit to the downstream users who are at the heart of different agriculture-related activities (e.g., production, productivity, consumption and marketing). Their involvement in the various processes can considerably contribute towards enhancing wellbeing and livelihoods. The main actors in this category include resource-poor farmers, small-scale entrepreneurs, rural and farming communities, farmer groups and other farmer-based organizations. Most of these actors are generally interested in scaling up agricultural technologies that will increase their productivity and incomes. However, they hardly ever fully participate in the overall innovation process. This actor category is the most fragmented in the AIS process because of several factors such as lack of capacity and inadequate resources/assets and power that limit their influence to the process (Rajalahti et al. 2008).

2.3. Actors providing an enabling environment for AIS

Conducive policy mechanisms, trade environment, and access to infrastructure are necessary to foster development and advancement of agricultural technology. Additionally, the institutions (norms, rules and regulations) governing the socio-economic process of innovation shape how various actors become involved in production, dissemination/transfer, and application/use of innovative agricultural technologies and practices. This actor category features a cross-section of stakeholders involved in agribusiness systems, policy-making systems, and supporting institutions all working towards facilitating value-added opportunities to stimulating and scaling up agricultural innovation.

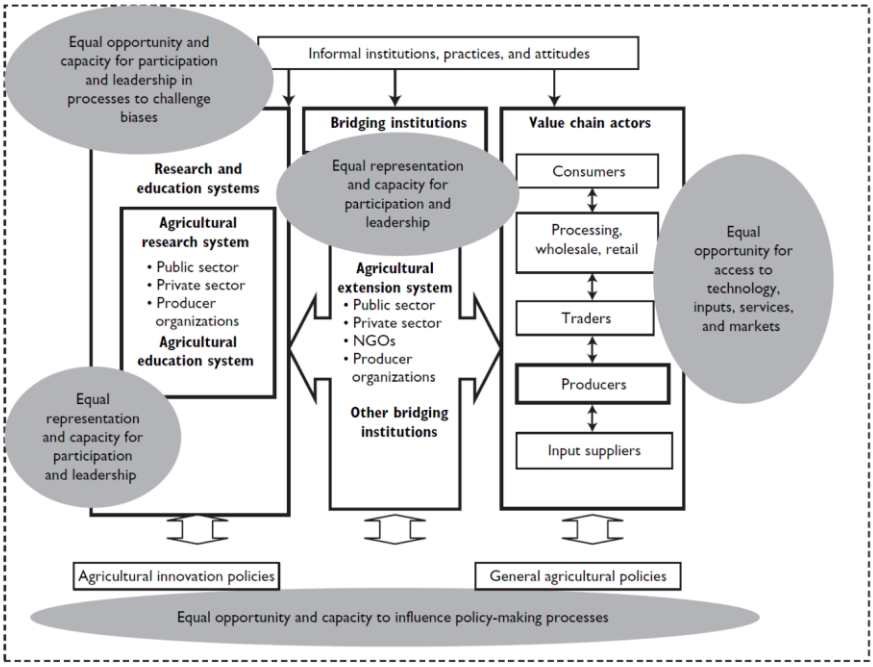
- ***Agribusiness systems*** focus essentially on the utilization of agricultural technology to increase profitability. Agribusiness systems cover a coordination of actors involved in agriculture and related value chains including, farmers/agricultural traders; input suppliers; organizations dealing with activities, such as, agro-processing, packaging and storage, and other relevant actors involved in marketing and distribution activities, such as transporters and brokers.
- ***Policy-making systems*** play a key role in the decision-making process at the macro level. State agencies (ministries of agriculture/sector ministries), working with decentralized bodies, are primarily in charge of formulating policy decisions while various official entities mediate policy implementation. This actor category predominantly comprises national actors, including: state and local governments; regulatory/legislative bodies that enforce agricultural biotechnology laws and regulate prices; and monitoring institutions that ensure the quality of agricultural inputs such as modern seed varieties.
- ***Support institutions*** are generally responsible for building broader support for adoption of agricultural technologies and especially those that are market-driven. This actor group is dominated by financial entities, public and/or private (state/government, banks, micro-finance institutions, etc.) and donor-led initiatives often implemented through non-governmental organizations. Other formal institutions such as the state, market and family structures and also

informal structures such as ascribed cultural roles can potentially affect promotion and adoption of agricultural innovation.

3. Rationale for a gendered approach to AIS

The few studies conducted on the nexus between gender and agricultural innovation agree on the need for gender mainstreaming in AIS processes. Specifically, the studies highlight the dangers of disregarding gender as an analytical variable and a crucial driver of development, of which AIS is one path towards its attainment (Ajadi 2013; Kingiri 2013; Meinzen-Dick et al. 2011a; World Bank, FAO and IFAD 2009). FAO (2011) noted that owing to gender gaps, women's productivity is often constrained, causing their contribution to the agriculture sector and broader economic and social development to be inadequate. A major cause of gender gaps is that women often have less access to and control over tangible and intangible assets– capital, social, human, physical, political and natural resources– (Meinzen-Dick et al. 2011a, b). There is also the issue of limited actor linkages in the innovation process as, for example, agricultural researchers working on gender-related issues and those working on agricultural innovation are not always adequately connected. However, researchers and practitioners working on gender and AIS seem to agree that gender should be mainstreamed simultaneously into all parts of the AIS (Kingiri 2013; World Bank, FAO and IFAD 2009).

Figure 3: Gender mainstreaming in AIS - Likely gender equality outcomes anticipated



Source: World Bank, FAO and IFAD (2009), adapted from Spielman and Birner (2008)

Figure 3 illustrates this point whereby a schematic representation of AIS actor categories and their relational linkages is overlaid with bubbles, demonstrating outcomes of integrating gender

in AIS. What is unclear from this framework (Figure 3) is how one gets to the required gender equality. The questions on how and where to engender AIS, thus, still loom large. This paper suggests conceptual and analytical perspectives that provide some insight on how and where to engender AIS processes. Viewing AIS as a system and unpacking it to its components for analysis and then repacking the components is inspired by the work on vulnerability analysis that illustrated the complex interactions of the array of factors that potentially affect the vulnerability of the coupled human-environment (H-E) system (Turner et al. 2003). The authors draw a parallel to this illustration and perceive AIS as a whole H-E system and the gender relations as some of the linkages constituting the multifaceted system of relations with connections operating at social, spatial, and temporal levels.

4. Engendering AIS: A theoretical perspective based on the Social Relations Framework

The Social Relations Framework (SRF) is based on the premise that gender analysis should go beyond analysing roles and responsibilities for men and women to include how gender inequality is created and perpetuated through the patterns of social interactions in different contexts (Kabeer 2000, 1994). The approach places institutional social relationships at the core of its analysis, suggesting that social institutions shape the rules, distribution of roles and responsibilities (activities), distribution of resources, and interactions among people through powered gender relationships (Ibid).

4.1. Dimensions of the SRF approach

The SRF is articulated around five key dimensions:

- ***Rules*** can be formal or informal, and constitute the norms, values, laws, traditions and other customs practised in a community or society as a whole. As the AIS process involves a community of actors interacting to achieve social outcomes, it may focus on laws and regulations that enable or constrain innovation among actors while also taking into account gender considerations.
- ***Activities*** are based on the differing roles performed to achieve goals. Activities can be productive, distributive or regulative. In the AIS process, one may also think of prescribed gendered roles and responsibilities that can be established by determining the gender ratio for productive and reproductive roles; time consuming and mundane versus quick and interesting roles; if the roles change, in what ways and under what circumstances they change (Moser 1993).
- ***Resources*** (including capital/assets) can be human (labour, education and skills), natural (crops and livestock), physical (farm machinery), financial (money), social (networks) and political (influence) (Meinzen-Dick et al. 2011b; Bebbington 1999). Inequalities in the AIS process can be identified by examining the presence or absence of – and the different existing – mechanisms for access, control and ownership of resources (Meinzen-Dick et al. 2011a; Agarwal 1997).

- ***People*** determine who is included in or excluded from various social processes, such as agricultural innovation, and who belongs to what position in the hierarchy when it comes to being assigned tasks, resources and participation in particular contexts.
- **Power** determines who decides and whose interest is served. Individuals with power promote practices that entrench their privileged position and are most likely to resist change. In the AIS process, power dimensions can be determined by asking what linkages exist between actors, if they are unidirectional or inter-relational and which actors have control over resources and authority over others (Meinzein-Dick et al. 2011a).

4.2. Linking SRF dimensions to potential gender issues within AIS

The five theoretical dimensions are interlinked. For example, the rules may determine what activities are undertaken, how resources are distributed and which people are included or excluded, whereas the powerful decide what rules to enforce and so on. Regarding AIS processes, social outcomes and impacts may also be determined by the different dimensions of the SRF model. Our analysis of potential gender issues among and between AIS actor categories builds on the SRF approach and is informed by an extensive literature review.

In some cases, actors within one category have been identified and set apart if their social relational issues are distinct. For example, among the category "actors initiating innovation", agricultural research actors and agricultural extension/education actors have been analysed separately. For other categories, actors within one category have been collapsed into one group; for instance "actors using or promoting use of innovation" have been collapsed to one actor labelled as "end users" because the issues associated with them may be similar. Identified gender issues are discussed across the rows and summarized in Table 1.

4.2.1. Actors initiating agricultural innovation – *Research actors*

Within this category, the main gender issues identified from the literature were in the *activities* dimension. In this dimension, investments in human capital seemed to show some gender gaps with the share of women in agricultural research and education being persistently low, especially across Africa (Manfre et al. 2013; Meinzen-Dick et al. 2011a; UNESCO 2010).

- Between *research* and *extension/education actors* and *research actors* and *policy makers*, no explicit and direct gender issues were identified from the literature. One might, however, consider implicit issues, especially given the extent of social interactions between these actor groups. For example, considering the interaction between *research actors* and *policy makers*, implicit gender issues may be discussed in terms of policy interventions to reduce existing gender gaps in agricultural research. On the interaction between r*esearch* and *extension actors*, implicit gender issues may be analysed with respect to inadequacy in research/knowledge transfer translating into inappropriate technology dissemination and leading to gendered differences in participation and contribution to agricultural extension activities.

- Between *research actors* and *support institutions* and between *research* and *agribusiness actors*, hardly any gender gaps have been documented in the literature. While social interactions exist between these groups, these may not necessarily occur in the context of gendered relations.
- Between *research actors* and *end users*, gender issues are primarily discussed in terms of *people*. Agricultural research has tended to neglect the relevance of gender representation in agricultural production systems. Moreover, the lack of gender statistics (UNECA 2009; Sanga 2008) coupled with limited information on the contributions in agriculture has often led to a lack of consideration of the specific needs of the priority groups in the innovation–diffusion process (FAO 2005; 1999). Most analysis has focused on female- and male-headed households while ignoring data on intra-household distribution of farm and non-farm responsibilities, resources, and other dynamics, which are equally relevant in gender analysis (Doss 2014).

4.2.2. Actors promoting agricultural innovation – *Extension/education actors*

Within this actor category, the dimensions of *people* and *power* were inextricably intertwined (Sulaiman and Davis 2012; Davis 2008). This is supported by empirical research which has revealed highly unequal gender ratio - generally in favour of male extension officers - in different agricultural extension programmes in Africa (Manfre et al. 2013; FAO 1993). Such dynamics were also found in various country case studies where agricultural extension organizations were predominantly staffed by male agents (Manfre et al. 2013; World Bank and IFPRI 2010; Akeredolu 2009; 2008).

- Between *extension/education* and *research actors* and actors in the interaction between *extension/education actors* and *policymaking systems,* gender issues were not evident in the studies reviewed. One might, however, think of implicit issues possibly caused by the indirect interaction with other actors through, for instance, mediating parties (end users) in the AIS process.
- Between *extension* and *agribusiness actors* and between *extension actors* and *support institutions*, gender issues are highly unlikely, as direct social interactions with these actors seemed to be very minimal.
- Between *extension/education actors* and *end users*, gender issues are mainly related to power, people and activities. In terms of *people*, several authors have argued that public and private agricultural extension programmes mainly focusing on farming activities dominated by men rather than female farmers, thus contributing to the under-representation of women in agricultural training activities (Manfre et al. 2013; Swanson and Rajalahati 2010; Jiggins et al. 1997). With regard to *power* dynamics, literature reveals existing gender inequalities that can be reinforced through agricultural extension systems as service provision is often biased against women and even more against female heads of households (Quisumbing and Pandolfelli 2010; Swanson and Rajalahti 2010; Monge et al.2008; Meinzen-Dick et al. 2003). This was illustrated in various programmes for selecting intended beneficiaries whereby extension agents tended to seek out better skilled farmers, usually men, yet extension services must also benefit less endowed/productive farmers, usually women, who need agricultural advice and guidance to improve their production abilities (Ragasa et al. 2013). On the *activities* dimension, research has

showed that the lack of gender-based assessment of proposed agricultural activities by extension providers can contribute towards ineffective solutions to addressing the differing needs of marginal groups (Manfre et al. 2013).

4.2.3. Actors triggering agricultural innovation – *Agribusiness actors*

The review of literature indicated that little research has been undertaken on the possible gender issues in agribusiness systems and in relation to other AIS actor categories. As a result, agribusiness actors have poor social links within their own category and with other actor groups because of their reliance on market forces and indifference to social issues of inclusion and exclusion. An exception to this pattern is that they can be directly linked socially to end users mainly in terms of power and people. With regard to *people* and *power* dynamics, few studies have documented that trading systems (e.g., input suppliers) could significantly influence technology dissemination at the grassroots by pushing for the adoption of particular technologies while restricting access to others. By doing this, trading systems create through these interactions, an apparent bias in favour of those with good asset base and access to markets - usually male farmers (Rajalahti et al. 2008; Meinzen-Dick et al. 2003).

4.2.4. Actors triggering agricultural innovation – *Policy/decision makers*

Implicit gender issues might exist as a result of the rules and regulations policy makers develop or enforce between this actor category and others actors like agribusiness actors and support institutions. For the other actor categories, studies have stressed that gender issues are likely to occur in the rules domain (particularly interaction with research and extension actors) and in the dimensions of people, power and resources (interaction with end users).

- With the *research and extension actor category*, literature has documented the lack of gender mainstreaming in agricultural policies and research programmes (*rules*), often resulting in gender invisibility in several agricultural research activities (e.g., time allocation and mobility constraints, paid and unpaid activities) and extension programmes (Meinzen-Dick et al. 2003; Cagatay 1996; Floro 1995).
- With the *end user category*, the dimensions of people, power and resources were inextricably intertwined. On the *people* dimension, lack of gender sensitization among policy makers may reinforce the non-recognition of gender-differentiated demands and perception of technology needs. As a result, this contributes also, to the *powerless* directly being excluded and their exclusion resulting in their reduced or lack of access to and control over available *resources* (Kabeer 2000; Agarwal 1997).

4.2.5. Actors triggering agricultural innovation – *Support institutions*

Social interaction within this actor category and with most AIS actors implies relationships that do not necessarily require direct linkages and thus, are unlikely to bring gendered power relations in the innovation process. Because of this, most actor linkages based on existing gender issues

initiated by this actor group remain unclear. Some research has however, emphasized potential gender differences in access to financial capital for the specific end user category.

- Gender relations that exist between *support institutions* and *end users* are therefore *resource* associated in terms of, for example, financing institutions not effectively contributing to facilitate technology uptake by poor rural women and men farmers. Studies indicate that compared to male farmers, fewer opportunities exist for women to access public and private loans due primarily to the lack of collateral (FAO and UNDP 2003; Meinzen-Dick et al. 2003). Recent estimates also give the share of female smallholders with access to credit at 5-10 percent lower than their male counterparts (FAO 2011).

4.2.6. Actors adopting and or adapting agricultural innovation – *End users*

Within this actor category, because of multiple (direct) interactions between individuals and groups of individuals, gender issues are most likely to occur at all five SRF dimensions, namely rules, power, people, resources and activities.

Culture and traditions constitute a major medium through which *rules* and *power* are developed and sustained at the individual and household levels and even among communities (*people*) (Kabeer 2000; Argawal 1997). Research has identified gendered power relations relevant to technology adoption as playing out between individual farmers, at the household level and within communities (Meinzen-Dick et al. 2003).

On *resources*, abundant literature has shown gender gaps in access and control of productive assets and resources at the household level (see FAO 2011; Quisumbing and Pandolfelli 2010; Deininger et al. 2006; Goldstein and Udry 2005; Meinzen-Dick et al. 2003; 2011b).

With regard to the *activities* dimension, activities vary with gender, age and all other social hierarchies (Kabeer 2000, 1994). More specifically on gender, the context of activities takes on different perspectives depending on the gender division of labour (Barrientos et al. 2003; Kinnaird and Momsen 2002; Brydon and Chant 1989). Studies have shown that critical constraints (e.g., resources/assets, time and mobility) that smallholder farmers and particularly women face as they engage in rural livelihood activities reinforce the need for understanding how gender relations affect various agricultural processes requiring both labour-saving and productivity-enhancing technologies. Such persistent barriers are likely to continuously exclude some groups from the innovation process because they cannot take on certain roles (Johnston et al. 2015; Meinzen-Dick et al. 2003; Arndt and Tarp 2000).

- Between *end users* and *research actors*, gender relations are primarily based on the *resources* dimension. Successful adoption of varied agricultural technologies at the grassroots often requires access to a combination of assets (land, water, labour, credit and other critical assets). However, research has shown that, in many instances, women and poor farmers cannot afford or may not have access and control over the required assets, thus leading to their exclusion from technology benefits (Quisumbing and Pandolfelli 2010; Deininger et al. 2006; Goldstein and Udry 2005; Meinzen-Dick et al. 2003).

- Gender linkages between *end users* and *extension actors* span all five dimensions of power, people, rules, resources and activities.

With regard to *power*, a good part of extension work involves persuading end users to use technology, however, extension agents may be unable to earn farmers' trust and to meet their needs and priorities (Monge et al. 2008). On the *people*, studies have demonstrated that communication dynamics were most effective when extension agents shared similar social characteristics, particularly gender, with their clients (Manfre et al. 2013; Kyaruzi et al. 2010; Mlozi 2005; Lahai et al. 2000; FAO 1993).

On the *rules*, literature has documented that in some communities, reaching out to women remained a challenge to the effective promotion and provision of agricultural advice and technologies (Meinzen-Dick et al. 2011a).

In terms of *resources*, evidence exists that provision of rural and advisory services has been more often biased against female farmers (Ragasa 2014; Ragasa et al. 2013; Quisumbing and Pandolfelli 2010; Swanson and Rajalahti 2010; World Bank and IFPRI 2010; Swanson et al. 1990).

With regard to the *activities* dimension, abundant research has emphasized that provision of extension services is often hindered by the limited participation of female farmers due to the burden of household responsibilities, inappropriate timing of the meetings, restricted mobility (e.g., meetings held far from the village) and other socio-economic barriers that contribute to exclusion from community networks (FAO and UNDP 2003).

- Gender relations between *end users* and *agribusiness actors* are likely to occur in two main dimensions, power and resources. On the *resources*, studies have outlined gender inequalities in farmer's access to agricultural inputs. Specifically, agricultural inputs are often too costly for most women and poor farmers living in rural areas (World Bank, FAO and IFAD 2009; FAO and UNDP 2003; Meinzen-Dick et al. 2003). In terms of *power*, market forces are likely to favour individuals with access to and control over productive resources over individuals without. Gendered power relations may, however, arise from the end users in the case of inappropriate technology resulting in low technology adoption rates (Meinzen-Dick et al. 2003).

- On the social interaction between *end users* and *policy makers* and *end users* with *support institutions*, the five dimensions of social exclusion (by gender) do not seem to apply as direct linkages between these actor groups to bring in gendered power relations. One might, however, consider the role of other AIS actors (e.g., extension agents and research actors) to envisage implicit gender issues.

Table 1: Summary of potential gendered dimensions arising from interactions within and between actor categories in the AIS

	Research actors	Extension/ education actors	Agribusiness actors	Policy/decision makers	Support institutions	End users
Research actors	Activities	Implicit gender issues	Hardly identifiable	Implicit gender issues	Hardly identifiable	People
Extension/ education actors	Implicit gender issues	Power People	Hardly identifiable	Implicit gender issues	Hardly identifiable	Power People Activities
Agribusiness actors	Hardly identifiable	Hardly identifiable	Hardly identifiable	Hardly identifiable	Hardly identifiable	Power People
Policy/decision makers	Rules	Rules	Implicit gender issues	Implicit gender issues	Implicit gender issues	Power People Resources
Support institutions	Hardly identifiable	Hardly identifiable	Hardly identifiable	Hardly identifiable	Hardly identifiable	Resources
End users	Resources	Power People Rules Resources Activities	Power Resources	Implicit gender issues	Implicit gender issues	Power People Rules Resources Activities

Source: Compiled by the authors from an extensive literature review

Note: Implicit gender issues are considered where there has been anecdotal evidence, but which has not clearly been documented in the literature.
Hardly identifiable is considered when the authors could not find anecdotal evidence.

5. An analytical model for engendering AIS

Innovation dynamics emerge from the structural relationships between a set of heterogeneous social agents including, organizations/institutions, individuals and other social collective entities. As such relationships are likely to feature linear and non-linear processes emanating from different perspectives (e.g., cooperation, friendship, communication, etc.); they also depend largely on several relational characteristics which include class, ethnicity, power and gender (Kürtösi 2004). In social analysis, gender has been viewed as a "system of hierarchical [inter/intra genders] relations" that also affect actors' practices and behaviour in a networking process (Lusher and Robins 2010; Kabeer 2000, 1994; Argawal 1997).

5.1. Gender, AIS and Social Network Analysis

Social network analysis (SNA) was developed as a theoretical and methodological approach for exploring patterns of social relationships and their implications for networked actors (Scott 2000; Wasserman and Faust 1994). Numerous applications of the SNA model have emerged and been applied in different studies including technology diffusion and adoption (see, for example, Asres et al. 2012; Matuschke 2008; Borgatti 2006; Biggs and Matsaert 2004). The approach has also been extended to study gendered relations, their extent and the possible reasons for gender differences in various social networking processes (Lusher and Robins 2010; Kürtösi 2004).

Among the studies focusing on agricultural innovation, however, hardly any work has been documented which explores technology development, diffusion and uptake as a function of gendered relationships among actors involved in innovation process and outcomes. Yet, analysing gender as a "relational construct" (Lusher and Robins 2010: 22) or construct of social interactions in the AIS can contribute to explaining how actors are positioned with respect to different socio-economic dimensions and particularly, those discussed in Kabeer's SRF dimensions.

We extend the SNA model to investigate the extent to which gender can potentially influence social relationships within the AIS. By modelling gendered relations in the AIS process, we attempt to demonstrate the specific actor linkages in which constraints to technological innovation and investment can be even more onerous if strong gender differences exist and persist. We posit that the process of engendering AIS may be mediated through interventions of a magnitude that is directly proportional to the gender differences identified at those linkages. The proposed analytical model is focused on the following two dimensions:

- The first dimension looks at the direction of actors' interactions and the extent of potential gender issues affecting their relationships in AIS. This dimension intends to capture gendered patterns among actor categories, particularly the possible sources (*who causes?*) and bearers (*who bears*?) of gender issues within the AIS. Additionally, it also aims to demonstrate that the weightier the issues, the greater will be the effort to reduce the gender gap/disparities in the interventions intended to empower the innovation process.
- The second dimension analyses the position of actors in recognition that often, relational linkages within the AIS may lead to a situation where some actors potentially hold a central

position in the networked system as a result of existing (strong) or implicit gender issues affecting the overall innovation process.

5.2. SNA simulation model for integrating gender in AIS

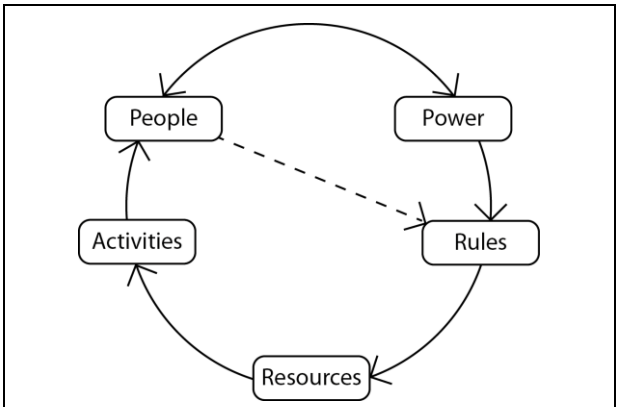
The starting point for analysing potential gendered patterns of AIS is to describe its main components as part of a networked system. AIS actor categories (researchers, extension agents, agribusiness actors, policy institutions, support institutions and end users) are described as *nodes* in the network. Their relationships (ties, links or edges) are analysed using the five SRF dimensions and according to their theoretical and/or empirical interpretation from the literature.

5.2.1. Simulated relational data

Based on SRF, we set the initial conditions comprising a hypothetical network which describes the nature and distribution of gender issues across the different nodes. From different theoretical considerations and particularly Kabeer (1994), a hierarchical relationship is likely to exist between the five dimensions (power, people, rules, resources and activities) that shape social relationships.

Power is generally determined by people, which makes these two dimensions almost inextricable. Powerful actors and entities make and defend the rules that keep them more powerful. The rules determine resource distribution. Resource availability determines activities and the intended beneficiaries from the actions and activities undertaken (Kabeer 2000 and 1994; Narayan et al. 2000; Argawal 1997).

Figure 4: Hierarchical relationships between the five SRF dimensions



Source: Authors (adapted from Kabeer 1994)

Following this theoretical reasoning, we deemed quantifying actor linkages to be appropriate so that actors potentially responsible for creating or bearing gender issues more than others could be identified within the AIS. Gendered dimensions suggested in the SRF were ranked and weighted. The ranking criteria were determined according to which dimension was the most difficult to change owing to its entrenched-ness and pervasiveness in society and hence the potential intensity of resistance to change of gender differences. Gender issues were therefore, rated on a scale of 0 to 6. A code 0 was given in case of hardly identifiable gender issues within the nodes whereas a value 1 was considered to account for the presence of gender issues implicit in nature (Table 1). Based on the assumption of hierarchical links between the five SRF dimensions (Figure 4), potentially identified gender issues were weighted 2, 3, 4, 5 and 6 as they fall under activities, resources, rules, people and power respectively.

This information was compiled in a two-dimensional ($n \times n$) matrix of n actors (nodes) in which matrix element $n_{ij} = 0$ denotes absence of gender issues (hardly identifiable) in a particular linkage while $n_{ij} > 0$ denotes presence of gender issues within and between actors i and j. For those ties where $n_{ij} > 6$, weights were obtained by summing up different values of gendered dimensions identified in Table 1. The measures generated allow accounting for the nature - in terms of activities; resources, rules, people and power- and the weight of different gender issues in each actor linkage (see Table 2).

Table 2: Weighted values of gender relations within and between AIS actor categories

	Research actors	Extension/ education actors	Agribusiness actors	Policy/decision makers	Support institutions	End users
Research actors	2	1	0	1	0	5
Extension/ education actors	1	11	0	1	0	13
Agribusiness actors	0	0	0	0	0	11
Policy/decision makers	4	4	1	1	1	14
Support institutions	0	0	0	0	0	3
End users	3	20	9	1	1	20

Source: Authors' construction based on literature review

Note: Weighted values were obtained by allocating (in case of one issue) or summing up different values of gendered dimensions. For example, considering the interactions between end users (in the row) and the other actor categories (in the columns), we note that end users influence research actors in terms of limited resources (coded 3); the five SRF dimensions apply in the interaction between end users and extension actors (weighted 20 as the sum of Power, People, Rules, Resources and activities rated 6, 5, 4, 3 and 2 respectively).

Table 2 illustrates the simulated network data in a matrix form; where cells in the matrix represent the sum of weighted gendered dimensions. Specifically, actor categories in the rows are at the root of the gender issues (*out-directed ties*) while the receiving actor groups appear in the columns (*in-directed ties*).

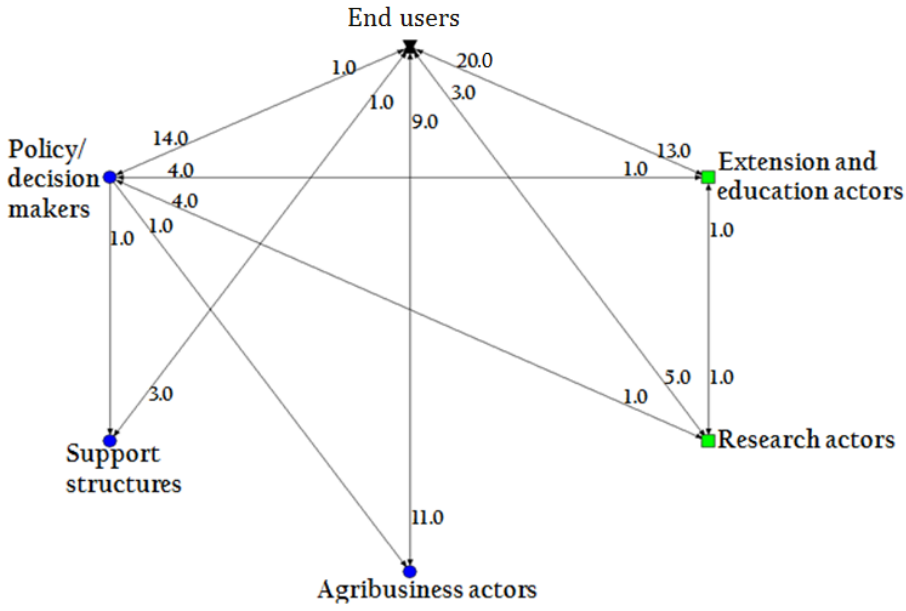
5.2.2. Mapping the direction and extent of gender issues in AIS actors' relationships

From the generated network data, we derive an overall picture of the likely gendered patterns emerging from the social interactions among AIS actors. The weights, out- and in-directed relationships between actors in the nodes are shown in a directed graph (Figure 5). Two main categories of gendered relationships in the AIS can be identified, namely:

- Unidirectional relationships exist where gender issues are identified at only one actor level. The links are mainly out-directed. Such linkages exist between policy/decision makers and agribusiness actors as well as between policy/decision makers and support institutions. Moreover, as already noted, for these actors' relationships, gender issues remain unclear. This may suggest

sensitization on gender dimensions as a minimum intervention for engendering AIS at least between these nodes, in addition to considering gender issues arising from the interaction with other actor categories.

Figure 5: Graphic representation of actors' relationships in the AIS (with respect to direction of ties and weighted gender issues)



Actors providing an enabling environment for AIS

Actors initiating the AIS process

Actors using – adopting/adapting agricultural innovation

Source: Authors' illustration based on literature review

- Bidirectional relationships exist in three forms: i) bidirectional relationships with *similar issues reciprocated* by two actor categories; ii) bidirectional relationships with *similar gender issues reciprocated* and *additional gender issue(s)* generated by one of the two actors; and iii) bidirectional relationship composed of different gender issues reciprocated between actors.

i) Bidirectional relationships with *similar* and *reciprocated gender issues* are identified only in one tie: extension/education and research actors. For this reciprocal relationship, the importance of gender issues seems to be minimal as they are implicitly referred to in the literature.

ii) Bidirectional relationships with *similar gender issues reciprocated and additional gender issue(s) generated by one of the two actors* is displayed in two gendered relationships within the network. First, for the linkage between end users and extension actors, Figure 5 shows reciprocity between these actor categories in three dimensions: *power*, *people* and *activities* while those related to *rules* and *resources* are generated from the end users' perspective. Second, the relation between end users and agribusiness actors shows reciprocity only for the *power* dimension while those related to people and resources are generated by agribusiness actors and end users respectively. *Possible interventions should therefore, focus on reducing such mutual gendered*

influences while also identifying gender-specific actions to overcome different gender issues arising from each actor category.

iii) Bidirectional relationships with gender issues of different nature reciprocated between actor categories are identified between five ties: research actors (*people*) and end users (*resources*); research actors (*implicit issues*) and policy makers (*rules*); extension actors (*implicit issues*) and policy makers (*rules*); policy makers (*power, people and resources*) and end users (*implicit issues*); and support structures (*resources*) and end users (*implicit issues*). *Gendered relationships where different gender issues could be identified between actor groups reflect the complexity and diversity of interventions required to narrow the gender gaps in each of the linkages. During interventions, therefore, closure of gender gaps should be addressed at the source of gender gaps using specific strategies that work for the specific issue and actor node causing the gap*.

5.2.3. Analysing the position of networked actors in a simulated gendered AIS

Characterizing the position of actor groups with respect to their gendered relationships in the AIS is based on a discussion of basic centrality measures drawn from the simulated relational data (Table 2). These measures which include size, tie strength, betweenness, out-degree and in-degree are computed using UCINET, a software package suited for the analysis of social network data (Table 3). Definition and interpretation of the measures was derived from Hanneman and Riddle (2005) and Prell et al. (2009). The three first measures (size, tie strength and betweenness) are based on the existence of gendered relationship between actor categories, which UCINET computes as binary data; 1 in case of gendered linkage and 0 otherwise. The other measures of degree centrality are based on the weighted values of gendered linkages (Hanneman and Riddle 2005).

Table 3: Summary of basic network measures from simulated gendered relationships

	Size	Ties	Betweenness	Out degree	In degree
Research actors	3.00	6.00	0.00	7.00	8.00
Extension/ education actors	3.00	6.00	0.00	15.00	25.00
Agribusiness actors	2.00	2.00	0.00	11.00	10.00
Policy/decision makers	5.00	10.00	10.00	24.00	3.00
Support institutions	2.00	2.00	0.00	3.00	2.00
End users	5.00	8.00	50.00	34.00	46.00
Source: Authors' computation and simulation					

- The *size* of the network indicates the number of actors with whom an AIS actor has linkages with gender issues. In this case, end users and policy makers are linked to more actors (five for each) than agribusiness actors and support institutions who are linked to only two actors.

- In terms of *tie strength*, policy makers and end users had the highest number of ties (10 and 8 respectively) and agribusiness actors the lowest number (2). Using size and tie measures therefore policy decision makers and end users were the most connected in the AIS network.
- *Betweenness* centrality describes the extent to which an actor is between all other actors as they interact in the AIS. Actors with a higher betweenness are likely to act as brokers in their network. The 50 percent betweenness of end users from our simulation means that end users can be intermediaries to half of the AIS linkages and suggests that investment in gender interventions at this node alone is likely to narrow the AIS gender gap by half. According to this simulation, interventions at any other actor node alone are likely to have 0–10 percent narrowing effect on the AIS gender gap.
- *Degree* centrality is the sum of the weights of gender issues assigned to the ties associated with the node (excluding linkages within the node). For a directed graph, in-degree is the sum of weights of issues assigned the ties from other actors of incoming to the node edges and out-degree is the sum of weights issues outgoing from the node to other nodes. A balanced in- and out-degree indicates that the linkages are reciprocal with other actors. An imbalance with a higher out-degree means that the actor exerts more influence on other actors than they do on that actor, whereas and imbalance with higher in-degree means that other actors exert more influence on this actor than the actor on them. Table 3 shows that end users had the largest out-degree and in-degree, of 34 and 46 respectively, followed closely by extension/education actors with out-degree and in-degree, of 15 and 25 respectively. Support structures had the lowest out-degree and in-degree (Table 3).

In summary, the experimental results on the centrality of AIS actors in terms of gendered relationships suggest that the end user category constitutes the most central actor with 34/46 reciprocal linkages and 50 percent betweenness and among actors with the highest size and tie strength. From our simulation model, the end user group represents the node that requires the greatest investment in terms of gender interventions in the AIS framework. According to the simulation, intervening in this node alone is likely to narrow the gender gap by 50 percent. The policy makers' category constitutes the second most central node owing to its high scores in the various measures. Policy makers' influence is poorly reciprocated (24/3), which suggests that the linkages of this actor group with other actors contribute to enhancing gender inequalities in the different linkages. The results using simulated data indicate that interventions to narrow the gender gap in the AIS should, therefore, be primarily concentrated at the end user and policy maker nodes. Beyond this direct focus, gender-sensitive interventions may also consider the extent to which other actor categories affect and are affected by the gendered dimensions discussed.

Conclusions, policy implications and further research

To achieve more success in technology adoption in agriculture and related sectors, researchers have developed and recommended technology initiatives of varying relevance for different

contexts. One such recommendation has been to bring a more "gendered" inclusive approach to the agricultural innovation process, the rationale being that although the AIS approach calls for more systematic and closer collaboration between (and among) stakeholders involved in the innovation process, the outcomes may still benefit some networked actors unequally while also excluding others. Gendered relationships therefore, constitute an integral component of AIS linkages. Such relationships are, however, complex and relevant in varying degrees to all actor categories involved in the innovation process. Gendered dimensions identified in this paper were either implicit or explicit in nature and may be considered when conducting interventions to narrow the potential gender gaps in the AIS framework. Owing to the differences in and the extent of gender issues between actor categories, interventions should be tailored for actors according to the gender issues identified.

The authors' simulation results have suggested that end users potentially experience the greatest gender disparities and policy makers are likely the greatest contributors to gender differences in the AIS. Integrating gender in the end user (50 percent) and policy maker actor (10 percent) categories in the AIS may result in 60 percent of gender mainstreaming in the AIS framework. For the policy/decisions makers, it might be sufficient to create awareness on gender by demonstrating the harm done by policy interventions that take advantage of existing and rigid gender norms and are most likely to exacerbate the gender inequalities among end users. For end users, interventions may require gender transformative approaches that encourage critical awareness of gender roles and norms among men and women while challenging and addressing the distribution of resources and gendered power relationships. The aim is for all interventions to narrow the gender gaps in the AIS framework. This should be tailor made for each node and implemented in the different AIS nodes simultaneously.

This paper opens a door for further analysis particularly to investigate how to establish simulated gendered patterns in real life situations, looking for instances of diversity and longevity of innovations, uptake and outcomes of innovation uptake. More specifically, the proposed analytical model needs to be tested in the field on actual AIS projects to see if the hypotheses stand. Future investigations should therefore consider further disaggregating actor categories, refining criteria that need to be evaluated to account for different behavioural decisions and finally, validating methodology and results with data on gender relational issues within and between actor categories collected and estimated through a more comprehensive SNA model.

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