Who Maintains Crop Genetic Diversity and How?: Implications for On-farm Conservation and Utilization

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Introduction

Natural evolutionary processes together with human-managed factors greatly contribute to agricultural diversity, and it is now well recognized that different levels of diversity exist on-farm. In addition to selection, other key factors that affect genetic diversity are mutation, recombination, genetic drift and migration (Frankel, Brown, and Burdon 1995; Hancock 1992). Migration (i.e., exchange of seed flow) can act to supply variability to a farmer-managed population. Varying socio-cultural preferences, the needs of the farming communities living in different circumstances, as well as their selection processes also influence the diversity on-farm. Although technological modernization and its promotion have threatened crop diversity, a large amount of diversity encompassing local cultivars still exists in most of the non-commercial production areas. Individual farmers and farming communities at large have been playing an important role in conserving them. They are not only the custodians, but also the managers of this crop diversity and are maintaining its dynamic processes. In the process of conservation and utilization, they have developed their own management strategies of which an informal seed system is an important component. Such an informal seed system fundamentally occurs through the interpersonal relationships of the individuals creating their networks in the community.

Most community members grow different cultivars. It is found, particularly from Diversity Fairs, that certain farmers maintain a larger crop diversity than others in the community. However, it is not well understood what type of individuals in the community play a significantly greater role in maintaining the diversity and what processes are involved in maintaining that diversity. Hence, there is a need to examine and explore these aspects in order to better understand and thereby further strengthen the informal system of managing diversity on-farm. Such a system can be effectively explored through a network analysis approach. Analyzing the networks of a social system traces the flow of materials and information, identifies nodal individuals in the community and can capture the context in which network members make behavioral decisions. Therefore, with the objectives of exploring and examining the informal flow of genetic materials, identifying nodal farmers in the community, and to understand the dynamic processes of an informal system of crop diversity management, a study of farmer seed flow networks was carried out in Begnas and Kachorwa ecosites of Nepal as a component of a project entitled "Strengthening the scientific basis of in situ conservation of agrobiodiversity on-farm."

Methodology

A network analysis approach was adopted to explore and map seed flow networks and the processes involved in maintenance of crop diversity. A sociometric survey using a snowball-sampling technique was employed to collect the network data. A sociometric survey is a means of obtaining relational/linking data among the individuals in a social system. Snowball sampling involves an initial sample of respondents as "starters" from whom data on their sociometric links are collected. The sociometrically indicated individuals then become the second-stage respondents. These second-stage respondents consequently lead to the third-stage respondents and so on.

Thus, snowball sampling follows a multistage design in which respondents at each stage sociometrically determine who the respondents are at the following stage (Burt 1980; Knoke and Kuklinski 1982; Rogers and Kincaid 1981; Scott 1991; Warner and Moul 1992).

An initial sample of 24 respondents was drawn on the basis of stratified random sampling from the list of a baseline study (n = 206 at Begnas and 202 at Kachorwa) carried out by Rana et al. in 1998 (Rana et al. 2000a). Thereafter the respondents were taken from the sociometrically identified individuals by the interviewees. The snowballing was carried out until the third stage. The total respondents after the third stage interviews were 78 in each ecosite.

As most of the individuals indicated in the interviews were not listed in the baseline survey, information on their personal attributes and level of diversity maintained was collected using a checklist after the network data collection.

Network mapping was done manually from the relational data obtained from the survey. Nodal farmers were identified by using criteria such as: frequency of mention of their names as source of seed in the community, their links with other individuals in obtaining genetic materials for themselves from within or outside the community, maintaining relatively high diversity, and perceived source of knowledge. To identify such knowledgeable persons, respondents were asked to name three men and three women farmers as the most knowledgeable persons in the community as perceived by them on matters related to seed, selection of good planting materials, production environments of different cultivars, diversity conservation and use, research mindedness and opinion-former in the community.

Findings

Flow of Genetic Materials in the Study Areas

The study has revealed that flow of planting materials occurs mainly from exchange and barter (bartering either grain for seed or seed for seed but of different cultivars), followed by gifts (Table 1). Seed flow also occurs through purchase from within or outside the community while about 10 percent of flow, particularly in Kachorwa, occurs from borrowing of either seed or seedlings (Table 1). These exchanges and borrowing are done for different reasons, such as a shortage or to replace poor-quality seed, interest in growing better cultivars as observed in other farmers' fields, desire to test a new cultivar, looking for suitable cultivars to replace the existing one for a specific land parcel, etc.

Table 1
Means of Informal Flow of Rice Seed/Planting Materials through Farmers' Networks

Means of Flow	% Flow of Genetic Materials[†]	
	Begnas	Kachorwa
Exchange	53	64
Gift	31	17
Purchase	16	9
Other (e.g. borrowing seed/seedlings)	-	10

[†] Number of cultivars involved in the flow was 42 in Begnas (10 MV and 32 Landraces) and 35 in Kachorwa (25 MVs and 10 Landraces).

With regard to the type of cultivars (i.e., improved varieties or landraces), Table 2 shows that in Begnas, which is a moderately accessible area, more landraces were used in the flow than modern varieties (MVs) (74 vs. 26 percent). In contrast, in Kachorwa, a much larger number of MVs are used than landraces (94 vs. 6 percent). This is mainly because more MVs are grown by farmers in Kachorwa, and farmers are more exposed to new innovations due to a higher level of intervention than in Begnas. The details of the cultivars involved in the informal flow are given in Table 3 for Begnas and Table 4 for Kachorwa.

Farmer Networks, Nodal Farmers, and Their Characteristics

The Networks

The analyses show that there are a few larger networks and several smaller networks in both study areas. There are more smaller networks in Kachorwa (Figures 1a and b) than in Begnas (Figures 2a and b). The probable

Table 2
Comparison of Seed Flow between Landrace and Modern Varieties (MVs) in Rice Crop through Farmers' Networks

Means of flow	% Flow of Genetic Materials			
	Begnas		Kachorwa	
	Landrace	MV	Landrace	MV
Exchange	67	33	6	94
Gift	79	21	3	97
Purchase	84	16	14	86
Others	100	0	0	100
Overall	74	26	6	94

Table 3
Seed Flow of Different Rice Cultivars through Farmer's Network in Begnas, Kaski

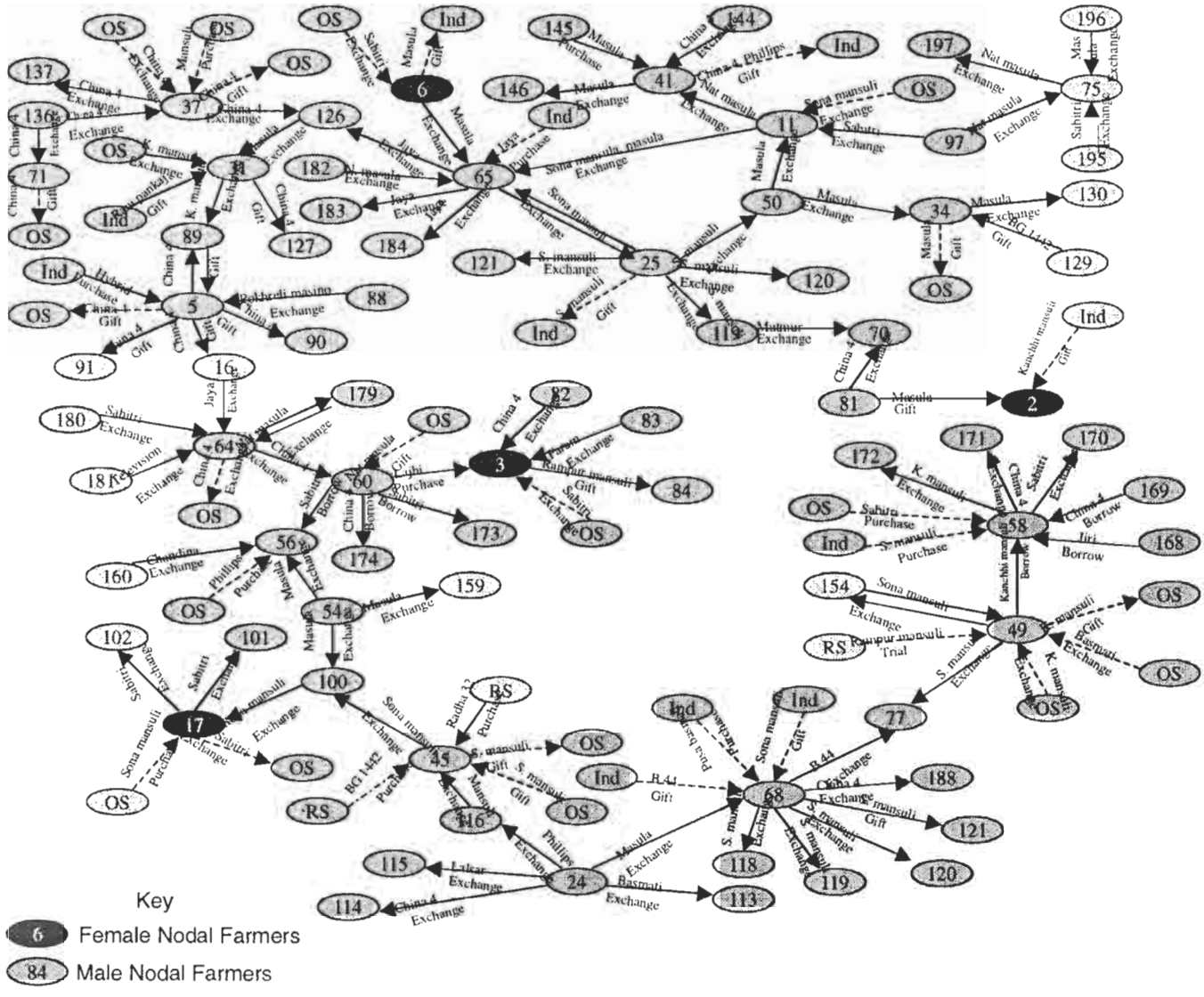
Rice Cultivar	Cultivar Type	Exchange	Gift	Purchase	Other	Total
Ango	Landrace	0	3	0		3
Ekle		14	8	11		33
Anadi		2	3	1		6
Dudhe anadi		0	1	0		1
Gurdi		5	1	4		10
Pahele		0	1	0		1
Jetho budho		5	1	1		7
Kathe Gurdi		9	0	2		11
Mana muri		1	0	0		1
Pakhe Jarneli		3	3	2		8
Thulc madhese		0	1	0		1
Biramful		1	1	0		2
Panhele		2	0	0		2
Setc Gurdi		1	0	0		1
Madhese		10	2	3	1	16
Mansara		4	3	2		9
Rato anadi		1	2	0		3
Sano madhese		0	0	1		1
Bayerni		1	2	0		3
Naltumme		0	3	0		3
Thinuwa		3	3	0		6
Jarneli		1	0	0		1
Tunde		2	1	0		3
Naulo madhese		1	1	0		2
Bhadaiya		0	1	0		1
Rate		0	3	0		3
Basmati		3	1	0		4
Chhote		1	1	0		2
Lahare gurdi		1	0	0		1
Kalo masino		1	0	0		1
Clobo		1	0	0		1
Tarkange		0	3	0		3
Radha	MV	6	0	0		6
Masuli		10	3	2		15
Radha 9		8	3	0		11
Radha 7		6	3	2		11
Sabitri		0	1	0		1
Thulo mansuli		1	0	0		1
Makawanpur		1	1	0		2
Naulo mansuli		1	0	0		1
Khumal 4		1	1	0		2
Chaite		2	1	1		4
Total		109	62	32	1	204

Table 4
Seed Flow of Different Rice Cultivars through Farmer's Network in Kachorwa, Bara

Rice Cultivar	Cultivar Type	Exchange	Gift	Purchase	Others	Total
Pokhreli masino	Landrace	1	0	0	0	1
Lalsar		1	0	0	0	1
Basmati		2	0	0	0	2
Dudhraj		0	1	0	0	1
Mutmur		1	0	0	0	1
Faram		2	0	0	0	2
Lajhi		1	0	1	0	2
Saro		1	0	0	0	1
Nakhi saro		0	0	1	0	1
Sokan		0	0	1	0	1
Masula	MV	34	2	1	5	42
Sabitri		11	0	2	2	15
Nat masuli		8	4	1	0	13
China-4		23	12	1	4	40
Phillips		7	1	1	0	9
Jaya		16	0	1	0	17
Hybrid		0	0	1	0	1
Mansuli		1	2	1	0	4
BG 1442		0	1	1	0	2
B 44		1	1	0	0	2
Sona mansuli		19	8	2	0	29
Radha 11		0	0	0	1	1
Kanchhi masuli		5	2	0	1	8
Jiri		1	0	0	1	2
Rampur Masuli		1	1	3	0	5
Pusa Basmati		0	0	1	0	1
Chaite 4		0	1	0	1	2
Radha 32		0	0	1	1	2
Television		2	0	0	0	2
Rani Pankaj		0	2	0	0	2
Chandina		2	0	1	3	6
Dipahiya		1	0	0	0	1
Makawanpur		0	0	0	2	2
Radha 7		0	0	0	1	1
Panjabi		1	0	0	0	1
Total		142	38	21	22	223

reason for this is wider contacts of different individuals and choice of varieties from different farmers as well as from other seed sources. However, this needs to be further explored in a follow-up study. But even in such larger networks, not all the individuals are connected to each other at the community level. Instead, there are sub-networks, which are linked to one or the other through certain individuals. This indicates that informal flow of seed/planting materials does not necessarily have to occur among all the members of the community. There would be greater flow of materials through a number of spatially distributed smaller networks. In a large social network,

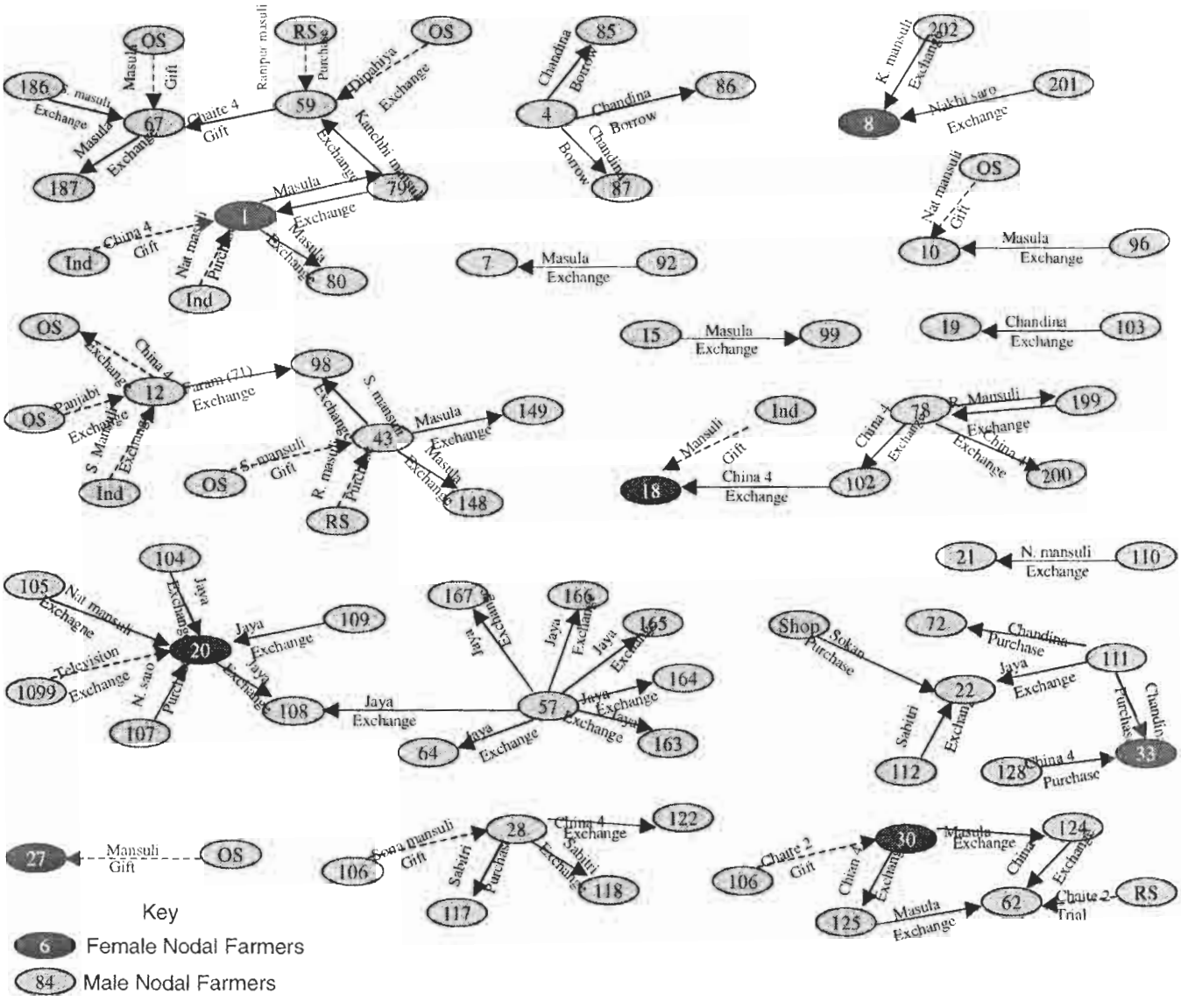
Figure 1a
Farmers' Network for Rice Seed Flow in Kachorwa (Network I)



direct contact with all the individuals may not be possible (Barnes 1979), while occasional network links may be strong in the diffusion of innovations and messages since occasional links will provide opportunity to find more new information and materials (Granovetter 1973).

There are no separate networks for gender groups. There are men and women members in the same networks suggesting a men-women-men type of network. Genetic materials flow through the mixed groups of men and women farmers in both the study areas. This is in contrast to the networks of information flow found by Subedi and Garforth (1996) where men-men, men-women (men led), women-men (women led), and women-women networks were found in certain communities of the western hills of Nepal. Similarly, the networks are not wealth category based since members in the network belong to different wealth groups although the proportion of the network members from the wealth categories differs. This indicates that there is no barrier among the members of the gender and wealth categories in the flow of genetic materials and knowledge associated with it.

Figure 1b
Farmers' Network for Rice Seed Flow in Kachorwa (Network II)



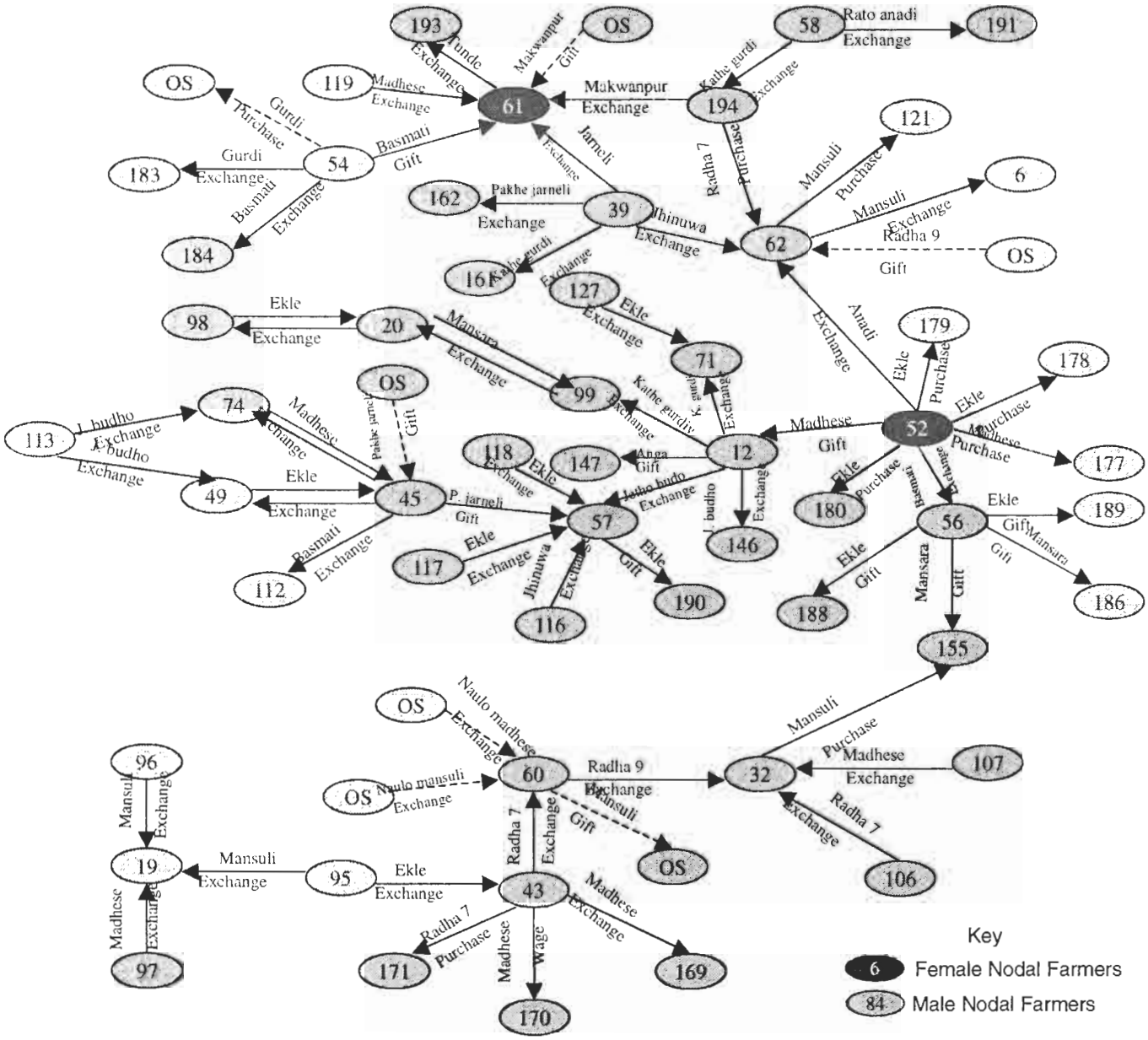
The Nodal Farmers and Their Characteristics

There are certain individuals who play a significant role in the flow of genetic materials and crop diversity. Such individuals occupy a relatively more central position in the network and have been termed "nodal farmers." At Begnas and Kachorwa study sites these nodal farmers are found spatially distributed in different sections of the settlements. The nodal farmers surveyed at Begnas range in age from 29 to 62; those at Kachorwa from 29 to 70-years old.

Gender and Wealth Categories

Both men and women farmers are found to be nodal persons. However, the number of women nodal farmers is less in both study sites (three in each site) compared with men nodal farmers (ten and 12 in Begnas and Kachorwa respectively). The majority of the nodal farmers in both ecosites belong to the rich wealth category (nine in Begnas and 11 in Kachorwa), although a few are also found from the medium (three each in Begnas and Kachorwa) and poor categories (one each in Begnas and Kachorwa).

Figure 2a
Farmers' Network for Rice Seed Flow in Begnas (Network I)

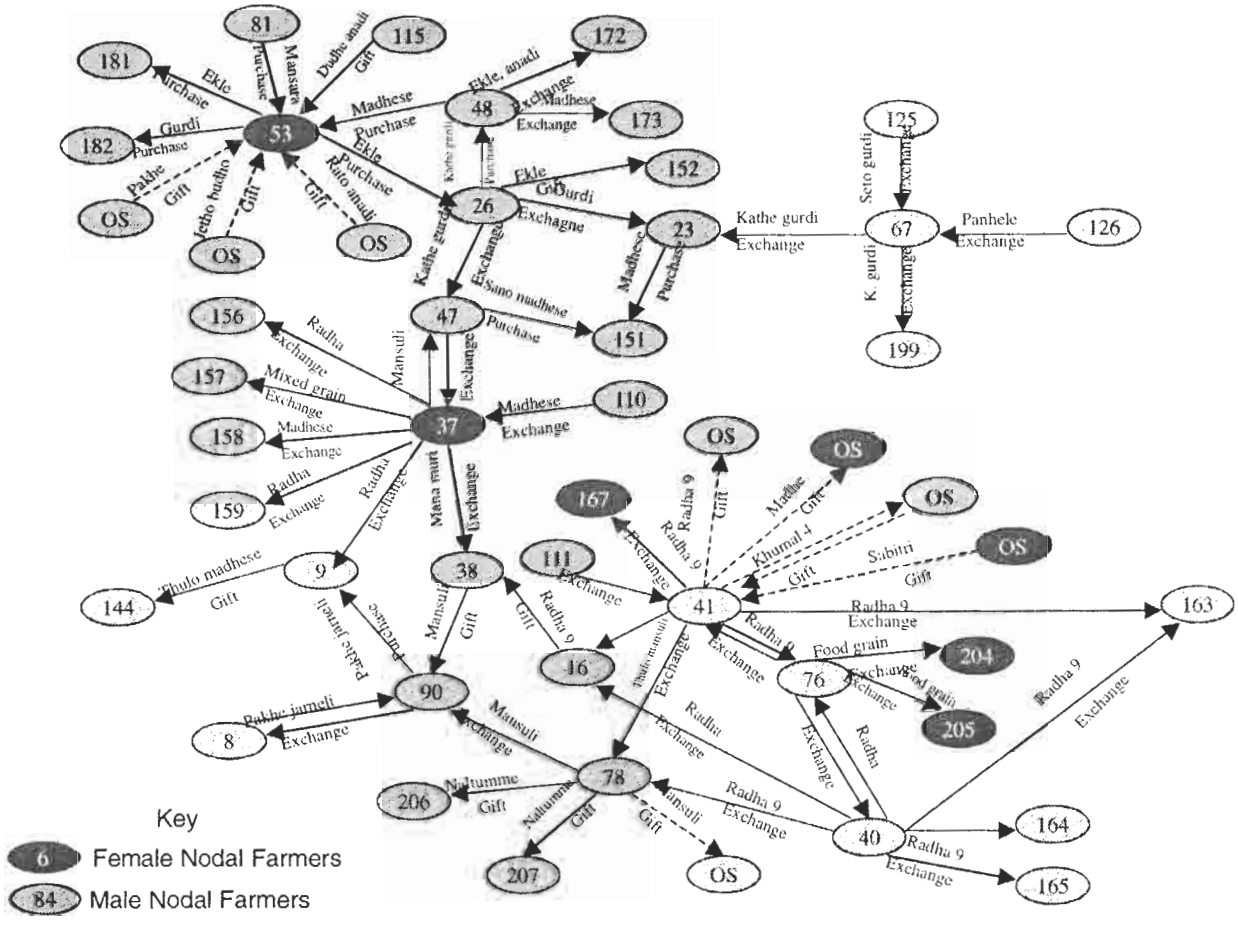


Crop Diversity

The majority of the nodal farmers in both the ecosites are maintaining a high level (three and more rice cultivars) of diversity on their farms. They also attach great importance to having a wide range of crop diversity on-farm including important landraces. Therefore, these nodal farmers can be said to be "diversity-minded."

In terms of the type of cultivars grown, there is a difference between Begnas and Kachorwa nodal farmers. In Begnas, the nodal farmers possess mainly landraces, and only a few of them grow improved varieties, whereas the Kachorwa nodal farmers possess mostly improved varieties, although certain landraces are also grown by them. This is, however, determined by the production ecology as the Begnas ecosite has different niche

Figure 2b
Farmers' Network for Rice Seed Flow in Begnas (Network II)



environments where different cultivars are adapted and grown than in Kachorwa ecosite (Paudel et al. 2000; Rana et al. 2000b).

Flow of Genetic Materials

The nodal farmers play an important role in the seed flow. They give seed to other farmers within and outside the community and are thus the source of seed. At the same time, they also bring in materials from other farmers within and outside the community. These farmers are creating a dynamic process of diversity on-farm through germplasm flow. In this process of material flow, it was also reported that non-material information like traits of the materials, management practices or how they would perform in different conditions as well as their uses associated with the genetic materials is also acquired. This indicates that nodal farmers play an important role in dissemination of knowledge-based information. This was supported by the fact that nodal farmers were reported to be the perceived knowledgeable persons in the community when respondents were asked to indicate the most knowledgeable persons as mentioned in the methodology section.

Implications for Conservation and Utilization

Strengthening On-farm Conservation

Understanding the patterns of social networks and identifying the nodal farmers in a community will enhance conservation efforts. The nodal farmers identified through this process can be well used in conservation and management of useful plant genetic resources. This can be achieved by involving these key persons in awareness

classes so that they will later become conservation farmers and a source of information for other farmers in the community. Since the nodal farmers maintain a high level of diversity, strengthening the linkage of these farmers with other members of the community can also lead to on-farm conservation of agrobiodiversity in situ.

Diversity Deployment

Involvement of a large number of farmers in a community for participatory plant breeding (PPB) can take advantage of existing social networks. Nodal farmers are playing an important role in the flow of genetic materials and managing a large diversity. This implies that these famers are constantly trying out new planting materials and making selection in their varied farm environments. Such individuals can be usefully involved in diversity deployment through participatory variety/landrace selection and PPB. This will give a greater control of the breeding process to farmer representatives. Participation of the nodal farmers will follow the course of natural farmer-to-farmer seed diffusion through their networks. Imparting new breeding skills to such individuals can further enhance their capacity.

Strengthening the Seed Supply System

Access to sufficient seed, particularly of the desired/preferred varieties, is one of the important variables encouraging farmers to maintain a large number of crop and varietal diversity on-farm (Cromwell and van Oosterhout 2000). As the results of the study show, effective exchange of seed at the local level depends on different sections of the community interacting with each other. Steps to facilitate the informal seed supply system could include encouraging increased contact of the community members through the nodal farmers. They could be effectively involved in the seed production activity as well.

Training and Dissemination of Local Cultivars

Nodal farmers can be effectively used as trainers on local crop diversity, their management and associated knowledge. This will strengthen farmer-to-farmer dissemination. They can also be involved in the development of extension messages of the local cultivars and knowledge as well as on conservation and utilization. At the same time, a group of nodal farmers can be involved effectively in a community biodiversity register (CBR), a registry held and updated by farmers. The CRB records cultivars within the community; it lists who has the cultivars and provides farmer descriptions of the cultivar properties; and serves as a resource on the subject.

Conclusion

Farmers' network analysis can be an effective tool to explore and analyze crop diversity management in a community and identify those who are actively engaged in dynamic processes of conservation and management of crop genetic resources. The present study has revealed that the farmers' seed system is influenced by the informal flow of genetic materials, which largely contribute to creating diversity on-farm. Community members have networks of affiliations through which the flow of genetic materials takes place, and which influence the management of crop diversity and decision-making processes of the network members. Certain members of the community play a key role in the maintenance of crop diversity on-farm and managing the processes involved in it. Such nodal farmers select and maintain high diversity of cultivars at individual farms, as well as at the landscape levels, frequently exchange cultivars with a relatively large number of individuals, try to introduce new diversity from different sources and act as the source of knowledge in the community as well. Thus, nodal farmers tend to address the seed needs of the larger section of the community.

The informal seed system is basically dependent on the exchanges of genetic materials, which is based on a barter economy. As the cash-based economy develops, such a system may gradually decline, thereby influencing the means of obtaining seed materials of different cultivars in the community and affecting the crop diversity on-farm (Cromwell and van Oosterhout 2000). Hence, ways to enhance the informal seed systems by which farming communities benefite should be found. In this context, farmer's networks and nodal farmers will play a significant role in strengthening the informal system. Through these, seed exchange during diversity fairs can be strengthened, use of Community Biodiversity Register (CBR) for locating seed and information source can be promoted, and nodal farmers can be effectively involved in germplasm enhancement and diffusion of the local landraces and associated knowledge.

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