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THE CERTIFIED SWEET POTATO SEED SYSTEM EVOLUTION PROCESS: A CASE OF OMORO AND MPIGI DISTRICTS IN UGANDA

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ABSTRACT

Opportunities for Ugandan farmers to undertake the production of sweet potato have resulted in certified sweet potato seed (CSS) innovations being pursued in recent times. The CSS and farmer-saved vine sources co-exist with the latter still predominant despite the formers' on-farm superior performance as regards yields, disease reduction and promotions. Information on the evolution process is missing, leading to ambiguous interpretations of its impact on uptake. This study described the evolution stages, emerging delivery structure and actor interactions during the CSS development process in Uganda. A case study design was employed, and data were collected through focus group discussions (FGDs) and key informant interviews (KIIs), and anchored into actor-network theory (ANT) to generate actor actions and interrelationships. Transcripts were analyzed using the thematic analysis approach by Braun and Clarke. Network analysis was done using UCINET6 V6.759 and a Network visualizer (Net Draw 2.179). Results depicted a six-stage evolution process with most actors having multiple roles, business actors involved at utilization stage only and each stage being triggered by an event. During the process, an integrated CSS system emerged with only 35.6% of the potential direct links between actors being present. The major central actors that had closer interactions with farmers and seed growers were largely public sector, with private sector coming in late. Actors were location-specific with those of Mpigi being many, more interactive (average degree of 7.8) compared to Omoro (average degree of 4.5), and high average path lengths (1.7) implying actors are remotely connected with farmers and vine multipliers being most influential. It is envisaged that the involvement of business actors in product innovation stages and imparting entrepreneurial skills to key farmer groups and vine multipliers will spur the CSS system. Future research into CSS systems should focus on building business ecosystems.

Key words: Certified sweet potato seed, Evolution process, Delivery structure, Actor interactions

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INTRODUCTION

This paper provides an analysis of the events during the evolution from informal to formal certified sweet potato seed (CSS) systems in Uganda. It is poised on the changes in the last ten years, the emerging trends therein, and how these offer explanations for observed delivery structures and actor interactions. Sweet potato seed system has evolved towards a formal seed system hence several seed chain actors have emerged [1]. Thus, seed systems stakeholders need to respond to these demands by availing quality vines that meet the preferences of end users. The study employed the actor-network theory (ANT) to analyze the process, looking at the emerging networks and empirically analyzing the nature of the actor-network through which CSS is delivered. Particularly, it focuses on the diversity of actors, their roles, timelines, and interrelationships, and how these informed the current development of the sweet potato seed system.

Informal seed systems also referred to as farmer-managed seed systems, traditional seed systems, or local seed systems cover methods of seed selection, production and diffusion by farmers. Farmers obtain seeds and varieties through informal networks based on exchange with, or gifts from, relatives and neighbors, or through bartering with other farmers or purchasing from local markets [2]. Farm-saved seed is the most prominent source of seed [3]. Notably, informal sources usually fail to provide sufficient planting materials at the onset of rains, delaying planting, with shortages of planting materials having been reported in Uganda thus calling for community-based decentralized vine multiplication schemes [4, 5].

The formal seed, also known as certified seed on the other hand provides tested seeds of uniform varieties that have been evaluated for their adaptation to certain farming systems. The structure of the formal seed system is guided by scientific methodologies for plant breeding and controlled multiplication operated by public or private sector specialists [6]. It is a deliberately constructed and bounded system to maintain varietal identity and purity, produce seeds of optimal physical, physiological and sanitary quality usually sold through a limited number of outlets. Seed may also be distributed (free) by national research programs, universities, or Non-Governmental Organizations (NGOs) with a central premise of clear distinction between seed and grain [7]. It is a linear multistage process with actors at each stage feeding into the next and comprising four components: basic, foundation, certified and quality-declared classes [8, 9].

Seed systems pass through several phases as they evolve from informal systems where all production and supply functions are carried out by the farm household to a more complex system in which many different organizations (seed companies, seed growers, farmer-based seed enterprises) and legal institutions (seed

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standards, regulations and certification) play specialized roles in the supply chain [10]. In this study, it was hypothesized that how actors perform activities, relate and influence each other during CSS technology innovation progress is what shapes the evolution process and was characterized using the ANT.

Specifically, this study extends the literature by identifying key CSS evolution stages, describing the emerging CSS delivery structure arising from the evolution process, as well as examining actor interactions in the CSS system.

BACKGROUND

The formal uptake of vines in Uganda can be traced as far as 2005, arising from distributions in the north under the returnees' resettlement initiatives. The performance of the material was affected by diseases which prompted the Food and Agricultural Organization (FAO) to demand certification. Policy protocols did not embrace Vegetatively Propagated Crops (VPCs), prompting FAO and partners to formulate Quality Declared Seed (QDS) guidelines for cassava, Irish potato, and sweet potato [11]. The transition has seen the establishment of seed chain pillars; and capacities to produce pre-basic, basic, and certified seed [1], leading to strong on-farm conservation and multiplication approaches especially mini-screen shade nets for early generation seed. This is enhancing on-farm wide-scale timely distribution. Subsequently, formalization is occurring with results indicating that the production of clean vines via tissue culture and virus indexing, coupled with certification along the vine value chain ensures continuous sweet potato productivity [12], leading to the evolution process.

The product evolution process is a cycle where the product evolves in terms of features, functionalities, quality and offerings over time to better serve its purpose and customer needs [13]. Designing innovations takes time and requires a focused effort to take a product or service from idea to market. Together, the efforts comprise the new product delivery process which is commercial for the case of CSS. It is pointed out in Schilling [14] that the commercial performance of a new product is influenced by the approaches used to bring it to market. Also, there are calls for more qualitative and context-sensitive investigation of evolution processes as well as their empirical reality [6], as this leads to a better understanding of the interaction processes and the dynamics of systems [15, 16, 17]. This notwithstanding, there is scanty information on how evolution processes affect seed systems in VPCs [6]. Hence, generating evidence-based information was needed to reduce misconceptions about what is driving CSS service structures and actor interactions paving the way for new intervention strategies to take CSS innovations to scale.

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This study employed the ANT which has been used to characterize processes and in designing models involving independent players in a variety of industries [18, 19]. It stipulates that everything exists in a network of interactive relationships including people, technology and inanimate objects [20] as well as emerging social relationships that are key to explaining both individual actions and collective outcomes [21]. Actor actions are a multidimensional concept affected by the interplay of actors' connections and dispositions [22, 23]. The creation and management of boundary objects are key in developing and maintaining coherence across intersecting social worlds [24]. The model characterizes a network by its relationships, fluidity, and dynamics, matching aspects considered relevant when analyzing an inter-organizational business model as is the case for the CSS system. Considering that information-supported systems like seed systems often fail due to social and organizational factors than technical ones, ANT gives the chance to consider the role and nature poised by the emerging seed system.

MATERIALS AND METHODS

Description of the Study site and sampling procedures

The study was conducted in two districts of Uganda: Omoro and Mpigi districts representing low and high sweet potato virus disease pressure areas, respectively [25]. Overall, the highest disease incidences were encountered in districts in western and central Uganda (high disease pressure zone) and lowest in eastern and northern Uganda (low disease pressure zone) [26]. The two districts were purposively selected based on the presence of certified seed growers with net shades [27], farmers having been exposed to CSS interventions and high production of roots. In Omoro district, three sub-counties of Lakwana, Koro and Bobi while in Mpigi, Nkozi rural, Kayabwe, and Buwama sub-counties were selected purposively based on their experience and awareness of CSS [27]. The study targeted different actors, individuals, as well as organizations along the pillars of the sweet potato seed system. Particularly targeted were farmers, extension service providers, traders, researchers, seed inspectors, seed entrepreneurs, laboratory investors and donors. The selection was purposive based on actor knowledge and participation in sweet potato activities.

Sample selection and data collection

Extension agents assisted in selecting the individual participants for the gender-segregated FGDs based on farmers who had consistently been growing sweet potatoes for over five years. In total, the FGDs involved 2 study districts (1 per disease pressure zone), 6 sub-counties (3 per study district), 18 villages (3 per sub-county), and 288 respondents (16 per village). Meanwhile, key informants

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were identified during the review of literature on actors promoting the sweet potato interventions and articulated during the FGDs.

The FGDs were guided by an FGD guide, developed based on the objectives, and facilitated by three people. Key informant interviews (KIIs) were also conducted to augment the data [28]. The tools were subjected to reviews by peers and supervisors for the flow of the questions, and translation. The data collected included steps in the evolution timelines of CSS, actors, and their roles. The central actors were taken as farmers.

Research design

An instrumental case study was deployed [29]. Case studies are used in scientific research to investigate a real-life phenomenon in depth and within its environment and context. They can help enhance scientific understanding of how and why things happened in a certain way or evolved in a certain direction [29, 30] or can help create, advance, test, or extend current theories [31].

Data analysis

The analysis followed a qualitative process focusing on thematic analysis as described by Braun and Clarke [32]. Where the local dialects (Luganda and Acholi) were used during the interview, responses were first translated into English. UCINET6, v6.759 was used to analyze linkages and interactions between actors in the CSS system. The Network visualization tool (NetDraw 2.179) of UCINET6 [33] was used to illustrate and visualize the network maps. Network mapping helped to identify the different actors involved, linkages and influence on the flow of information and resources [34].

RESULTS AND DISCUSSION

Certified sweet potato seed evolution stages

A thematic analysis identified six main themes that led to the development of CSS described in Figure 1 as process stages.

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Actors	*Activators:* Researchers, Farmers, Agric extension workers	*Facilitators:* Researchers, Donors, NGOs, Farmers	*Browsers:* NGOs, Researchers, Laboratory contacts (MUARIK, BIOCROP, SENAI), Farmers	*Creators:* Vine multipliers, NGOs, Agric extension workers, MAAIF, Transporters, Schools	*Developers:* Vine multipliers, NGOs, Agric extension workers, MAAIF, Transporters, Schools, Traders, Community leaders	*Executors:* Vine multipliers, NGOs, Agric extension workers, MAAIF, Transporters, Schools, Traders, Community leaders, Processors, Exporters
Activities	-Exchange of farmer saved seed -Conducting research on virus indexing -Introducing disease and pest tolerant varieties	-Development of Protocols for quality declared seed (QDS) for sweetpotato in Uganda spearheaded by FAO	-NGOs disseminate QDS -Multisectoral gov't projects disseminate QDS -Labs emerged -In vitro cleaning and bulking of vines	-Screen house and open field vine multiplication by secondary multipliers -Guidelines for CSS submitted to MAAIF and inspection kick started -Promotion of CSS by NGOs and Local gov't	- Contracting of tertiary multipliers -Training of tertiary multipliers -Open field multiplication by secondary & tertiary multipliers -Inspection and certification of vines as CSS -Promotion of CSS	-More institutional buyers, individual farmers, and niche market buyers (e.g., processors, exporters and local markets) link to CSS sources
Process	1.Strategy Planning and tactics of how to produce clean sweetpotato vines →	2.Obtaining external resources and allocating internal resources →	3.CSS variety selection and basic development in labs →	4.Screen house and open field vine production by secondary multipliers →	5.Open field vine production by tertiary multipliers →	6.Linkage development between vine multipliers and niche market root buyers
Trigger	Farmers rely on localized sweetpotato seed produced by fellow farmers with high pest and disease incidence	Food crisis created by refugees in Northern Uganda resulting into need; FAO demands for quality vines	Increasing demand by NGOs and multisectoral gov't projects for QDS dissemination with accompanying certification	Increasing local demand for QDS across the country	Secondary vine multipliers fail to meet some inspection requirements like land for rotation	Increased awareness about CSS by sweetpotato value chain actors
	Before 2005	2005-2009	2010-2014	2015-2019	2015-2019	2020

Figure 1: Certified sweet potato seed evolution canvas

The nature of the evolution involved transforming the product (farmer-saved seed) to CSS and developing a delivery system hence, a systemic innovation that requires significant adjustment in other parts of the system in which it is embedded [35]. The process involved an interplay of research and development involving virus cleaning, indexing, foundation and certified seed multiplication, inspection, certification and creation of delivery mechanisms. Many new actors came on board to coordinate with producers of CSS rather than only suppliers and customers as is frequently the case in closed innovations. This highlights the significant role of networks and new forms of collaboration in driving change. The six stages are fully described by timelines below.

Timeline one: Reliance on farmer-saved sweet potato seed

Before 2005, communities could only access vines through farmer-saved seeds, hence recycling and were misinterpreting the causes of vine degeneration:

> *"Vines are like co-wives, when a new variety comes the old one becomes jealous and often disappears" (Nanozi Edith, Nindye farmers group in Nkozi).*

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Volume 24 No. 3
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Timeline two: Identification of causes of vine degeneration and the need to address them.
During the period 2005 to 2009, FAO embarked on supporting the mass distribution of vines and found out that they did not meet their expectations as described by one of the key informants who participated in the exercise:

> *"We often delivered vines that were of mixed varieties, perforated with insect damage, with obvious signs of viral infections and sometimes rotten" (Sam Namanda, Sweet potato extension expert).*

Various partners including the Consortium of International Agricultural Research Centers (CGIAR) and National Agricultural Systems (NAS) joined the dissemination effort with the release of the first nutrient-dense orange sweet potatoes in 2007 [36].

Timeline three: Actors engaged in in vitro virus elimination and multiplication of clean vines.
The guidelines set disease, pest and off-type levels acceptable for the different seed classes through processes viewed as most cost-effective to address the predominant constraints:

> *"Given the high incidence of sweet potato virus disease, weevil infestations and presence of tolerant varieties with a high propensity to breakdown, it was clear that cleaning vines in vitro would be the most feasible option to archive desired guideline levels" (Private lab entrepreneur).*

Timeline four: Emergency of a distribution network of seed growers and associated services.
The actors wanted tangible output as a measure of the success/impact of cleaned vines. This paved the way for the identification of potential seed out-growers with net shades (*secondary producers*) to offtake laboratory vines (the *primary producers*). The secondary producers soon felt the need to engage other seed growers to grow in the field (*tertiary producers*) due to the need to meet inspection guidelines, mainly isolation and rotations.

This necessity to modify the delivery mechanism for clean vines increased the number of actors as it required a complex interaction of public, policy and reforms to legislation, changes to organizational cultures and practices as well as a shift in attitudes and behavior. Such systems are slow to shift because they tend to be optimized around their current forms and powerful interests combine with personal relationships to maintain the status quo [35]. This can explain the slow pace of events.

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Timeline five: By 2020, business ecosystems linked to root markets started emerging as seed growers and started segmenting their markets in line with the varieties required as one seed grower said:

> *"People still insist on growing so many varieties which I cannot produce for them profitably. I am now going to concentrate on a few where I have core customers" (Lwanyaga Vincent, Seed grower in Mpigi).*

Interaction is along the sweet potato food system, hence issues to do with entrepreneurship ecosystems are key in the future of CSS. All the six main stages had triggers indicating they were crucial in the process. Many actors had multiple roles, indicating lack of specialization: this might be due to either resources / technical incapacity by individual actors or absence of actors. According to Autio [37], ecosystems are "fundamentally interaction systems" and it is precisely this interaction logic that differentiates innovation systems, and other forms of systems [15]. It is anticipated that these interactions will lead to the creation of formal and informal networks and as such will present a critical ingredient of the interdependence of the ecosystem in the next life cycle.

In general, the system evolved albeit at a slow rate from proof concepts to delivery implying most pillars for certified seed systems were missing at the start, with few private sector actors with potential demand from niche markets coming in late during the development process; implication on sustainability, hence nurturing is key.

Emerging certified sweet potato seed delivery structure

The current sweet potato seed system structure emerging out of the evolution stages is presented in Figure 2. Substantially, the evolution process has led to the interaction between formal and informal actors leading to an integrated seed system. All the pillars necessary for certified seed have been established implying readiness to go to scale (breeding, foundation seed, inspection and certification, seed multiplication, dissemination and use). The farmers are in a central position in the interaction between informal and formal, an indication that farmer decisions and actions are key in uptake. This, coupled with multiple linkages at breeding and marketing levels, suggests an integrated seed system has emerged.

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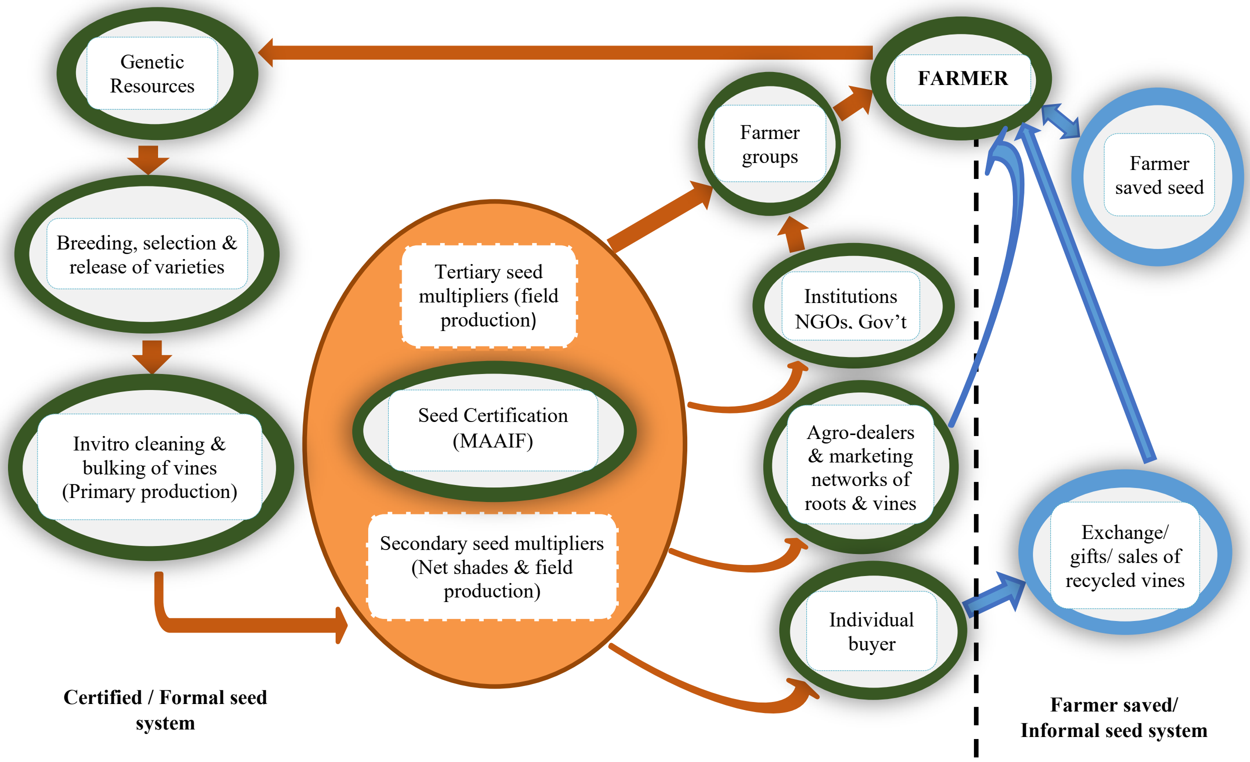

Figure 2: Certified sweet potato seed delivery structure in Omoro and Mpigi districts

The emerging structure proves that CSS is a knowledge-based product with three intellectual assets embedded in the structure: a) disease detection and elimination that leads to quality seed and offers a solution to degeneration, b) three tier multiplication and delivery model that incorporates inspection and certification c) linkages to end users which incorporates business ecosystems. The last two provide avenues for replenishing deteriorating materials; however, the drawback is if farmers do not periodically purchase vines. Periodic replenishments call for efforts to cultivate a series of formal and informal working relationships between various actors. Farmer groups play a central role in linking the informal and formal systems. Therefore, activities should be decentralized and revolve around local entrepreneurship with the farmer groups and vine growers seen as game chargers and viable opportunities by actors.

Actor Linkages and interactions

Actor linkages in the CSS network

The Sweet potato seed system has attracted a diversity of actors albeit with varying degrees of involvement. The Social Network Analysis (SNA) results revealed 180 connections/ties that existed among the 23 actors in the network of Mpigi district, while 64 ties existed among the 14 actors in the network of Omoro district. The ties represent linkages and interactions in relation to the flow of information and tangible resources such as CSS (Figures 3 and 4).

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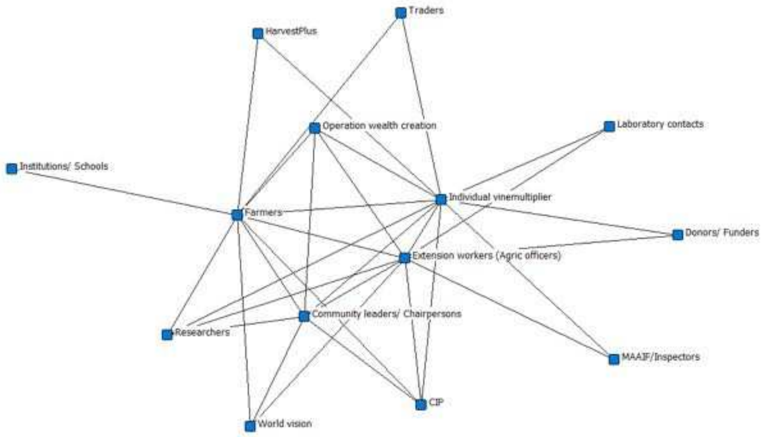

Figure 3: Network map for information and tangible resources between actors in the CSS evolution process of Omoro district

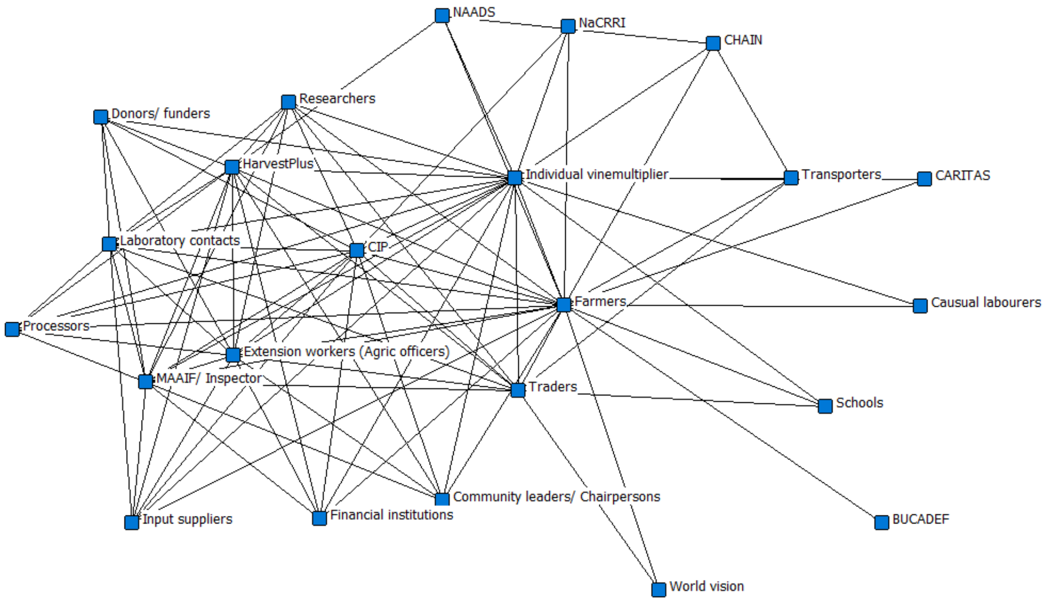

Figure 4: Network map for information and tangible resources between actors in the CSS evolution process of Mpigi district

The network maps implicitly show that the major central actors that have closer interactions with end users (farmers and seed growers) are largely public sector a) Researchers: University, HarvestPlus, CIP, and NaCRRI b) Extension service providers including NGOs and Government (Agricultural extension workers, world vision, BUCADEF, CARITAS, CHAIN, NAADS, operation wealth creation, and community leaders). Private sector actors are fewer (traders, Schools/institutions, laboratories, transporters, and processors), except for input dealers.

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Performance of the CSS network

a) Network density

The density of the CSS network was 0.356 and 0.352 in Mpigi and Omoro districts, respectively. This indicates that only 35.6% and 35.2% of the potential direct links between actors that could exist in the network are present (Table 1). This implies the existence of weak linkages among actors in the CSS system, which indicates discrepancies in access to information and resources among actors, with a possible mismatch of product and service requirements in the CSS system. Information and knowledge are transmitted more accurately and timely in networks where many actors are intensely and directly connected to one another. Such a scenario also indicates the under-utilization of the potential relationships that would otherwise foster the development and uptake of new CSS. The average degree was 7.826 and 4.571 for Mpigi and Omoro districts, respectively. This shows that actors in Mpigi on average interacted with more actors as compared to their counterparts in Omoro district. The geodesic distance results show that the longest path was 3 in both locations, while the average path length was 1.652 and 1.681 for Mpigi and Omoro districts, respectively. This represents the direct and indirect distances between actors in the networks and the ease with which actors can connect with each other.

b) Network centrality

The centrality of the CSS network was determined based on the results of the three most important measures, namely, network degree, closeness and betweenness [38]. Centrality degree measures the importance of actors in a network by capturing the level of connectedness and status which helps to explain their positions in a network based on their prominence and influence. Results of centrality degree in Table 3 indicate the most prominent actors in Mpigi and Omoro districts in descending order.

Closeness centrality measures the average of the shortest path link from one node to every other node in a network. The lower the average shortest path link, the closer an actor is to other actors in a network. Generally, actors in both locations had higher average path links implying that actors were remotely connected. On the other hand, betweenness centrality indicates the number of times an actor is located at the shortest path of all pairs of actors who are not linked to each other directly. A higher betweenness measure indicates an actor in the most favored position of a network. Results of betweenness centrality in Table 2 indicate actors in the most favored positions of the network in Mpigi and Omoro districts in descending order. Generally, these favored actors should have the right mindset about CSS since they interact with most other actors.

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There are more connections within vine supply actors than within and between business actors who are at the periphery. What is needed, therefore, is to build more connections between business actors and other actors since the more connected individuals are exposed to more diverse information and may be better able to mobilize their resources, key to a sustainable CSS system. Also, most actors are not closely related, implying that information must pass through several layers. This has the potential of stratification of actors usually based on social classes and not so much on the number of connections actors have, but whether connections overlap and constrain or extend outward and provide opportunities. The current level of closeness between actors suggests they are locally connected hence less diffusion, homogeneity and solidarity.

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Certified sweet potato seed has become increasingly central in sustainable sweet potato production due to its potential to address the degeneration of vines. It is, therefore, important to understand how the evolution processes shape seed systems. Evidence shows that there are six stages in the fifteen-year evolution journey of developing and delivering CSS with new actors executing multiple roles and business actors coming in only at the utilization stage. This implies plausible priority mismatch and delayed specialization. There is also a significant change in the delivery structure with the creation of all the required pillars for certification, albeit with very weak linkages among the actors. This undermines the potential relationships that would spur use. Interventions dealing with the transition to CSS systems require that business actors get involved in the early stages of CSS development. As well, donors, farmers, policymakers, and researchers must focus on creating strong linkages and building business ecosystems based on end-user variety requirements.

The investigations revealed that developing and delivering CSS takes time, hence actors must be willing to invest time and resources as a prerequisite for the transition to occur. Also, business actors must come in at the research and development stage so that market requirements are articulated.

Future research into CSS systems and other VPCs should focus on establishing a clear picture of how business ecosystems can be natured and action research should be conducted to gain more insight into building long-term linkages among emerging actors.

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Volume 24 No. 3
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Table 1: Measures of network density for the CSS network

Measure	Values	
	Mpigi	Omoro
No. of ties	0.356	0.352
Average degree (Average no. of ties a node has to other nodes)	7.826	4.571
Diameter (Longest geodesic distance)	3	3
Average path length (No. of links)	1.652	1.681

Table 2: Descriptive measures of centrality in the CSS in Mpigi and Omoro districts

Actors	Degree		Closeness		Betweeness	
	Mpigi	Omoro	Mpigi	Omoro	Mpigi	Omoro
Individual vine multiplier	**0.909**[2]	**0.846**[1]	0.917	0.867	**21.875**[2]	**29.169**[2]
World Vision	0.091	0.231	0.512	0.565	0.000	0.000
Farmers	**0.955**[1]	**0.769**[2]	0.957	0.813	**33.751**[1]	**27.671**[1]
Extension workers (Agricultural officers)	**0.591**[3]	**0.769**[2]	0.710	0.813	1.817	**19.979**[3]
Community leaders/ Chairpersons	0.273	**0.538**[3]	0.579	0.684	0.036	**2.671**[4]
Traders	**0.500**[4]	0.154	0.667	0.542	**4.076**[3]	0.000
Researchers	0.364	0.308	0.611	0.591	0.036	0.000
HarvestPlus	**0.591**[3]	0.154	0.710	0.542	**3.296**[4]	0.000
MAAIF/ Inspectors	**0.591**[3]	0.154	0.710	0.520	1.817	0.000
Donors/ Funders	0.273	0.154	0.550	0.520	0.036	0.000
Institutions/ Schools	0.136	0.077	0.537	0.464	0.000	0.000
Laboratory contacts	**0.500**[4]	0.154	0.667	0.520	0.850	0.000
CIP	**0.591**[3]	0.308	0.780	0.591	**3.296**[4]	0.000
Operation wealth creation	-	0.308	-	0.591	-	0.000
BUCADEF	0.045	-	0.500	-	0.000	-
CARITAS	0.091	-	0.524	-	0.000	-
Casual laborers	0.091	-	0.524	-	0.000	-
CHAIN	0.182	-	0.550	-	0.144	-
NAADS	0.182	-	0.550	-	0.144	-
NaCRRI	0.136	-	0.537	-	0.000	-
Transporters	0.182	-	0.550	-	0.144	-
Input suppliers	0.318	-	0.595	-	0.036	-
Processors	0.318	-	0.595	-	0.036	-
Financial Institutions	0.273	-	0.579	-	0.036	-

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