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Farmers' Seed Networks and Agrobiodiversity Conservation for Sustainable Food Security: A Case from the Mid-Hills of Nepal

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ABSTRACT

This paper evaluates the nature and functioning of seed networks for rice, maize and finger millet, and explores the effect of such networks on agrobiodiversity conservation and food security. Using snowball sampling, ninety-five farmers from the Dhikurpokhari Village Development Committee in Kaski district, a representative site for western mid-hills of Nepal, were interviewed. Data were collected through semi-structured interviews, focus group discussions and field observations. Social network analysis tools and maps, with the help of NetDraw software, were used to examine the status of the network and identify the key nodal and connector farmers. It was revealed that there is a loose network of seed exchange in the community, varying according to crop. While nodal farmers play a more pivotal role than other farmers in seed exchange, only marginal differences were found in the characteristics of nodal and non-nodal farmers, apart from their age and education. More than 90% of farmers had saved seeds of maize and finger millet on their own, mainly local varieties, while only 70% of farmers had saved rice seed. Farmers' practices of saving seed at home, limited varietal options in locality, a declining interest in agriculture, rural-to-urban migration and thence scarcity of labour have all contributed to a reduction in the exchange of seed. This in turn has affected the on-farm conservation of agrobiodiversity and food security at the local level.

Keywords: Seed network, Connectors, Nodal farmers, Agrobiodiversity, Conservation and Food security

1 INTRODUCTION

The world's population is expected to exceed nine billion after 2050. In order to feed this growing population and attain sustainable food security, the conservation and management of agrobiodiversity is crucial (Pautasso et al., 2013). Despite a number of conservation efforts, in many regions agrobiodiversity is under severe threat (Lotti, 2010; Shen et al., 2010; Engels et al., 2011). The world relies on only 82 crop species for 90% of the energy needed for human consumption (Prescott-Allen and Prescott-Allen, 1990). From the perspective of agrobiodiversity management, the sustainability of in situ conservation is critically dependant on the nature of seed systems, which influences the adaptability of crops (Thomas et al., 2011). The farmers in Nepal have maintained a system of seed flow within and between communities, which constitutes the informal seed system (Subedi et al., 2004; Baniya et al., 2005; Baniya et al., 1999). Such an informal seed system is created through the interpersonal relationships of individuals in the community, a process shaped by the wider social, cultural and economic structures (Subedi et al., 2003). Farmers' seed supply is a complex and dynamic system of interrelated activities and components, which can be compared to the principal components of a formal seed system: breeding, seed production and distribution (Almekinders et al., 1994). The degree of access to seed and plant materials indicates the seed system of a community and gives a broad picture of the conservation threats or opportunities of local crop biodiversity.

In developing countries like Nepal, a large spectrum of traditional farming practices related to the exchange of seeds still exists, shaping the varietal and genetic diversity in a dynamic way. Nepalese farmers mainly depend on informal seed systems to meet their seed demand and farmers in remote regions likely save seeds, as they do not have access to other seed sources. They exchange seeds among themselves and form networks based on the type of crop, sociocultural setting, economic context and individual preference. These farmers' seed networks, can be considered a building block of an informal or a local seed system, play a significant role in the flow of seeds and other planting materials, which consequently contributes to on-farm agrobiodiversity, food security and evolutionary change in the agroecosystems (Subedi et al., 2003). In other words, farmers' seed networks lead to a greater crop diversity, which not only contributes to their economic resilience and control over genetic materials, but also offers a sustainable solution to food and nutrition security through creation of dietary diversity (Pellegrini and Tasciotti, 2014).

It is clear that the actors and methods as well as the degree, nature and process of seed exchange are entirely crop-specific; however, to date the research associated with these issues has been limited to major crops such as rice, wheat and maize (LI-BIRD, 2012). Despite playing an important role in biodiversity conservation and people's food and nutrition security, traditional crops like finger millet have not received enough attention in the research and policy arena (Padulosi et al., 2009). Based on a study carried out in the mid-hills of Nepal, this paper identifies seed networks for finger millet, rice and maize; analyses the farmers' seed system using social network analysis tools and maps; identifies the nodal farmers, assessing their key characteristics along with their contribution to maintaining balance in the local seed system, and identifies the link between seed exchange and agrobiodiversity conservation for sustainable food security. The findings offer researchers and policymakers an improved understanding of the importance of seed and its networks for identifying areas for seed sovereignty, maintaining agrobiodiversity, and contributing to a sustainable solution for food security in the area.

2 REVIEW OF LITERATURE

Agrobiodiversity refers to the diversity of agricultural systems, from genes to varieties and species and from farming practices to landscape composition. This diversity is maintained through a range of formal and informal networks of seed and planting materials, and is governed by the social, cultural, political, economic and technological factors of a particular geographical territory (Pautasso et al., 2013). Calvet et al. (2012) report that informal networks of seed exchange can play an important role in maintaining agrobiodiversity, underlining the link between seed exchange and the in situ agrobiodiversity conservation of home gardens. Another assertion is that seeds and knowledge are transmitted together (Vogl and Vogl-Lukasser, 2003; cf. Calvet et al., 2012), which directly contributes to the conservation of genetic material along with the associated knowledge.

While farmers preserve agrobiodiversity both by saving seeds and exchanging them with neighbours, friends and relatives, conservation is not necessarily their intended goal (Pautasso et al., 2012). They often do this as part of their usual livelihood practice, through their social networks – the interpersonal relationships among a set of persons connected through the flow of information or goods and materials, or through joint activities or other social bonds (Subedi et al., 2003). Thus, the exchange of seeds and planting materials is an element of the social networks that are part of peoples' everyday practices.

However, the knowledge possessed by the farmers through their years of experience is not well valued or acknowledged. Studying the contribution of seed networks to the maintenance of local crop varieties only makes sense if the scientific community recognizes the conservation of agrobiodiversity as one of its fundamental goals.

2.1 Informal seed systems and farmers' seed networks

Seed is the carrier of genetic diversity and one of the most important inputs for agriculture. It is critical for agricultural change, technology transfer and technological development (Louwaars and Engels, 2008; Neate and Guei, 2010). The access and availability of seed determines the food security for a country (McGuire and Sperling, 2011). Thus, studying seed systems is important not only to understand farmers' access to planting materials, but also to understand the overall state of agriculture and agricultural biodiversity in a particular region. Generally, there are two types of seed systems: formal and informal. In a formal seed system the components, including breeding, management, replacement and distribution of seed, are regulated by public sector; in an informal seed system (also called a traditional seed system) these components are managed by farmers using their own knowledge and capacity (Almekinders, 2001; Thiele, 1999).

In classical terms, formal seed supply systems are characterized by a vertically organized production and distribution of tested seed and released varieties through public and private organizations, using strict quality control. Even though these are operated in the developing countries, but basically copied from seed companies of the developed countries. In the case of an informal seed system, however, the use of seed is integrated within the agronomic and sociocultural practices of the farming community. In most developing countries, the informal seed system is the major source of seed for farming communities (Almekinders et al., 1994; Thiele, 1999; Baniya et al., 2005; Pray et al., 2001), with smallholders relying on it for 75 to 90% of their food crop cultivation (Gill et al., 2013). Informal seed systems form an integral part of diversity management for farmers in developing countries where farmers get seed materials from diverse sources, including their own farm-saved seed, and through exchanges with their relatives and neighbours (Shrestha, 1998; Louwaars and Engels, 2008). Informal seed systems are flexible, dynamic and managed by farmers themselves (Ravinder et al. 2007). They are usually made up of multiple components such as farmers' self-saved seed, farmer-to-farmer seed exchange, informal seed storage and the conservation of knowledge base surrounding the local seed system (Gill et al., 2013).

In an informal system, farmers maintain and conserve crop varieties through their own selection process, based on environmental suitability and preferences. Their knowledge and cultural practices are crucial for decision-making, which in turn provides space for maintaining farmers' networks of seed exchange (Balemie and Singh, 2012). In Nepal, the informal seed system is the most prevalent system, utilizing and managing both landraces and modern varieties with better information on local production environments, user needs and preferences as compared to formal seed systems (Joshi, 2001). The small farmers have established a pattern of seed saving and exchange based on the availability of and access to seed and planting materials of various crops. Seed exchange is more frequent and important between poor households, while it is less significant between poor and rich households (Gill et al., 2013; Almekinders et al., 1994), indicating the critical role of social ties in seed saving and exchange (McGuire, 2008). Exchange of seeds among farmers provides them with the opportunity to connect to different networks. The networks of seed exchange often differ based on the type of crop, sociocultural settings, economic contexts and personal preferences.

2.2 The farmer's role in agrobiodiversity conservation

Numerous crop species in the world are underutilized or overlooked by the mainstream research and development initiatives, yet individual farmers save diverse and useful varieties informally for their own use. Farmers use the diversity of seeds and other resources available from their surroundings for home consumption, medicinal purposes, income generation, landscape management and so on (Kahane et al., 2013; Uniyal and Vandana, 2005), which directly or indirectly contributes to conservation of the crop species. Jarvis et al. (2011) state possible reasons and options for agrobiodiversity conservation, while Shen et al. (2010) indicate a significant threat to the loss of agrobiodiversity in China despite a number of efforts already in place.

Farmers and farming communities play a significant role in the preservation and conservation of agrobiodiversity and ecosystem (UNEP, 2008; FAO, 2011); thus, discussions on sustainable livelihoods mostly revolve around farmers, agrobiodiversity and agroecosystem management. Most of the agricultural crops and varieties have been conserved as a result of farmers' efforts and could have been lost if farmers did not cultivate, save or exchange seeds. The practice of seed saving or exchange adopted by farmers over the years is likely to be the key to management of crop diversity, which is now at a point of being lost from the agroecosystem (Serpolay et al., 2011). However, farmers' knowledge and practices related to seed materials can be useful for formulating strategies for conservation of agrobiodiversity (Baniya et al., 2005).

The adoption and cultivation of the varieties of various crops differ based on household characteristics, endowments and ease of access to agricultural extension, which directly affect farmers' valuations of crop variety traits (Asrat et al., 2009). In the majority of developing countries, the public sector is more inclined towards establishing and strengthening the formal system of seed production and distribution (Louwaars, 2013). In this context, empowering farmers to maintain genetic integrity for improved seed systems through farmer-harvested seeds in local areas needs to be emphasized, in order to promote sustainable agrobiodiversity conservation.

2.3 Agrobiodiversity conservation and food security

The biological components that constitute agrobiodiversity – crops, livestock, fish, and the interacting species of pollinators, predators and competitors – are also the basis for food and nutrition security. Both cultivated and wild relatives of crops provide human beings with genetic resources for food and agriculture (Jackson and Ford-Lloyd, 1990). In fact, the global food supply rests essentially on the biological diversity developed and nurtured by indigenous communities and farming communities located in the centres of origin and diversity of genetic resources (Sundar, 2011). Food and nutrition security exists when all people at all times have physical, social and economic access to food that is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life (FAO, 2011). However, this definition lacks a discussion on the social control of the food system where producers' freedom to choose own crop and seed, maintaining (agro)biodiversity for sustainable production and empowerment of producers to control the local food market are the necessary condition for a long-term food security as envisioned by the food sovereignty movement (Patel, 2009). In this perspective, agrobiodiversity and locally controlled seed system (also called seed sovereignty) are the important components of food and nutrition security (Kloppenburg, 2010). Agrobiodiversity contributes to farming system resilience, maintaining nutritional balance, improving income and balancing ecosystem services in farms such as pollination, fertility and nutrient enhancement, insect and disease management and water retention (Thrupp, 2000).

Food security is influenced by a number of socioeconomic variables such as income, gathering of wild foods, community support, assets and migration (Sen, 1981). It is also negatively influenced by pest and disease infestation causing significant declines in crop yields. Pimental et al. (1997) report that pests reduce global crop yields by about 40% each year. Due to the homogenization of crops, species, landscapes and farming systems encouraged by green revolution technologies, crops are increasingly vulnerable to pest and diseases (Oerke, 2006). Frison et al. (2011) reveal that the use of both inter- and intra-species diversity enhances resistance to outbreaks of pest and diseases and thus is an effective mechanism for increasing yield and food security.

In this context, agrobiodiversity is valuable for scientific and technological advancements in crop production. Starting in the late nineteenth and early twentieth centuries, scientists who recognized the value of diverse crop varieties discovered plant breeding methods that boosted crop productivity. The innovative use of plant genetic resources has continued to be important for scientific advances in plant and livestock breeding and seed improvements up to the present day (Thrupp, 2000). Thus, increase in crop productivity is directly or indirectly linked to crop diversity. Frison et al. (2011) report that adopting diversity could increase productivity more effectively than only stressing a higher management intensity. A study by Zhang and Li (2003) reveals that wheat shows a 74% yield increase when intercropped with maize and a 53% increased when intercropped with soybean, which relates to the diversity of crops at the species level.

3 RESEARCH METHODOLOGY

3.1 Research location

This study was part of an action research project named "Revalorizing Small Millets in Rainfed Regions of South Asia (RESMISA)," implemented between 2011 and 2014 by Local Initiatives for Biodiversity, Research and Development (LI-BIRD), Nepal, together with other Canadian and South Asian partners[1]. Data for the seed network study were collected from the Dhikurpokhari Village Development Committee (VDC),[2] one of the working sites of the

[1] Financial support for the project came from the International Development Research Centre (IDRC) and the Department of Foreign Affairs, Trade and Development (DFATD) of Canada, under the Canadian International Food Security Research Fund (CIFSRF) program.

[2] A village development committee (VDC) in Nepal is the lower administrative part of the local development ministry. Each district has several VDCs, similar to municipalities but with greater public-government

RESMISA project. This VDC is located in the Western Development Region, about 25 kilometres west of Pokhara city in Nepal (Figure 1).

Figure 1: Map of Nepal showing the research location.

The altitude of the research area ranges from 841 to 2,074 meters above sea level. It is densely populated, with a total population of 8,081 and average household size of 4.8. The literacy rate in Dhikurpokhari is 64% (DDC Kaski, 2010). This VDC area is characterized by rain-fed farming with a maize-millet cropping system at the higher elevations, and a rice-based cropping system at the lower elevations made possible by irrigation water from small streams during the rainy season. The VDC is located in the western mid-hills of Nepal. The community is characterized by ethnic diversity, and rural-urban migration is an integral part of people’s livelihood. While traditional agriculture is the common practice in the area, this is changing over time due to increased road access, market infrastructure and other developments in the area. The study team assumed that these changes have influenced the traditional (or informal) seed system used by farmers, and that in the long run this will affect food security and agrobiodiversity conservation in the area. The site was selected for the seed network study with the objective of identifying the key nodal farmers and the primary seed flow system, and

interaction and administration. There are 3,915 village development committees in Nepal. A VDC is further divided into wards; the number depends on the population of the district: the average is nine wards.

introducing the project's major intervention of strengthening the local seed system. Based on their geographic and socioeconomic similarities, three adjoining villages within the VDC were selected for the study.

3.2 Research design, data collection and analysis

This study was conducted from August to December of 2012. Two major cereal crops, rice and maize, and a minor cereal crop, finger millet, were used to compare farmer networks for major and minor cereals. The research team used semi-structured interviews, focus group discussions and field observations to collect primary data. Using snowball sampling, a total of 95 respondents (36% male, 64% female) were selected from the three villages, using information collected for baseline survey for the RESMISA project. At the first stage, 90 respondents – 30 from each village – were selected for the study. The first round of data analysis showed that five key connectors, or nodal farmers, were missing in the earlier data collection list. To include them, a second round of data were collected from these purposively selected additional five respondents. All respondents were stratified on the basis of a well-being ranking, defined by the farmer groups who participated in a focus group discussion organized for this purpose (Table 1). Productive landholding, total household income and food sufficiency month per household were used to classify respondents into rich, medium and poor groups.

Table 1: Distribution of sample respondents

Village	Number of respondents			Total
	A	B	C	
Dhikurpokhari-5	12	15	16	43
Dhikurpokhari-6	10	11	10	31
Dhikurpokhari-7	7	10	4	21

A = rich well-being; B = medium well-being; C = poor well-being

Data were entered and coded in a spreadsheet and into VNA format, and the data analysed using NetDraw (version 2.087) computer software. For purposes of the analysis, farmers were considered as node data and their characteristics such as sex, ethnicity, occupation and wealth category as node properties. The means of seed flow such as exchange, gift, purchase among farmers and the crop varieties in transaction were used as tie data. Degree and betweenness centrality were computed for identification of nodal farmers and their networking. Centrality values were used to generate the network maps.

Both parametric and non-parametric statistics were employed to analyse the relationship and effects of gender, education, age, ethnicity, occupation and wealth characteristics on nodal and non-nodal farmers. The data on age is numeric in nature and a parametric test was used, while an independent t-test was used to determine if a statistical difference exists between nodal and non-nodal farmers by age. The null hypothesis for this is “There is no significant difference in age between nodal and non-nodal farmers”; the alternative hypothesis is “There is significant difference in age between nodal and non-nodal farmers.”

Data on gender, occupation, education, ethnicity and wealth were of a categorical nature. Thus, the relationships between nodal and non-nodal farmers were assessed through a Chi-square test. The underlying null hypothesis is “Farmer type (nodal or non-nodal) is independent of gender, occupation, education, ethnicity and wealth”; the alternative hypothesis is “Farmer type is dependent on gender, occupation, education, ethnicity and wealth.” Those categorical variables that showed a significant relationship with farmer type, were further tested using a column proportionate and Z-proportionate test.

3.3 Analytical approach: centrality theory

The literature shows that local seed systems can be explored through a network analysis approach that allows for both visual and mathematical analysis of human relationships (Jamali and Abolhassani, 2006). This can be done by mapping the associations among or between farmers for the sharing or exchange of seeds (Poudel et al., 2006; Subedi et al., 2003). Social seed networks vary due to a multitude of factors: networks may be loose or closed, depending on the type of crop and access to seed sources. Various sociocultural and economic factors influence exchange or sharing of seed, which critically defines the type of seed network for a particular location or community.

Thus, for an analytical approach we used the centrality theory. In this theory, three different centrality measures – degree centrality, betweenness centrality, and harmonic closeness centrality – are computed to locate the position of farmers in the social network (Poudel et al., 2006). In this paper, we have considered only degree centrality and betweenness centrality. Degree centrality measures the number of direct connectedness of an individual farmer with other farmers in the network where a high degree centrality means many direct connections with other network members (Wasserman and Faust, 1994). In the seed network analysis, numerous nodes (representing farmers) and ties (links) appear. Those nodes that have a higher number of ties than others are considered nodal farmers. In other words, farmers in the network having a high degree of centrality or a greater number of direct connections or links are considered nodal farmers (Poudel et al., 2006).

Betweenness centrality measures the relationship of a farmer with other members in terms of the position he or she occupies to control the flow of seed or information within the network. This measure is used to identify a connector farmer in the network. It also explains the interaction between two farmers who are not connected directly but are linked indirectly through a third farmer. Connector farmers are also sometime referred to as bridging farmers, as they bridge two sub-networks. Farmers having a high betweenness centrality value occupy the central position in the social seed network map. These farmers may not be directly connected to many other farmers in the network, as nodal farmers are, but by playing a connector role by linking two or more sub-networks, they help maintain the long chain of the seed system (Wasserman and Faust, 1994). Their significance lies in how strongly they can bridge the two sub-groups. Such farmers are potentially critical to the network; that is, they could be the point of failure for the social seed network if they discontinue farming, migrate elsewhere or die.

4 RESULTS AND DISCUSSION

4.1 Socioeconomic characteristics of sample households

The average household size of the sample group was calculated as six. In terms of ethnic distribution, 52% respondents were from Brahmin/Chhetri group, 38% were Janajati and the remaining 10% were Dalit. By religion, the majority were Hindus (96%). The literacy rate was found to be 63%: higher in males (75%) than females (51%). The average landholding size of the respondent households was calculated as 1.24 acre, which is less than the national average of 1.75 acre (CBS, 2011). The majority of earning members (74%) were engaged in agriculture as their major occupation. Labour out-migration was common in the area, where members of the households migrated within and outside the village, district and outside the country. Out of 95 sample households, 42% had one migrant and 52% had two or more migrant members going out for job and study purposes. The remaining 6% did not have any existing migrant members.

4.2 Cropping pattern and food self-sufficiency in the study area

The study site is mainly an upland, called *bari* in the local language, and agriculture is completely rainfed. The major crops grown are maize, finger millet, wheat and mustard; farmers also cultivate pumpkin, cowpea and soybean as mixed crops with maize. Farmers commonly cultivate finger millet as a relay crop with maize. Similarly, cowpea, blackgram, horsegram and soybean are grown as mixed crops with finger millet, and wheat, mustard and buckwheat are grown after harvesting finger millet. The cropping pattern of the study sites is summarized in Table 2. The cropping pattern also influences the seed exchange habits of farmers. Farmers do not have alternatives to maize and finger millet during the season when these crops are grown. If the farmers abandon either of these two cereal crops, there is a greater probability that the land will remain fallow. Due to labour shortage and tedious cultivation practices, some farmers will leave their land fallow after maize harvesting. In general, farmers do not want to keep the land fallow, but if they were forced to do so, they would leave out finger millet and continue to grow maize. According to the participants of a focus group discussion, maize is preferred because of its easy cultivation practices and as compared to the tedious cultivation practices for finger millet. Further, the cost of production is high for finger millet and its consumption is less than that of maize.

Table 2: The cropping pattern (crop combinations) observed in the area

SN	Crop combination
1	Maize – Fallow
2	Maize + Pumpkin – Finger millet + Blackgram
3	Maize – Finger millet + Horsegram/Ricebean
4	Maize + Pumpkin – Finger millet – Wheat + Pea/Blackgram
5	Maize + Pumpkin – Finger millet + Soybean
6	Maize + Pumpkin – Finger millet – Mustard
7	Maize + Cowpea – Finger millet + Cowpea – Wheat/Mustard
8	Maize + Soybean – Finger millet – Mustard
9	Maize – Finger millet + Blackgram – Wheat/ Buckwheat

Source: LI-BIRD, 2012

The combination and availability of crops grown in the area are important factors for accessing seed, which has implications for a household’s food self-sufficiency and ultimately its food and nutrition security. The RESMISA baseline report shows that about 13% of households did not have all three meals in a day during the previous year (LI-BIRD, 2012). The focus group participants indicated that though local crop varieties are rich in nutrient content and have a greater sociocultural value compared to the high yielding and improved varieties, the latter are preferred over local varieties if easily available. Moreover, rural-urban migration and the consequent declining interest in agriculture, labour scarcity and high wages rate have forced farmers to grow a limited range crops with a focus on economic rather than sociocultural value. This has resulted in the loss of local varieties and associated knowledge, along with a less diversified food availability in the long run. If the diversity of crops is limited, the supply of nutritionally diverse food is also limited in the community. This points to the importance of biodiversity conservation for sustainable food security. Pautasso (2014) indicates that as part of humanity's cultural heritage, the conservation of agrobiodiversity is important for many reasons, and is essential to avoid yield losses due to pests and diseases. It is also an important resource for adapting to climate change (Bellon et al., 2006).

4.3 Crop and varietal diversity and seed flow mechanism at the local level

The comparison of seed flow networks for major and minor cereals in this study is deliberate. No new finger millet varieties have been released or registered in Nepal for more than two decades (Dalle-1, and Okhle-1 were released in 1980, while Kabre Kodo-1 was released in 1990 [NARC, 2005]). Study results showed that among the finger millet growing households, 97% grow local varieties. In the case of maize, the majority of sample households (91%) grow released varieties. Maize varieties released many years ago (such as Manakamana 1, released in 1987 [SQCC, 2012]), are considered local by the farmers, since farmers have been growing the same variety for a long time and the variety has been well adapted to local conditions. The farmers are saving or exchanging seed of these varieties locally. With respect to rice, more than 90% households grow local varieties. Available varieties of these crops along with number of households and average area and source of seed are presented in Tables 3a (rice), 3b (maize) and 3c (finger millet). One reason that farmers mostly grow local varieties could be that there are very few new varieties released for the mid-hills and high altitude areas.

Table 3a: Varietal details of rice.

Name of varieties	Number of households (HHs)	Average Area per HH (ha)	Seed Source
KaloPatle	25	0.26	88% own source
Marsi	20	0.20	70% own source
Juwari	10	0.30	70% own source
DeupareJuwari	3	0.46	100% own source

DhampuseJuwari	1	0.05	100% own source
JharuwaKathe	12	0.28	58.3% neighbours
JhinuwaKathe	1	0.10	100% neighbours
DeupareKathe	14	0.31	64.3% own source
Kathe	8	0.26	62.5% own source
LumleKathe	4	0.38	50% own and 50% neighbours
KhariKathe	1	0.31	100% own source
Silange	13	0.31	69.2% own source
Bagali	3	0.17	66.7% neighbours
Bayeli	2	0.20	100% own sources
Jethobudo	3	0.24	100% own source
Anadi	1	0.05	100% own source
Bhalu	1	0.10	100% own source
Thakkhole	1	0.41	100% own source
Rato	1	0.10	100% neighbours
JeeraMasino	2	0.20	50% own and 50% neighbours
Chhhomrong Local	16	0.15	75% own source
Machhapuchhre-9	1	0.20	100% own source
**Khumal-4*	6	0.17	50% own source
**Machhapuchhre-3*	11	0.16	45.5% own source
Lumle-2	7	0.15	57.1% neighbours

** indicates released variety; others are local.*

Table 3b: Varietal details of maize

Name of varieties	**Number of households**	**Area coverage (Ropani/HH)**	**Seed source**
**Mankamana 1*	58	2.7	91.5% own source
**Ganesh 2*	16	2.1	81.2% own source
**Manakamana 3*	2	2.3	50% GOs and 50% NGOs
**Khumal Pahelo*	23	2.3	87% own source
Bhalu Maize	2	6.0	100% own source
Local Seto Maize	1	4.0	100% neighbours
Sano Maize	1	4.0	100% own source

** indicates released variety; others are local.*

Table 3c: Varietal details of finger millet

Name of varieties	**Number of households**	**Area coverage (Ropani/household)**	**Seed source**
Kalo Urchho	4	2.8	100% own source
Urchho	4	1.9	100% own source
Thulo Urchho	3	3.7	100% own source
Musure	6	2.8	100% own source
Kalo Musure	2	1.5	100% own source
Kalo Ghude	43	2.6	95.3% own source
Mangsire	21	2.1	95% own source

MangsireDalle	5	2.8	100% own source
MangsireSeto	1	4.0	100% own source
Kartike	1	4.0	100% own source
SetoDalle	5	2.5	80% own source
Oralle	2	1.5	100% own source
Jhaype	2	0.5	100% own source
Bhalu	2	1.0	100% own source
**Dalle 1*	1	2.0	100% own source
**Okhle 1*	3	1.8	100% own source

** indicates released variety; others are local.*

Table 4 shows that the most common means of seed flow on the whole is by the exchange of seeds with seeds/grains, which accounts for 42%, followed by purchase (37%) and gift (22%). The seed flow was also analysed separately for rice, maize and finger millet. The major means of seed flow in finger millet was found to be the exchange of seeds with seeds/grains. Seeds received as a gift from relatives or neighbours almost one-third, while only 16% of the finger millet seed was purchased in the community. It was also revealed that there is very loose seed network for finger millet in the community. Similarly, analysis of seed flow for rice showed that majority of farmers purchased the seeds, while 39% exchanged with others. In the case of maize, about 35% of farmers purchased seeds, another 35% exchanged seeds, and the remaining 30% received or shared seeds in the form of a gift.

Table 4: Means of seed exchange within the seed network (%)

Crops	**Means of seed exchange**		
	Exchange/barter	**As gift**	**Purchase**
Rice	39	14	44
Maize	35	30	35
Finger millet	52	32	16
Total	42	22	37

The study showed that there is less exchange of seed among farmers within and outside the village in the area. This may be due to the fact that most of the farmers in the study area grow local varieties (94%) of rice, maize and finger millet, and they typically save seeds (89%) at home for their needs. For rice, there is a greater number of nodal farmers and somewhat larger network as compared to maize and finger millet. This is because rice has more varietal options than the other crops.

4.4 Nodal farmers and their characteristics

Using the computation of NetDraw, farmers who play an important role in the informal seed systems and management of agrobiodiversity on farms in the community can be traced. These farmers can play a nodal or a connecting role. The results of the overall analysis using the degree centrality measure showed that 16 out of 95 farmers were directly linked with another three to six members in the network. These 16 are called the nodal farmers. Among the nodal farmers, only one female farmer was linked with other six farmers. Similarly, five farmers were linked with another four farmers and nine were linked with three farmers for the exchange of rice, maize and finger millet seed in the community. Out of 16 nodal farmers, eight were male and eight were female. These nodal farmers had a high degree centrality, or more direct connections or links with other network members than did other farmers (Poudel et al., 2006; Wasserman and Faust, 1994).

The major farmers occupying the central positions in the study – that is, the connector farmers – are indicated in Table 5. Most of these farmers are both nodal and bridging farmers; very few in the network are either nodal or bridging farmers alone. The farmers with high degree centrality scores identified as nodal farmers are often more likely to be leaders, key conduits of information, and more likely to be early adopters of anything transmitted via the network. High degree centrality individuals tend to be important influencers within their local network community. They may not be public figures to the entire network, but they are often respected locally and they occupy short paths for spreading information within their network community. A farmer with a high degree centrality may not have high betweenness centrality, or vice versa. Therefore, farmers need to be characterized as nodes, connectors, or combinations of both. Understanding farmers' roles in the community will help to identify the intervention or approach that can be employed efficiently and effectively for conservation, breeding or purely seed interventions (Abay et al., 2011). Social seed network analysis provides such details, and farmers can be approached strategically for various purposes. Understanding a farmer's position in the seed network can be useful for the design of interventions or strategies targeting conservation, participatory crop improvement, variety and seed dissemination, and seed business development at local level.

Table 5: Centrality values of the farmers in overall seed network study

SN	Respondent No	Degree centrality	Betweenness centrality	Position in network*
1	7	6	20	NC

2	25	5	66	NC
3	58	4	29	NC
4	51	4	29	NC
5	12	4	69	NC
6	83	4	24	NC
7	8	4	49	NC
8	23	3	25	NC
9	48	3	17	NC
10	28	3	15	NC
11	78	3		N
12	3	3	17	NC
13	60	3		N
14	5	3		N
15	85	3		N
16	87	3		N

**N= nodal farmer; C = connector farmer; NC = both nodal and connector farmer*

Table 6 shows that the nodal farmers' mean age is significantly higher (54) than the non-nodal farmers' (46). On the whole, the study suggests that age and education are important factors in becoming a nodal farmer, while other factors such as gender, ethnicity, wealth category and occupation play no distinct role. Age and education are considered important drivers of food security. It is revealed that relatively older and highly educated nodal farmers seem to be more food secure compared to the younger and less educated nodal farmers. Turyahabwe et al. (2013) also observe that households in Uganda headed by older and highly educated individuals are significantly more food secure than households with heads of lower age and education levels.

Table 6: Age-wise comparison between nodal and non-nodal farmers

	Nodal farmers	**Non-nodal farmers**		**p value (sig. 2 tailed)**	
Average age	54	46		0.003	
Relationship between type of farmers and their characters					
Type of farmer (Nodal and non-nodal farmer)	Gender	Occupation	Education	Ethnicity	Wealth
Chi-square	0.393	0.574	4.169	2.012	3.060
Degree of freedom	1	1	1	1	2
Sig.	0.531	0. 449	0.041	0.156	.217
Z-Proportion test between type of farmers and education					
Type of education	Type of farmer				
	Non-Nodal (%)			Nodal (%)	
Literate[3] (p)	15.9			34.5	

[3] Literacy is defined on the basis of farmers' capacity to read and write, acquired through both formal and informal education.

Illiterate (q)	84.1	65.5
Z=2.09; p=0.04		

4.5 Seed network mapping

Figure 2 indicates the network mapping in terms of degree centrality. In the figure, different colours represent different entities: red is for females, black for males and blue for unknown. The size of node denotes the degree centrality of farmers such that the larger the size of node, the higher the centrality and the greater the number direct connections with other farmers in the network (Poudel et al., 2006). Arrows indicate the flow of seed from one farmer to other and the number represents the crop that is transacted among the community members.

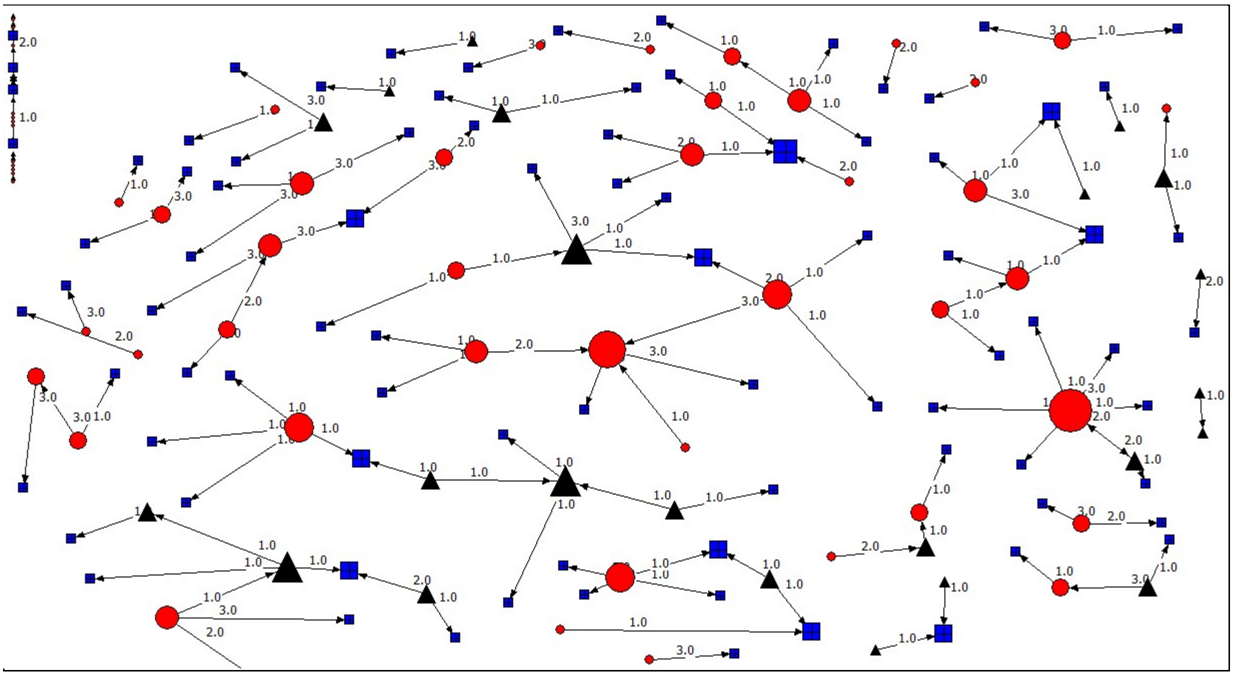

Figure 2: Network map showing the degree centrality in seed networking of rice, maize and finger millet in the research area

The number 1.0 indicates rice; 2.0 maize; and 3.0 finger millet

Figure 3 explains the process of seed flow or seed transaction in the community. The numbers represent the mode of transaction of seed/planting material in the community (1 for purchase, 2 for gift and 3 for exchange). The figure shows the existing main network of seed flow. The results of the study as indicated in the figures also show that there are some farmers who are not connected to the networks. These are referred to as isolates. These isolated farmers signify that there is always a scope to include them in the network. The network mapping also revealed that there are several networks in the community, either small or large in size (the size of the nodes). The numerous sub-networks within the main network are connected through nodal or connector farmers. All these networks are created as a function of social relationships or social interdependence in the community rather than by economic factors.

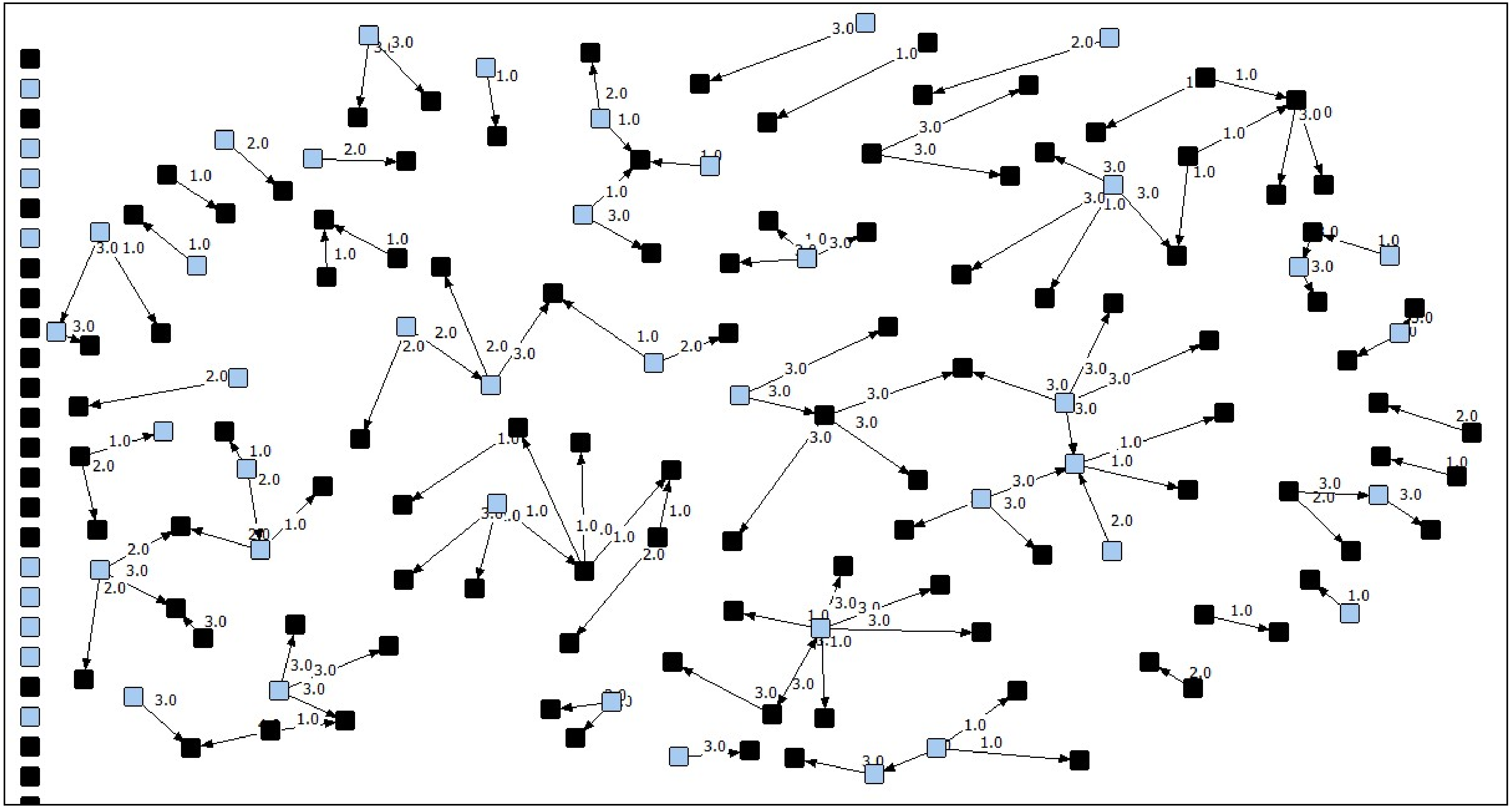

Figure 3: Seed network mapping of rice, maize and finger millet in study area
The number indicates the seed flow mechanism: 1.0 by buying; 2.0 for free; and 3.0 as gift.
Blue-coloured nodes indicate women and black, men.

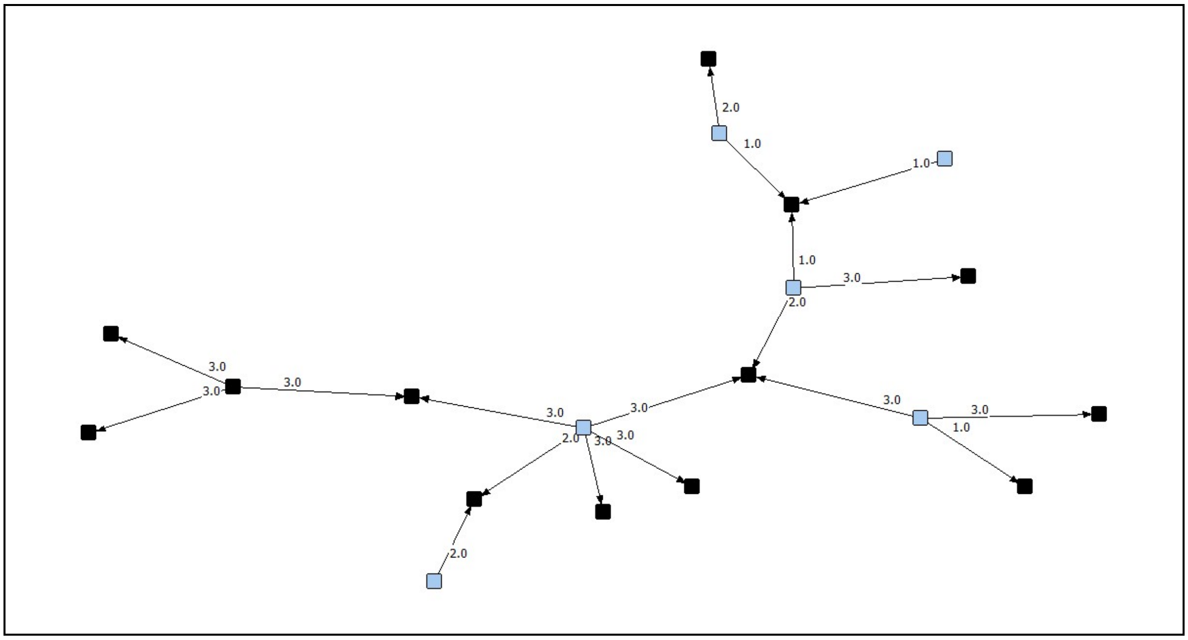

Figure 4: Main seed flow network of rice, maize and finger millet in the study area
The number indicates the seed flow mechanism: 1.0 by buying; 2.0 for free; 3.0 as gift.
Blue-coloured nodes indicate women and black, men.

The analysis showed that the network for maize seed flow in the study area is extremely limited. Most households had only one link (Figure 5a, 5b, 5c). This observation also agrees with the analysis of Abay et al. (2011), who identified households with a special role in conservation. Most research on networks has focused on the presence of undirected links, that is reciprocity (Pautasso, 2014). However, seed exchange networks are not necessarily reciprocal. The network simulation suggests that directedness, together with the absence of correlation between incoming and outgoing links, can contribute to local differentiation of landraces, because seed flows tend to remain confined within small groups of farmers. At the same time, such fragmentation can make seed systems more resilient to replacement of local varieties with improved ones (Marfo et al., 2008; Cavatassi et al., 2011).

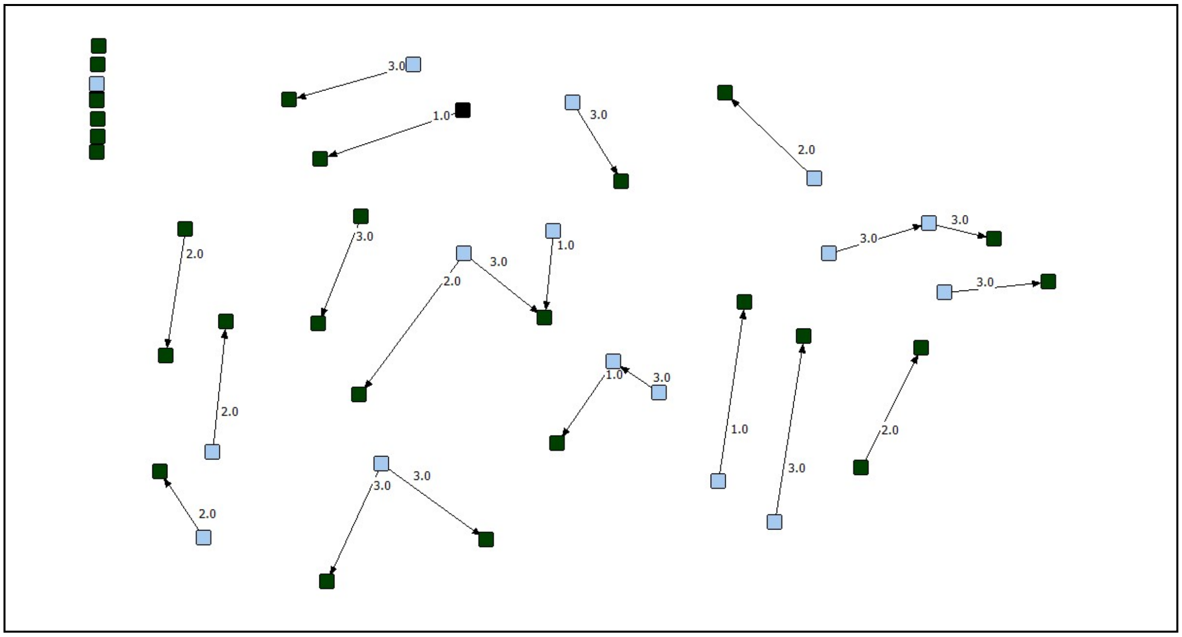

Figure 5a. Seed network map for finger millet.
The number indicates the seed flow mechanism: 1.0 by buying; 2.0 for free; 3.0 as gift. Blue-coloured nodes indicate women and black, men.

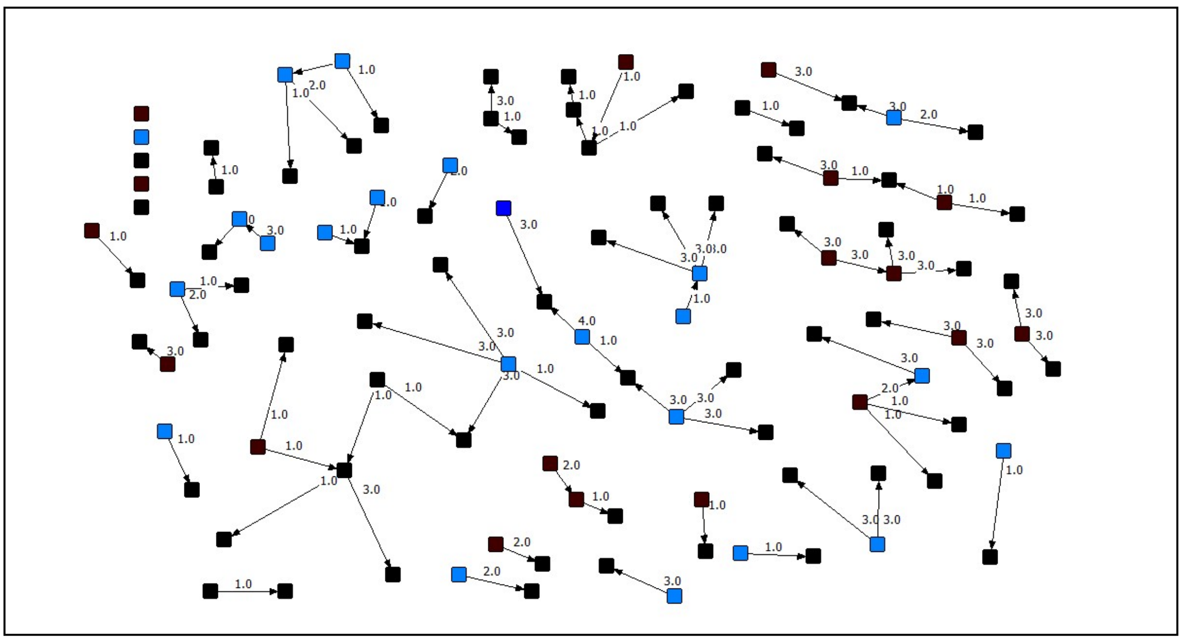

Figure 5b. Seed network map for rice.
The number indicates the seed flow mechanism: 1.0 by buying; 2.0 for free; 3.0 as gift. Blue-coloured nodes indicate women and black, men.

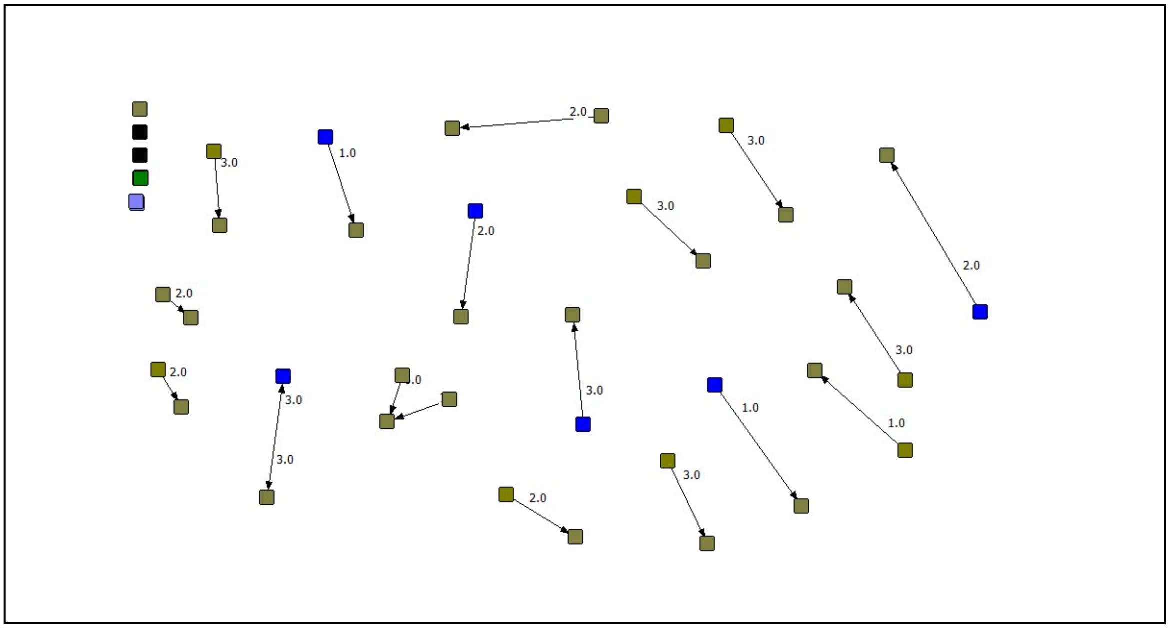

Figure 5c. Seed network map for maize.
The number indicates the seed flow mechanism: 1.0 by buying; 2.0 for free; 3.0 as gift.
Blue-coloured nodes indicate women and green, men.

Seed management at the farmers' level consists of selecting varieties and seed for the next planting season, as well as for seed storage, transfer, exchange or mixture (Bellon et al., 1997; Smale and Bellon, 1999; Hodgkin et al., 2007). Nodal farmers in the community networks are vital for maintaining crop diversity on-farm and managing the processes involved in it (Subedi et al., 2003), and they are mostly effective in sharing genetic resources in the community. Farmers with a high betweenness centrality connect the other members (or sub-networks) in the community and promote the flow of seeds. Such farmers connect two or more sub-networks that are not directly connected through other farmers. [However, these farmers are often also fragile as connectors; the links they form could be disrupted if they discontinue farming, migrate to other places, or if they do not have a successor.] The seed network analysis tool, when embedded within a larger context of community biodiversity management (Sthapit et al., 2008) or on-farm management of agrobiodiversity, may help communities recognize this weak point leading to development of option of the existing nodal or connector farmers. A nodal farmer is usually rich in terms of crop as well as varietal diversity, is known and recognized by many other farmers in the community, and is more knowledgeable compared to others. Thus, if nodal farmers are appropriately mobilized there is a greater chance that any new variety of a crop will be disseminated, thus improving food security. Furthermore, as nodal farmers are the custodians and promoters of diversity, their mobilization increases their potential to be agents for sustainable food and nutrition security.

The communities that are identified as vulnerable in their seed networks, with few nodal and connector farmers, can take necessary steps to maintain varieties in their locality (Abay et al., 2011). For sustaining the network, a collective effort is required (Badstue et al., 2003), and a community seed bank may be one such initiative (Abay et al., 2011). Some studies demonstrate that social seed network analysis is a practical and participatory tool for farming communities taking conscious and collective actions that will contribute to local on-farm conservation of agrobiodiversity (FAO, 1996, 2010). Moreover, the conservation of agrobiodiversity depends on the interplay between local differentiation of landraces and their diffusion so as to counteract local extinction (Abay et al., 2011; Dyer et al., 2011). Seed systems can maintain agrobiodiversity, but they can also replace it with new improved varieties introduced by research and extension systems (Almekinders et al., 1994; Portis et al., 2012; Kawa et al., 2013), which include both open pollinated and hybrid varieties. The general absence of reciprocity in the studied seed exchange network makes it less vulnerable to the replacement of farmer varieties by the so-called improved ones. The characterization of members in seed networks using measures of centrality provides detailed information on the role that those farmers play in the network, and as such on their potential contribution to conservation, crop improvement and seed business development. Moreover, the farmers who play key roles in seed networks are critical in sharing information relevant for selection of parents and traits during participatory crop improvement process and hold a crucial position for boosting dissemination.

5 CONCLUSION AND RECOMMENDATIONS

This paper identified and assessed the nature of seed networks for finger millet, rice and maize operating in Dhikurpokhari VDC of Kaski district in the western hills of Nepal. It was found that the households that occupy key positions in the network are important for seed flow and for agrobiodiversity conservation. By using social network analysis tools and maps, this paper examined the key characteristics of nodal farmers as age, sex, education, occupation, wealth category and ethnicity in determining whether a farmer can become a nodal farmer. The result of this study showed that age and education are important factors for becoming a nodal farmer, while other factors like ethnicity, gender, wealth category and occupation play no significant role.

The study further found that social seed network analysis is instrumental in locating farmers who occupy critical positions in the community as nodes of exchange and transfer, and who use high levels of crop and varietal diversity; or as connecters, linking communities. By identifying such farmers, their awareness or recognition of their critical role can be enhanced and specific actions can be initiated to strengthen their position, as a means to improve on-farm conservation and management of biodiversity and community food security measures. Moreover, understanding the patterns of exchange and flow of seed within and between the communities, and identifying nodal and connector farmers within seed networks can play a significant role in designing and implementing strategies for on-farm management of agrobiodiversity (Subedi et al., 2003; Sthapit et al., 2008). This understanding will contribute to the integration of a genetic resource and livelihood perspective for strengthening local seed systems (De Boef, 2008).

One approach to improving sustainable food and nutrition security is to increase the efficiency of seed flow among farmers through nodal and connector farmers. For this, it is important that the nodal and connector farmers are identified and empowered. These farmers should be provided with proper technical knowledge on crop, variety and diversity management by different research and development organizations working in the agriculture sector, especially those in the seed sector. The findings of this study are also useful for promoting community-based seed production (CBSP) groups at the local level; that is, making use of nodal farmers for disseminating new crop varieties. Easy access to knowledge, information and seed of both local and improved varieties will help improve diversity at the local level, which ultimately contributes to food security and on-farm conservation in the context of changing climatic conditions.

Many crops and varieties are getting less attention even though they have special value-based traits such as stress tolerance, eating qualities. It is worthwhile for development organizations (both governmental and non-governmental) working in the region to create awareness of the value of local varieties of different crops. The potential for using nodal farmers for promoting local crops and varieties can best be realized by providing capacity-enhancement opportunities and economic incentives to improve seed flow in the community. By doing so, not only do local farmers become important actors not only in the conservation and management of seeds and genetic materials, but also their control over the local seed system and their freedom to choose seeds from the variety of sources within the community are ensured. Empowering farmers within the local seed system will contribute to seed sovereignty and decrease market dependency for planting materials, which is an important aspect of sustainable food and nutrition security through conservation agriculture and increased agrobiodiversity.

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