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Cooperation and Innovation by Farmer Groups: Scale in the Development of Rwandan Valley Farming Systems

Michael E. Loevinsohn*

Applied Ecology Consultants, B.P. 259, Butare, Rwanda

Johnson Mugarura† & Augustin Nkusi

Projet Rizicole de Butare, B.P. 76, Butare, Rwanda

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ABSTRACT

In the densely populated Rwandan highlands, farmer groups of two organizational types participated in research on intensifying valley agriculture. 'Coopératives', farming collectively, and associations of farmers who cooperate on specific tasks both successfully integrated rice into their production systems. The latter in particular innovated so as to realize economies of scale, while expanding to accommodate new members. In contrast, the 'coopératives' proved better able to maintain the diversity of their farming systems. They were also more persistent and ultimately more successful experimenters with the difficult but scale-neutral technology of green manuring. These findings are considered in the light of current debate on agrarian reform in which the ability of small farmers to realize scale economies is a key issue.

INTRODUCTION

It is now increasingly recognized that Green Revolution-type approaches have poor prospects for wide adoption in much of sub-Saharan Africa: the diversity of ecological, agronomic and socio-economic conditions

* Present address: International Development Research Centre, 17 Jor Bagh, New Delhi 110 003, India.
† Present address: Metco Sales International Ltd, P.O. Box 8759, Kampala, Uganda.

requires an equally broad diversity of technological options. Although much remains to be done in matching research practice to rhetoric, there is also growing acceptance that participation by farmers can improve the identification and selection of alternatives, their testing being under realistic conditions and evaluation in terms that are locally meaningful (Chambers *et al.*, 1989; ILEIA, 1989).

Collaboration with farmer groups may be crucial to realizing effective participation. Enlisting groups as research partners has been found to facilitate the interaction between scientists and farmers (Norman *et al.*, 1988), to reduce the cost of on-farm research (Sperling, 1992), and to reinforce farmers' own analyses and experimentation (de Jager, 1989; Bebbington, 1991). However, the focus of research in these cases has generally been on innovations that are feasible for individuals acting alone: few accounts describe the development of alternatives whose benefits depend critically on the area over which they are practised or on the number of farmers adopting them. Exceptions can be found in the domains of irrigation management (Korten, 1982) and wide-area pest management (Loevinsohn *et al.*, 1993*a*), but in these cases farmer groups have most often been involved in the planning and implementation of pilot projects at a production scale, rather than in selecting among and testing technical options.

This paper describes the process and results of research with groups of small farmers on sustainable agricultural alternatives for highland valleys in Rwanda. We examine how groups of two contrasting organizational types responded to technological options that were either appropriable by individuals or required cooperation in varying degrees. Finally, we discuss our findings in the context of current debate in Rwanda, which finds echoes elsewhere, concerning the restructuring of agriculture, in which the capacity of small farmers to realize economies of scale in production is a key issue.

THE CONTEXT OF VALLEY BOTTOM FARMING

The Central Plateau of Rwanda is a region of rolling hills and generally well-watered valleys between 1500 and 1800 m in altitude. Population density is among the highest in Africa, with typical holdings of the order of 0.5–1.0 ha (Ministère de l'Agriculture, 1984). Highland valleys came under cultivation in the first decades of this century with the resolution of a longstanding conflict between herders and farmers and have since contributed significantly to food security. Although representing less than one-tenth of the cultivable area, the valleys are responsible for some

18% of food energy and 22% of protein production (Jones & Egli, 1984). With more assured access to water and less degraded soils, the valleys are generally capable of greater intensification than the hillsides (Ministère de l'Agriculture, 1987). Families that farm in both areas are able to spread environmental and market risks, as they do by cultivating genetically diverse varietal mixtures and crop associations.

The long dry season (June–August) is the time of most intensive valley use, but a second or third season may be possible where the risk of flooding is low. Maize, sorghum, beans, vegetables and especially sweet potato are grown on raised beds whose dimensions represent a finely calculated balance between drainage and irrigation requirements (Steenhuis, 1987). Dry season cultivation of sweet potato in the valleys ensures a continuous supply of planting material and has made possible a marked expansion of the crop on the hills (Jones & Egli, 1984).

Valley land is state property on which individuals enjoy only usufruct rights. 'Coopératives', formalized groupings expected to cultivate collectively, are favoured by government in the granting of parcels (Runyinya, 1987), often at the expense of independent farmers. Land may also be accorded to state or parastatal enterprises which then organize farmers around cash crop production, specifying techniques and ensuring inputs and marketing.

The Projet Rizicole de Butare (PRB) manages some 750 ha of rice paddies at around 1400 m altitude on the eastern edge of the Plateau. Low yields (the two annual harvests average 2.5–3.5 t/ha) and high production costs due to inefficient use of chemical inputs, expensive hydraulic infrastructure and overstaffing have threatened the project's objective of reducing dependence on imported rice. It was with a view to exploring the feasibility of farmer-managed, low input rice production in higher altitude valleys that the project supported the research here described. The scarcity of resources (3 person days/week of both researcher and technician time) and the diversity of conditions in highland valleys helped convince PRB management of the utility of participatory approaches.

METHODS

We began by conducting rapid appraisals of valley bottom agriculture in several communes of Butare Prefecture in the heart of the Central Plateau. In semi-structured interviews with farmers whom we approached in their valley fields, we asked about current agricultural practices and how they had evolved, the extent of cooperation within and among

households and the links between hill and valley cultivation. Where interest in further collaboration appeared real, we asked if it was possible to organize a meeting of those cultivating contiguously in a part of the valley.

These larger meetings, attracting 30 or more farmers and local authorities, focused on the problems people were encountering in the valleys and the options they saw for dealing with them. Most frequently cited among the constraints were the extreme shortage of land and insecurity of tenure, declining soil fertility and difficulties in drainage or irrigation. The solutions envisaged for the most part involved intensifying what was already being done, for example, renting more land (though cash was scarce) and using more compost or manure (though supply was limited and employed preferentially on hillside fields).

We were asked what solutions we saw and offered some ideas. Rice might help make more productive use of available land. It might be grown in paddies or in the uncultivated drains between their raised beds (a farmer was observed trying this with a handful of seed in one valley and Javanese farmers have a similar system known as 'sorjan') (Suryatna *et al.*, 1979). Would they like to try? We emphasized the range of ways rice could be integrated into their farming systems while maintaining or increasing crop diversity. For example, peripheral canals to improve irrigation could equally serve fish ponds, which might also be fertilized with rice straw. The choice of option, and its risks (primarily cold sterility and disease in the case of rice) would be theirs; we undertook to provide seeds and advice, but could only work with groups. We made no stipulations, however, about their size or form.

In a similar manner we discussed fertility management options. Two indigenous species of the leguminous tree *Sesbania* are exploited for forage and medicine and might be used as well as green manures. Although trials in highland valleys had shown *Sesbania* to be more productive than other agroforestry species (ISAR, 1986), no formal research had been conducted on green manuring in these systems. We described the Asian practice of sowing *Sesbania* in paddies after harvest, incorporating it before transplanting the next crop (Singh, 1984). Other possibilities included intercropping *Sesbania* on raised beds or planting it along their margins.

Four groups, of two organizational types, agreed to work with us (Table 1). As indicated earlier, the 'coopératives' in fact manage their land collectively, whereas farmers in the informal associations cooperate as and when their members see fit. Although situated within a radius of only 6 km, the groups differed markedly in their economic orientation and cropping pattern, as did their valleys in terms of soil, topography and hydrology.

TABLE 1
Characteristics of the Groups Participating in the Research and of their Valleys

Attribute	*Group*		
	Cyamuginga	*Gatovu*	*Rujangari (I and II)*
Type of group	Informal association[a]	Informal association[a]	'Cooperatives'[b]
Orientation	Subsistence/commercial	Subsistence	Commercial/subsistence
Initial members	20	24	7 and 13
Initial area per member	250 m^2	250 m^2	430 and 300 m^2
Dominant cropping pattern initially	Eggplant, sweet potato (rotation)	Sweet potato (monoculture)	Sweet potato, sorghum, maize, beans, vegetables (intercrop/rotation)
Harvests/year	2	1	Staggered
Dominant soils	Clay/sand	Organic (peat)	Mineral/clay
Valley topography	Wide with deep central stream	Narrow, steep sided	Broad bowl near head
Risk of flooding	Moderate	High	Low
Water source	Stream	Stream and spring	2 streams and spring
Altitude	1600 m	1640 m	1610 m

[a]Created by farmers at the beginning of this work.
[b]In existence for 1 and 6 years, prior to this work.

We encouraged innovation by several means. (1) During weekly visits to the valleys, we met groups or individuals, examined the progress of their experiments and discussed further ones. Experiments were either jointly- or farmer-designed, but always farmer-managed. For example, in three seasons, we made available trial quantities of nine cold-tolerant rice varieties. Farmers could try as many as they wished; we asked only that they include a check. (2) A 'travelling seminar' was held each season, in which groups visited each other and explained the experiments they were conducting. Time was set aside for a general discussion where the advantages of different options were debated. (3) In 1989, representatives of the groups were brought to the 'perimètres' to observe farmers' fields and researcher-managed experiments. These latter focused on themes the farmers were themselves pursuing: biological fertilization and varietal selection. Farmers chose from these trials varieties and practices they wished to try in their own fields. Restrictions on travel following the outbreak of war in October 1990 prevented us from continuing the practice.

RESULTS

Options with important scale economies

Rice culture and its organization

Appropriation of rice by each of the groups has been rapid, though no more than a handful of farmers had previously had direct experience of the crop. Marked improvements in irrigation, land preparation, transplanting and crop protection have been evident and are largely responsible for the increase in mean yields from 2 t/ha in the first season to 3–4 t/ha subsequently (Fig. 1). Yields have not differed significantly between the associations and 'coopératives' ($F_{1,8}$=1.79, ns). This production has been obtained without external inputs and thus far with little reliance on biological fertilization. As in the lower altitude 'perimètres', yields are constrained during the long rainy season (March–May) by diseases, primarily blast (*Pyricularia oryzae*) and sheath rot (mostly *Sarocladium* spp.).

Farmers are impressed by the productivity of rice, comparing it favourably to alternative crops, despite the greater labour requirements. A survey of neighbouring farms in February 1991 found that gross economic returns to rice were greater than for any other crop harvested at that time. The 'coopératives' sold some 80% of their production on the local market that season and the Cyamuginga association just over 50%; farmers in Gatovu apparently reserved all their harvest for consumption.

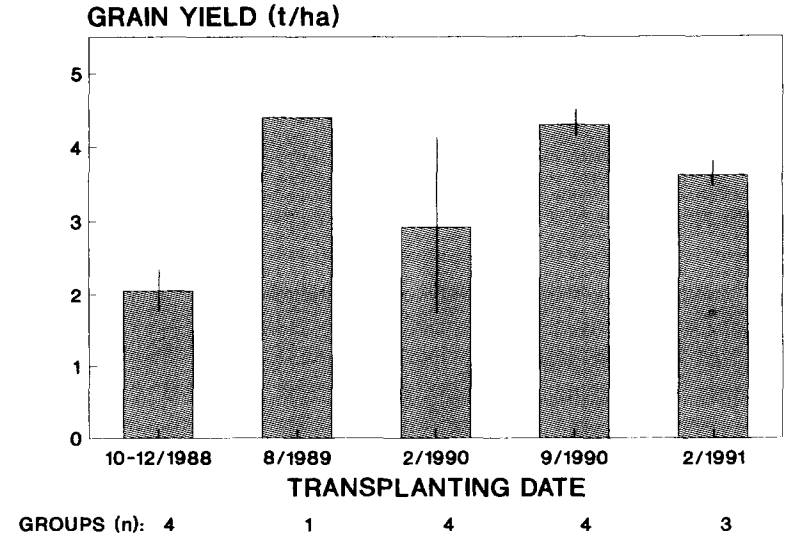

Fig. 1. Mean rice yields among farmer groups by season. Production was measured by researchers generally on > 50% of a group's fields. The bars indicate ± 1 standard error.

One index of the attractiveness of rice is the increase in group membership: 68% in the associations, 25% in the less open 'coopératives' over the first two years.

Farmers recognize economies of scale in several aspects of rice production. Organizing to meet these opportunities has required innovation, particularly on the part of the associations whose members previously farmed independently and which are larger and have grown faster than the 'coopératives'. Changes have been most apparent in irrigation. Stimulated by the first 'travelling seminar', all four groups constructed peripheral canals, up to 1 km in length, that efficiently feed each field. Beyond organizing construction, the associations have faced challenges in ensuring equitable access to water. By the second season, both had elected coordinators, two or three per group, responsible for mobilizing members for irrigation maintenance and, when necessary, enforcing cash or labour penalties (such provisions already existed in the 'coopératives' when we arrived). However, this has not entirely discouraged 'free-riders', people who evade cooperative work knowing others will complete it. The problem was most marked in Cyamuginga, where large stream volumes during the 1990 long rains necessitated frequent repairs to the simple sandbag-reinforced dam. The group has since largely avoided the problem by cultivating rice during the short rains, a strategy also favoured for agronomic and economic reasons. In the Gatovu association, new members at the end of the canal suffered drought because of inadequate irrigation flows and excessive water use by those upstream. The problem has been resolved by building a second dam to serve them.

The search for appropriate scales of cooperation can be seen in other production tasks. In both Gatovu and Cyamuginga, rice nurseries are now maintained by groups of 10–15, which more equitably share seedlings than was possible with a single nursery. On the other hand, children generally guard against granivorous birds on two or three adjacent holdings, roughly corresponding to the range of a thrown stone.

The associations have resisted calls from local officials to form 'coopératives', in large measure because they wish to avoid the close structure and full panoply of officers, though they do seek protection from expropriation. Farmers cite the brief lifespan of many 'coopératives', often created simply to obtain land. The Rujangari 'coopératives' may owe their survival to flexibility and the devolution of some responsibilities to members. While tasks with important scale economies, like irrigation maintenance and seedbed preparation, are always done together, smaller rice fields may be cultivated by individuals for their own subsistence. The larger fields are collectively cultivated for the market.

Diversified production systems

Each of the groups has experimented with the risk-reducing, diversity-preserving 'sorjan', but paddies have been, from the first, the preferred approach to growing rice. The reasons farmers give invariably coincide: the space available between their raised beds does not justify digging a canal, building a dam and sowing a seedbed, all of which could equally serve a larger area. However, in recent seasons, an association and a 'coopérative' have employed the 'sorjan' alongside or after paddies, thus benefitting from the infrastructure already created. While widespread use of the 'sorjan' would permit even greater land-use intensity, the introduction of paddies has reduced the uncultivated area to 11% of bottom land from 32% when raised beds are employed (n = 15 and 13 holdings, respectively, t = 9.5, $P < 0.001$).

Although their responses to the 'sorjan' have been similar, the associations and 'coopératives' diverge in the land-use strategies they are evolving. The former devote essentially 100% of the land available on a seasonal basis to rice cultivation: in Gatovu, rice now follows rice, while in Cyamuginga farmers plant other crops on raised beds rebuilt in the paddies during the long rains (Fig. 2). In contrast, the two 'coopératives' have maintained roughly constant, at between 25% and 40% of their holdings, the area planted to rice. Their cropping patterns conserve

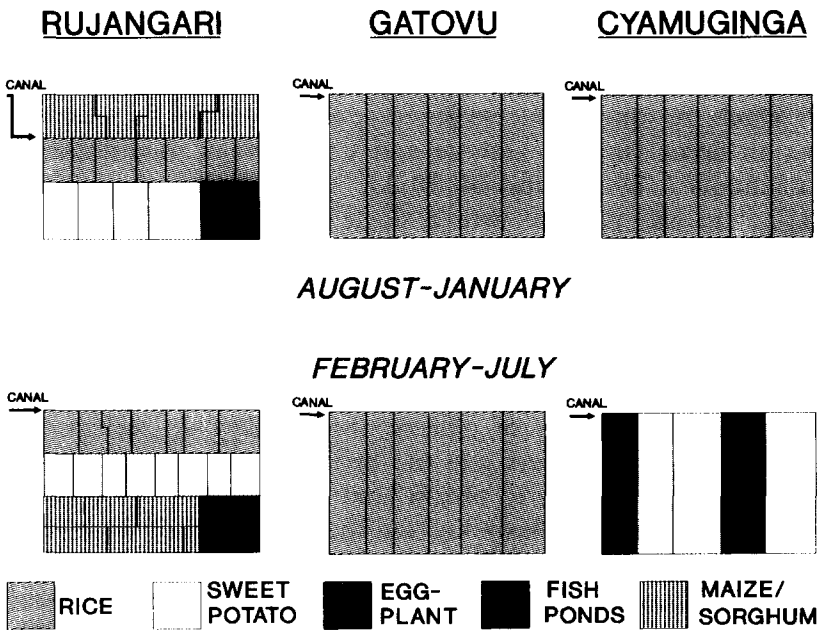

Fig. 2. Schematic diagram of rotations practised by farmer groups.

greater diversity: rice is present in all seasons, but is generally rotated between fields. Again, this involves building and then dismantling raised beds, a highly labour-intensive procedure.

The cropping patterns emerging in the four groups represent recognizable modifications of those that existed before the advent of rice: in Gatovu, for example, a single-season monoculture of sweet potato has given way to uniform double-cropping of rice. In part, cropping patterns respond to physical constraints. Gatovu farmers explain that nothing but rice supports the flooding they experience during the long rains, whereas the more moderate conditions in Rujangari permit greater crop diversity. However, differences in the scale of management also play a role in this variation: certain land-use options have minimum area requirements, such as fish ponds, and are difficult if not impossible to implement on an individual 250 m^2 holding, particularly if one wants to do rice at the same time. Other considerations encouraging wide and uniform rice cultivation are the difficulties intervening raised beds create for irrigation and the refuge they provide for granivorous birds.

The maintenance of diversity has been a recurring theme in discussions within and among the groups. Some farmers in Gatovu and Cyamuginga have suggested that their associations divide into contiguous rice and raised bed areas, rotating seasonally as in Rujangari, in order to spread risks, ensure a source of sweet potato cuttings for the hills and pursue speculative ventures (such as highly profitable out-of-season maize), while facilitating irrigation and crop protection. The idea has not received general support: most farmers see rice as the 'best bet' and are unwilling to accept the second best 'for the good of the group'. Our arguments that double cropping risks aggravating disease and fertility problems have not proved persuasive, at least in Gatovu: farmers are not convinced of the imminence of these threats and point to the double cropping long practised in PRB's 'perimètres'.

Options without important scale economies

Varietal testing

From the beginning, farmers have recognized the need to identify rice varieties adapted to their high altitude conditions. Of the two cultivars planted the first season, one, from Madagascar, suffered more than 80% grain sterility due to cold, while the other, from Yunnan in China, proved susceptible to blast and sheath rot. Farmers in all groups were eager to test the seven cold-tolerant varieties of diverse origin that were made available in September 1989 and the further two the next year.

Trials were generally well laid, permitting valid comparisons. The

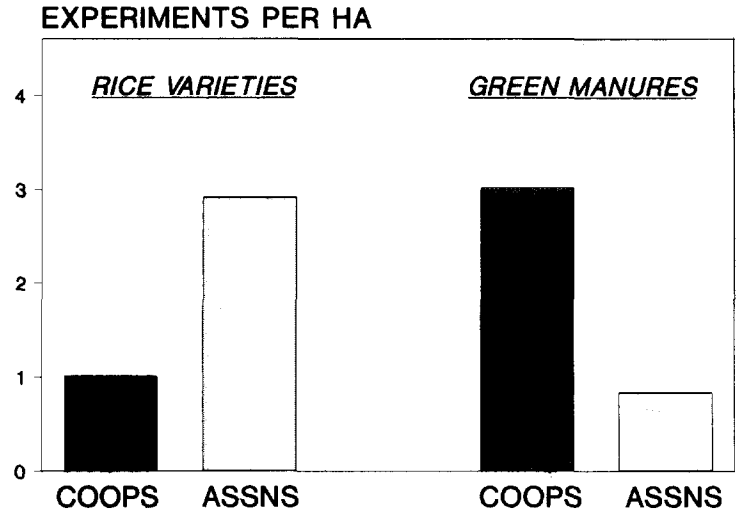

Fig. 3. Frequency of experimentation in farmer groups of different organizational type. Values are means over two seasons in the case of rice varieties and over three years in the case of green manures.

collectively managed experiments in the 'coopératives' were on average larger than in the associations, where they were the responsibility of individuals, but equally well tended. Farmers' interest in varietal selection, as indicated by the frequency of experimentation, was greater, though not significantly so, in the associations than in the 'coopératives' (Fig. 3; $F_{1,6} = 2.27$, $P = 0.18$). The first set of trials and farmers' observations of on-station trials in November 1989 resulted in the selection of a Yunnanese variety, Yuner Tian, which continues to be the most widely planted.

Biological fertilization

The groups have also experimented with green manures, primarily the two *Sesbania* species†. Although farmers have at times observed impressive growth rates, up to 87 t/ha fresh weight in four months, the trees' performance has been highly uneven, due to poor germination and nodulation, inadequate drainage and seasonally devastating pest attack. Countermeasures have proven only partially successful. On-station, *Sesbania* sown in paddies after harvest produced up to 5.5 t/ha fresh weight in 60 days, with a significant yield effect on the following rice crop (Loevinsohn *et al.*, 1993b); when farmers in Rujangari tried the same approach, they found the green manure not worth incorporating.

†The groups also received one strain of Azolla, an aquatic fern that fixes nitrogen through its association with a blue-green alga. It appeared poorly adapted to the plateau valleys and had disappeared by the end of the first season.

While in each of the groups there have been numerous attempts to grow *Sesbania*, making use of unproductive areas or short fallows, there have been far fewer instances where farmers have persisted in the face of the above problems to find ways of producing useful quantities of green manure. The 'coopératives', however, have been notably more successful in sustaining interest than the associations, with a frequency of experiments involving soil incorporation more than 3.5 times greater over the three years of our collaboration (Fig. 3; $F_{1,10} = 6.35$, $P = 0.03$).

Inherent scale effects of the technology do not appear responsible for this difference. More significant may be the closer and continuous work relationships in the 'coopératives' which aid in maintaining a common purpose when the interest of some individuals wanes. After the leader of the first Rujangari 'coopérative' reported that the group was no longer interested in research with *Sesbania*, we were told the next week, by another member, that they still wished to pursue some ideas. It is this group that has identified and developed what appears the most promising option to date, in which *Sesbania* is sown between sweet potato mounds, then incorporated *in situ* or in neighbouring fields. Maize yield was increased 30% in this way in one trial. Group support is of lesser importance in experimenting with varieties, a straightforward and well understood technology.

DISCUSSION

The diverse ways in which farmers have integrated rice into their production systems reflect the diversity of their physical and socio-economic conditions, underlining once again the need to ensure that a wide range of technological options are available to on-farm research. In collaborating with farmers from the earliest stages, we avoided investing time and effort in seemingly appropriate techniques that would later prove unacceptable. The 'sorjan' is a case in point: it appeared to offer a low-risk means of increasing the intensity of land use while conserving crop diversity. Farmers, however, were prepared to take a much larger step: many, including some of the poorest, turned all their valley land into paddies to accommodate a crop they had never before grown. We doubt whether, even with substantially greater research resources, it would have been possible to predict this response, which belies the common image of the risk-averse peasant. On the other hand, had we attempted to design technology in isolation before taking it on-farm, it is unlikely we would have considered the method employed in several groups to rotate rice and other crops. Building and then destroying raised beds is prodigiously

demanding of labour when considered on a hectare basis, but appears acceptable to farmers who manage only a few hundred square meters.

The joint evaluation by farmers of technological options that each has been testing on his/her own farm is a central feature of participatory research (Norman *et al.*, 1988; Chambers *et al.*, 1989). Such fora are particularly important in the development of elements of the farming system that may be coordinated between neighbouring farms, such as cropping patterns and calendars (as here, for example, to avoid bird damage) or whose scale exceeds the limits of individual holdings, such as irrigation management. Individuals will generally have immediate experience of just one such option and it is only by bringing groups together from different areas, as we did with the 'travelling seminars', that comparison among options is possible. These innovations are also the most difficult to test on-station and are likely to have important effects on other elements of the production system. By enlarging the base of comparison through group interaction, research and extension can help hasten technological evolution.

The integration of rice into these highland valleys has required innovation in organization, particularly on the part of those farmers who previously farmed independently. Their success in these terms is, we believe, largely due to the significant benefits they derive from cultivating rice and the relative evenness with which these benefits are distributed within the groups, two factors that Wade (1987) identified as crucial for sustained cooperative action. The associations were able to effectively realize economies of scale in rice production, lack of attention to which may explain the failure of earlier attempts to introduce the crop in the Central Plateau. They were also more successful than the 'coopératives' in accommodating new members. Follow-up in late 1992, a year after the research project ended, found new associations had been spawned up and downstream of the existing ones.

Although based on a small sample of groups, our findings suggest that the quality and not only the scale of cooperation affects the innovations that can be developed. Collective management makes possible a degree of crop diversity that escapes farmers in the associations. The minute size of holdings in the valleys severely limits the choices open to individuals but their situation is not unusual: larger Asian rice farmers find themselves similarly constrained, particularly by irrigation-related factors, in diverging from the prevailing cropping pattern (Barghouti *et al.*, 1990).

The relative success of the 'coopératives' in experimenting with the scale-neutral but difficult technology of green manuring also bears consideration, particularly in light of the disappointing adoption of fertility-enhancing agroforestry techniques in many parts of Africa (Scherr, 1991). Our analysis suggests that self-structured groups with demon-

strated cohesion and regular contact, possibly for reasons other than joint cultivation, make more persistent and dynamic research partners than those whose members have little ongoing relationship, for example where they are selected by scientists (Norman *et al.*, 1988).

Local institutions are now discussing how to build on these results in a larger extension program in the Central Plateau. A major challenge will be to maintain the flexibility in presenting technological options, where extension workers have generally been expected to transmit simple messages in a large number of domains. However, the utilization of our findings will also be affected by the outcome of current debate on agrarian reform in Rwanda. The Commission Nationale d'Agriculture (1990) contends that the minuscule size of valley holdings precludes significant technological advance and proposes that most valleys be cultivated by large, commercially oriented groups of farmers who will have surrendered their hillside fields. Our work suggests that even the smallest farmers have a capacity for innovation that includes a willingness to associate so as to realize scale economies. Except in bringing the valleys under cultivation, agriculture as commonly practised has not placed much demand on that capacity. An alternative to the Commission's proposal would involve presenting farmers new options that make co-operation worthwhile, then giving them the time to adapt the technology to local conditions and their organization to the new possibilities. In this way it may be possible to avoid the harm radical restructuring can cause to households now dependent on both hill and valley.

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