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Can cultivars from participatory plant breeding improve seed provision to small-scale farmers?

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Abstract Seed provision for small-scale farmers deals with multiple constraints. These include, on the supply side, high seed production costs and poor adaptedness of the cultivars, and on the demand side, anticyclical demand and low and variable sales. Approaches to improve seed provision to this sector of farmers have so far not been very successful. This paper discusses how well-adapted cultivars developed through participatory plant breeding (PPB) initiatives create new opportunities for production and distribution of quality seed. It reviews supply and demand-side issues, based on research and experiences with seed production. Given better adaptation of PPB-cultivars, the diffusion of seed of PPB initiatives should not be a major bottleneck. But constraints in the provision of quality seed from cultivars that are commonly used remain and need to be addressed. Major points of attention are cost-effective seed production and distribution, high information linked transaction costs, and appropriate seed production technology. Research on these issues is needed to understand farmers' seed demand. At the same time, these issues need to be taken into account in new seed production initiatives that apply integrated approaches. Long term commitment by farmers to produce, distribute and use seeds is a condition. Even if seed production is not economically sustainable at household or organization level, farmer-based seed systems generate benefits to society as a whole that justify long term public investment to maintain them.

Keywords Seed supply · Seed demand · Small-scale farmers · Participatory plant breeding · Andean region

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Introduction

The impact of the formal seed sector on small-scale farming in developing countries has been below expectations (Lipton and Longhurst 1989; Thiele 1999a; Tripp 2001; Evenson and Gollin 2003). Whereas the formal seed sector has been quite effective in providing seed for high-input commercial agriculture in uniform environments, it has not been able to cope with low-input, small-scale agriculture in highly heterogeneous environments like the Andean Region. Explanations for the low impact have been the unsuitability of the distributed cultivars for small-scale farmers in terms of adaptation to the environment and/or farmers' preferences, the relatively low quality and high price of the seed as compared to farmer-saved seed, the seed regulation and the complex farmer-demand for seed (Tripp 2001). Alternative approaches that build on farmer-based seed systems have been tried in recognition of this problem but appeared unsustainable in most cases. In this light, the success of participatory plant breeding (PPB) projects has revived questions surrounding seed provision for small-scale farmers. In the Andean Region and elsewhere, breeders, like those participating in the Preduza program (Daniel et al. this issue) have developed cultivars in collaboration with farmers. These cultivars, referred to as PPB-cultivars in this publication, are most likely better adapted to the growing conditions and preferences of the participating farmers than cultivars produced through the formal breeding approach. To share the benefits of the PPB initiatives with other farmers, the cultivars need to be diffused and quality seed is necessary to capture the full potential of these cultivars. However, financial support for Agricultural Research and Development is dwindling, and seed multiplication and diffusion have lost their attraction to donors. Activities to support quality seed supply to small-scale farmers only find financial resources if presented in a broader development context such as the sustainable use of agrobiodiversity and integration with markets.

To reflect on this issue, we review the role of farmers and farmer-based seed systems in (i) the diffusion of seeds of new cultivars and (ii) supply and demand of quality seed of commonly used cultivars. This discussion is complemented with the lessons and seed-strategy elements formulated by researcher-breeders in the Andean Region in a series of workshops organized by the Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP), Quito, Ecuador, the Instituto Nacional de Investigacion Agraria (INIA), Cuzco, Peru and the Fundación para la Promoción y Investigación de Productos Andinos (Proinpa), Cochabamba, Bolivia, with support from the Preduza program. The focus is primarily on food crops of small scale-farmers in variable, marginal environments like those in the Andean Region. These farmers produce for subsistence and the regional market. Although the focus is on the Andean Region we believe our conclusions are valid for seed systems in many other parts of the world.

Role of public sector in seed supply of major food crops in the Andes

The current picture of seed provision of food crops for small-scale farmers in the Andean Region is that of a public sector which produces small volumes of certified seed (CS), but which lacks effective mechanisms to diffuse this seed into the community of small-scale farmers. The data from Bolivia and Ecuador for seven food crops (common bean, field bean, barley, wheat, maize, potato and quinoa) are illustrative (Tables 1 and 2).

In Bolivia, most CS is produced and used by large-scale farmers who supply agro-industry in the low lying plains of the regions of Santa Cruz and Gran Chaco. The data for 2003 (Table 1)—for the CS production available per region; for the area planted only available as total of the country—show that the CS production in these two regions mainly refer to common bean, maize and wheat. Of maize, around 35% of the CS available is imported, most likely CS of hybrid cultivars. It can be assumed that most of this produced and imported CS is also planted in these two regions. In the Andean region, where open pollinated cultivars are used, the percentages of area planted with CS of bean, maize and wheat are therefore in fact quite low. For field beans, potato and quinoa the percentages planted with CS are referring to the Andean region as they are not grown in the low-lying plains. In Ecuador less than 2% of the area is planted with certified seed (Table 2). Data for maize seed in the Department of Cajamarca, Peru, showed that in 2002 and 2003, the seed production of the INIA Seed Unit served to plant 61 ha and 28 ha, less than 0.1% of the estimated total area of maize planted in the

Table 1 Area planted in Bolivia, amount of certified seed (CS) produced in Bolivia, in the regions of St. Cruz and Gran Chaco, in the Andean region and imported, the crop area that could be planted with the CS produced and imported, and the percentage of the crop area that could be planted with CS for six major food crops in Bolivia in 2003*

	Common Bean	Field Bean	Maiz	Potato	Quinoa	Wheat
Area planted in Bolivia (ha)	13,300	33,600	306,100	128,500	33,900	110,500
CS produced in Bolivia (tons)	394	81	1,824	5,590	7	1,600
of which in St. Cruz + Gran Chaco	352	–	1,579	141	–	1,450
of which in Andean region	42	81	245	5,449	7	150
CS imported (tons)	–	–	984	25	–	–
Area planted with CS, Bolivia (ha)	8,770	1,105	145,700	3,400	925	19,000
% Planted with CS, Bolivia	66	3	48	3	3	17

*Data adapted from Oficina de Semillas (www.semillas.org, accessed May 2005)

Table 2 Total area planted in ha and the percentage of that area planted with certified seed (CS) of six major food crops in Ecuador in 1999–2000*

	Barley	Common Bean	Maiz	Potato	Quinoa	Wheat
Total area planted	70,000	80,000	165,000	129,000	10,000	30,000
% area planted with CS	2	0	< 1	2	0	< 1

*Data adapted from Perry and van der Vossen (2000)

department. These data are in line with those from other parts of the world (Tripp 2001; Almekinders and Louwaars 2002). Also in the Andean Region the public sector usually offers cleaned and certified seed of improved cultivars but not of local cultivars. Hence it is clear that also for farmers in the Andean Region certified seed of the crops they grow is not readily available. In addition, the costs of production, cleaning, certification and distribution results in a seed price that farmers perceive as relatively high (Duijndam et al. this issue).

Constraints at the supply side

A range of constraints on the supply side makes seed provision to small-scale farmers economically unsustainable without subsidy. First of all, the costs of seed production are high, especially for crops with a low reproduction rate such as potatoes, common bean, wheat and barley. When quality breeders' seed has to be multiplied through several cycles of reproduction into commercial seed of a high quality (Parlevliet this issue), expensive infrastructure and labour, certification and logistics of seed processing and distribution increase costs. By the time farmers purchase the seed from local seed outlets, seed may have been stored for more than one season and the high price is combined with suboptimal quality. Breeders and other participants in workshops in Cuzco and Cochabamba also identified an inadequate regulatory framework, lack of coordination among interested partners, and market organization as important constraints in seed provision in the region (Almekinders et al. 2004a, b). Dry years especially may have a negative effect on the supply of seed and on the diffusion of new cultivars because of the strongly reduced yields. This needs to be taken into consideration when planning seed provision through for example specialized local seed producers. It may require investment in irrigation equipment, which increases production costs. Low and variable market prices for the produce give farmers low cash income and constrain cash investments in seed and other inputs.

In general, National Agricultural Research (NAR) systems lack financial resources for seed production and distribution. Earlier experiences have shown that provision of quality seed for small-scale-farmers usually depends upon subsidies. In the Andean Region this has been clearly shown for potato (Bentley and Vasques 1998). This makes governments and donors reluctant to provide funds for seed production and distribution. In a paper on improvement of seed provision, Tejada (2004) suggested that multiplication of high quality breeders' seed to commercial seed of adequate quality for prices that are attractive to small-scale Andean farmers is an essential but missing link between breeders and small-scale farmers.

Constraints from the demand side

There are also demand constraints that make it difficult for seed supply to be economically self-sustainable.

Anticyclical demand and price

Anticyclical demand for seed is a consequence of price variation in the marketed crop. High market prices for the produce at harvest in one year stimulate the purchase of high quality seed for the next planting. However, by the time these are harvested, the market is oversupplied and prices drop. This results in an uncertain and poor return on the seed investment.

Market prices and yield risks

In addition to the fluctuations in market prices that are caused by yield fluctuations and the anticyclical responses of farmers, there is a constant downward pressure on market prices for staple-food (Thiele et al. 1999b). Low market prices do not allow farmers to spend cash on the production of these crops. In such situations it is not logical to invest in quality seed. The fact that a slow but promising development of certified rice and cotton seed production in Peru has been reported (Bentley et al., 2001) confirms this argument. These crops are grown for commercialization by large estate-like cooperatives in the coastal region. The economics are quite different from subsistence small-scale farming in the mountainous region. Also the risks involved in investing in crop production are a factor to be considered. Small-scale farmers in areas with marginal and variable growing conditions prefer cultivars with stable yields and food security to cultivars with yields that may be higher on average, but much more variable.

Lack of information

Another constraint is the availability of information. Seed from formal sources is often not readily available to small-scale farmers. They may have to travel to a nearby town where there is an agro-chemical outlet. Usually the farmers do not have information about where seed can be purchased, nor do they know of which cultivars, quality or price. The importance of transaction costs related to obtaining the information about seeds and cultivars is receiving increasing attention (Bellon 2004; Tripp 2001).

The difficulties described above make it complicated to effectively match supply and demand for seed. Small-scale farmers do not find seed of their choice readily available with reliable seed quality at an acceptable price. As a result, they purchase small volumes of seed that they multiply on their farms. When this seed accrues benefits in subsequent multiplications, this is economically rational behaviour (Thiele 1999a). But the outcome for public seed programs is that they face a low and variable demand for seed, which is typical for a wide range of cultivars of various food crops.

The complementarity of formal and farmer-based seed systems

To improve seed supply to small-scale farmers, an integration of formal and informal seed systems has been advocated (Almekinders et al. 1994; Thiele 1999a), based on complementary strengths and weaknesses of both systems. Almekinders and Louwaars (2002) describe an integrated system in which the farmers are not passive clients of the formal system, but are active partners in the conservation of genetic diversity, crop development and seed production. Integration can occur in different ways. An example of how farmers can participate in breeding is found in the Andean Region (Danial et al., this issue). Breeders collaborate with farmers to take advantage of farmers' selection capacity and to better understand their selection criteria. This could be considered an example of breeder-led collaboration (Sperling et al. 2001). A farmer-led linkage could be a situation in which farmers look for support from breeders to obtain better adapted cultivars and quality seed. The linkages in participatory plant breeding (PPB) can refer to a flow of genetic materials, resources, and exchange of knowledge or a combination of these.

Whereas there are many examples of successful PPB, there are few reports of successful small-farmer seed supply. After disappointing experiences with formal-seed sector projects, the idea gained ground that farmers can produce and sell quality seed more cost-effectively than the formal sector. Basically, the seed provision strategy foresaw that a small number of specialized farmers or farmer groups could produce seed for other community members or for a wider area (Wiggins and Cromwell 1995; Kugbei and Turner 2000; Tripp 2001; Ndjeunga 2002; David 2004). With proper technical support and capacity building such specialized farmers could develop into seed entrepreneurs. They could link breeders and farmers and could multiply and distribute seed of improved cultivars. While considered a promising strategy since the '80s (Camargo et al. 1989), the authors found little evidence that this approach constitutes a sustainable way forward to seed provision of food crops for small-scale farmers (Almekinders and Thiele 2003).

Experiences with farmer-based seed production

In Latin America, numerous projects on Producción Artesenal de Semilla (PAS) were initiated in the '80s, many of them supported by CIAT in beans and by CIMMYT in maize (Ashby et al. 1989; Camargo 1989; Häbich 1991; Roa et al. 1991). But few projects have changed farmers' seed selection practices on a large scale and few small-scale seed enterprises survived beyond the project period. For small-scale seed enterprises, sustaining seed quality was one of the main difficulties. Typically, this becomes an issue when, because of economic or production factors, seed of suboptimal quality is sold, thereby damaging the trust, a vital component of seed transactions. PAS of beans in Northern Ecuador is an example of this. After a successful start, participating farmers were not able to unify the different business perspectives and the sale of poor quality seed attracted few returning buyers (Mazon et al. 2003). A recent case concerns a farmer-group in Cajamarca, Peru, that produced quality potato-seed tubers of an improved cultivar (Minchán, personal comm.). In September 2003, 2–3 months before planting, they found themselves still with all seed tubers in store because there were no farmers interested in buying seed at cost price. Market prices of consumer potato had been low over the season and few farmers were ready to invest heavily in a next-season potato crop. Fortunately, a big mining company operating in the area bought the entire seed lot and saved the group from bankruptcy. In general, these experiences raise the question about the willingness or ability of small-scale farmers to pay a just price for quality seed. This case illustrates the fact that in seed provision to small-scale farmers, farmer-based seed enterprises face the same constraints as the public seed sector. Apparently, seed provision is a bottleneck in the development of an effective integrated seed system, consisting of constraints on both the supply and demand side.

Diffusion of novelty seeds through farmer-based systems

With PPB-cultivars becoming available, seed provision to small-scale farmers needs to be re-addressed. In the Andean Regions, breeders developed PPB-cultivars with small-scale farmers in order to ensure that they were well-adapted to the farmers' conditions and preferences (Danial et al. this issue). The adaptation of these cultivars implies that farmers will be interested in the seed of these cultivars. This can present opportunities to overcome the complex bottleneck in the integration of formal and farmer-based seed systems. Below, the roles of the farmer-based seed system in the diffusion of seeds of PPB-cultivars are discussed.

The availability of novelty seeds, i.e., seeds of new, improved and well-adapted PPB-cultivars, may allow NAR programs to take full advantage of the potential of the farmer-seed system. It has been shown that strategically introduced small amounts of seed of new cultivars can rapidly diffuse through farmer-to-farmer seed exchange (Cromwell 1990; Grisley and Shamambo 1993; Jones et al. 2001). In addition, farmers are willing to pay a premium price for relatively small volumes of seed of new cultivars to evaluate these on-farm (Jones et al. 2001). If the cultivars are attractive, they multiply them and increase the area planted. In a crop like potato the attractiveness of small volumes of new seeds is coupled to a yield gain from virus-free high-quality seed. If farmers appreciate the cultivar, they continue growing it and they exchange seed with relatives and friends. Also in situ conservation activities in the region that aim to support conservation of crop genetic diversity can contribute to the diffusion of PPB-cultivars. Seed fairs (Scurrah et al. 1999) can for instance lower farmers' transaction costs as buyers and sellers come together and share both seeds and information about them.

At the same time, there are also factors that negatively affect farmer-to-farmer diffusion of new cultivars. First of all, the effectiveness of informal exchange mechanisms may be overestimated. These mechanisms seem to function well for potato in Peru and Bolivia (Scheidegger et al. 1989), but seed flows and exchange mechanisms of other crops are less well studied. Potato has two characteristics that favour farmer-to-farmer exchange of potato-seed tubers. First of all, potato is vegetatively propagated, which means that the genetic composition of its cultivars is fixed. In addition, the need for virus-free seed and seed with the appropriate physiological age are strong drivers of the informal seed exchange system in Peru which connects farmers at different altitudes over long distances (Scheidegger et al. 1989). In crops that depend more on farmer selection and less on altitude variation, the farmer-based seed exchange may be less dynamic and cover much smaller distances. Secondly, there are indications that the farmer-based seed system does not necessarily provide wide and inclusive access to all farmers. Different social classes can form different networks. Processes like migration of farmers and increased production for market are leading to fragmentation of seed exchange networks (Rana 2004; McGuire 2005). Poor farmers may therefore find access to seed reserves of better-off farmers not always easy. A third factor to consider is the maintenance of seed quality under local on-farm multiplication regimes. If on-farm multiplication reduces the genetic, physiological or sanitary seed quality, the yield gain of using the new cultivar will diminish, making an investment in seed by farmers less economical. Finally, it still remains to be seen how widely adapted the selected PPB cultivars are. It is suggested that PPB will yield cultivars that are well-adapted to specific local conditions. This means that their adaptation may be restricted and they may not be equally attractive to farmers in other locations. The total of these factors implies that the informal seed exchange may complement the formal sector activities but cannot be expected to replace formal seed distribution activities.

Use and provision of seed of common cultivars

Seed sources

For cultivars that are more commonly grown, farmers' own saved seed and other informal sources are the major sources for acquiring new seed lots (Almekinders and Louwaars 2002; Tripp 2001). From a study in three Meso-American countries, Almekinders et al. (1994) reported 75–80% and 60–80% of all seed lots were farmers' own saved seed in maize and beans respectively. Duijndam et al. (this issue) found for maize in the Andean parts of the Province Bolívar, Ecuador a similar situation. More than 80% of the seed lots were farmers' own saved seed. About half of the farmers buy some seed incidentally or more regularly. This seed can be of the same cultivar from elsewhere or of a different cultivar.

Quality of farmer-seed

The fact that farmers predominantly use seed produced on farm is not always a problem. A research on bean seed quality in Latin America showed that in 11 out of 13 cases farmer seed was at least as good as the seed from the formal sector (Janssen et al. 1992). Nevertheless, quality of farmer seed usually is far from optimal (although even seed from the formal sector is not always of a very high quality). In the Andean Region, the poor quality of farmer seed is often associated with pathogen contamination (Broers 1994; Duijndam et al. this issue). In cereals, the incidence of seed mixture is a factor of importance. Farmers tend to avoid roguing in order not to lose yield, thus reducing the purity of the cultivar (Coronel, personal comm.). In the case of cross-pollinating crops, like maize, quinoa and field bean, genetic degeneration plays a role: some see this genetic degeneration also as a process of genetic adaptation to the marginal growing conditions (Almekinders and Louette 2000; Bellon and Risopoulos 2001), others principally consider it a reduction of yield potential (Parlevliet 2003).

Variable farmer expertise

Improving quality of on-farm produced seed should build on farmers' knowledge and expertise. Breeders and technicians (Danial and Lindhout 2002) acknowledged that they had actually little knowledge of farmers' seed production practices and how these affected seed quality. Case studies reveal that both men and women farmers have expertise in seed selection (Almekinders et al. 1994). But studies are often anecdotal and usually give no indication of how widespread these expert practices are. It is likely that the majority of the farmers only practice a simple form of mass-selection. Data from a survey in Ecuador show that over 90% of the farmers who selected their own maize seed for next-year planting did not consider the characteristics of the mother plant. They predominantly selected after harvest for large ears with the right type of kernels, a type of selection that can easily lead to undesired lateness (Duijndam et al. this issue).

Acknowledging that farmers' expertise in production and selection practices exists, but is not necessarily widespread, raises the question of how this expertise can be identified and utilized in order to spread the benefit of PPB-cultivars to a wider group of farmers. It should also be remembered that the time that farmers invest in seed selection has an opportunity cost. Farmers who have been trained in seed selection practices seem often not to continue those practices after the project was finished, although the cost-benefit analysis of researchers shows significant economic benefit of the practice. Possibly, opportunity costs of labour have been seriously underestimated. Increasingly, farmers in developing countries have off-farm jobs and, particularly in the more heavily populated inter-Andean valleys, the nearby town provides income opportunities and farmers become weekend-farmers.

Increasing seed system integration through PPB-cultivars

The Preduza-supported workshops in Lima and Cochabamba clearly showed that with promising cultivars coming out of the PPB efforts, farmers and breeders are eager to produce and diffuse seed of these cultivars (Almekinders et al. 2004a, b). In these workshops also interest in collaboration emerged from other actors with links to the wider farmer-community, e.g., the Agencia Agria Canchis in Sicuani, the Pronamachics project in Cuzco, the Asociación de Productores de Trigo (APT) and the Oficina de Semillas in Bolivia. With these high expectations around, it is useful to reflect on the earlier experiences. Lessons learnt from earlier seed production initiatives of the type that Mazon et al. (2003) reported on in Ecuador, Peru and Bolivia are crucial inputs for new initiatives to avoid repetition of the same misinterpretation and errors. Failing projects can mean economic disasters for involved farmers.

With these considerations in mind, participants of the workshops in Cuzco, Peru, and Cochabamba, Bolivia (Danial and Lindhout 2002, Almekinders et al. 2004a, b) identified components of a strategy to diffuse seeds from PPB-cultivars. They considered that new initiatives should be based on:

- Well-planned promotion and diffusion
  - Considering that farmers lack sufficient information about available cultivars and seeds, there should be ample attention for useful and widespread information supply, for example via the radio. This should be combined with demonstration and evaluation trials at key places and with key actors.

- Collaboration among strategic partners:
  - breeders should not only be working with farmers, but also seek collaboration with market actors like middle men and the processing industry.
  - seed production and diffusion should be organized in collaboration with Non Government Organizations and projects to strategically share scarce resources.
  - involvement of the national offices in charge of the regulation of cultivar registration and seed certification. Such involvement may avoid misunderstandings and help a more flexibly functioning regulatory framework. In Bolivia, seed-regulation officers emphasized they do not want to be seen as policy enforcers, but solicit pro-active formulation of arrangements.
- Strengthening seed-producing farmers and farmer groups through:
  - capacity building and participatory research on effective seed production technology.
  - capacity building in entrepreneurial skills.

The wide range of activities and actors proposed by the breeders went well beyond their traditional way of doing business. It suggests that they are moving to what has been described recently as an innovation-system approach. This approach recognizes (i) the importance of linkages between researchers and many other actors and agencies and (ii) the need for concerted action in addressing bottlenecks, if a technological change such as the adoption of new cultivars is to be successful (Hall et al. 2003).

Conclusions

The arguments presented above provide support to continue integrating formal and farmer-based systems even though this strategy has not been very successful so far. As PPB-cultivars become available, new seed should be more attractive for more farmers. Farmers will want to buy small volumes of these novelty seeds, evaluate, multiply and exchange them with other farmers. The effectiveness of seed diffusion can be increased by understanding where strategic volumes should be introduced: farmer-to-farmer seed exchange does not automatically lead to widespread and rapid diffusion. Information about seed and cultivar characteristics does not necessarily travel with the seed in informal systems. Making sure this information reaches farmers significantly reduces transaction costs for the farmers and enhances diffusion. The PPB-cultivars linked with enhanced seed quality should provide yield gains. This will increase the incentive for farmers to invest in seed quality. However, so far, seed purchases by farmers have been small and variable, although the costs-benefit ratio, as calculated by researchers, showed favourable returns. This calls for research to better understand farmers' experiences and perception of costs and benefits of quality seed especially in marginal areas where the risk factors for investments by farmers are high.

Attractive PPB-cultivars will remove an important constraint in the seed supply to small-scale farmers, but others persist. A more holistic way of working and a well-orchestrated participation of a wider group of actors may overcome some of these. Latin America is rapidly urbanizing and new market opportunities associated with the growth of supermarkets are appearing. There is awareness on the part of breeders that for this reason, availability of quality seed needs to be accompanied by better information about new market opportunities. Partnerships with other actors like food processors or supermarket chains are needed to increase market integration and develop opportunities to capture added value. However, development of a stable seed market continues to be hindered by unfavourable market prices for the crops grown by small-scale farmers. Low, variable cash incomes from crop sales depress farmers' investment in quality seed. Some new market opportunities offer higher and more stable prices but these often impose quality and volume requirements that small farmers find hard to meet e.g. for potato chips. Under such conditions, building trust about the quality and availability of seed and ability to financially buffer variable demand and prices are crucial factors that require long term commitment of those who support the seed producing initiatives.

An important argument for a commitment to support farmer-based seed systems is their contribution to national food production. In Latin America, it is estimated that these systems contribute over 50% of the national food consumption. In addition, these seed and associated production systems provide services and goods that have value for human mankind, but are not captured in normal market mechanisms because they have public good characteristics (Gollin and Smale 1999; Weiskopf et al. 2003). Among these are the sustainable use and conservation of genetic resources and ecosystems. Support to these seed systems needs to be integrated with broader rural development policy. They need to be seen in a wider context of policies to maintain livelihoods in areas with widespread poverty and fragile, diverse ecosystems that, in Latin America, increasingly involve local-level governance institutions (Bebbington 1999; Faguet 2004).

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