# Chapter 3

## Sustainable Agriculture and Natural Resource Management in Farm Enterprise Systems

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Farm enterprises, especially those in developing countries, take on a large variety of activities. They may grow a number of rain-fed and irrigated crops for both home consumption and sale, raise two or three kinds of livestock on their own land or on common pasture, and gather wood for fuel and construction—and those are only the on-farm operations. Family members may also be engaged in education or employment off the farm. Among these various possibilities, household members must decide which activities to undertake and how, and they do not make their decisions in isolation. They are guided, sometimes forced, to one decision or another by considerations arising from aspects in their wider context, such as cultural norms, market conditions, technological possibilities, and land and water rights. It is because of the interconnectedness of farming activities and their links with off-farm environments that a farm is a system and not simply a bundle of operations collected together. Viewing a farm as a system is not new, and over the years the system has been presented in many different ways. As in the other chapters in this book, the focus is on decision making for adaptive management as it bears on agricultural livelihoods using natural resource management practices and improving sustainability through innovations in farming practices.

## Overview of the Farm Enterprise as a System

Figure 1 illustrates the farm enterprise system as it will be discussed here. This way of depicting the farm enterprise characterizes the system as a set of interacting components and influences on farm decisions. Also like other, similar diagrams, it is a less-than-perfect representation because it simplifies to bring out key points. It would be easy to complicate this one by, for example, adding arrows to show that output markets (box on the right) influence production possibilities and risk (oval on the left), but too much detail can be distracting. There are several features that this diagram aims to highlight in particular:

- ***The core elements of the farm enterprise make up a circular system, or feedback loop.*** Clearly farm level resources—most broadly its land, labor, and capital—are crucial in determining what a farm can produce, or its production possibilities. Furthermore, these resources can be augmented or diminished depending on how good farmers' management decisions are in raising the level of farm production and allocating it between household consumption, direct reinvestment back into farm resources (e.g., as seed or animal feed),

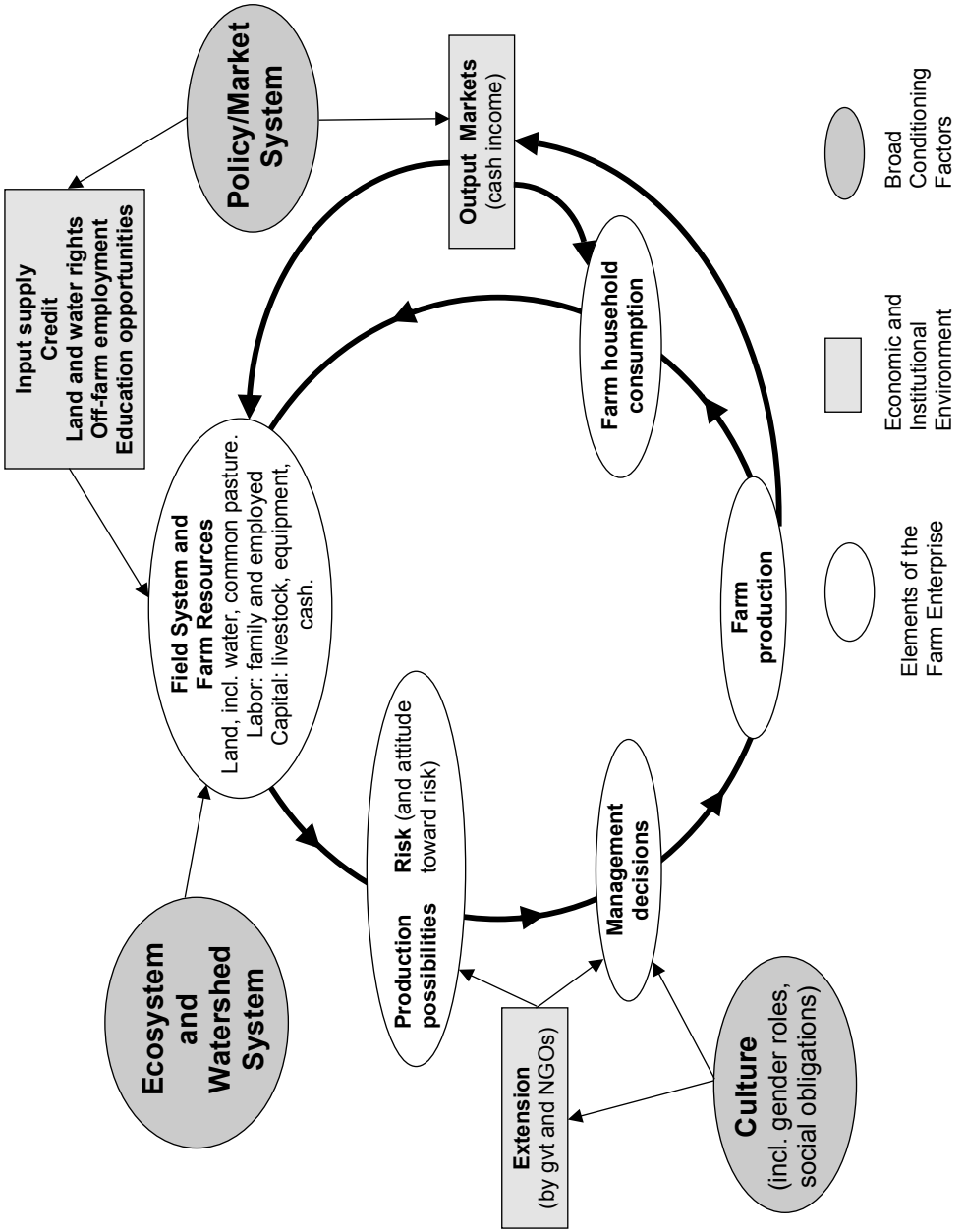


**Figure 1. Factors affecting farm enterprise decisions.**

and sales for cash to purchase more resources. Farmers will naturally be inclined to adopt innovations that they see as likely to have a positive effect on current livelihoods and future farm resources.

- ***There is an economic and institutional environment that is external to farms but has a very large effect on farmers' ability and incentive to make good use of their resources.*** The quality of advice that extension services provide influences the range of choices that farmers face and their ability to make wise decisions regarding them. Output markets and other aspects of the economic and institutional environment (input supply, credit) condition farmers' ability and incentive to convert production into cash income and shape farmers' choices of what, when, and how to produce. They also condition what farming innovations are appropriate or inappropriate to promote.
- ***Risk, and how it affects farmers' assessments of their production possibilities, emanate in large part from objective conditions, especially the nature of farm resources at their disposal and the farm's economic and institutional environment.*** Writers on technical change in agriculture have often put farmers into categories depending on their readiness to adopt new practices, attaching labels to them such as innovator, follower, or laggard. These terms allude to the psychological makeup of the people concerned, implying that they were somehow born with a greater or lesser eagerness to adopt change. However, while some farmers may be innately more or less timid than others in welcoming new possibilities, the resources they have available and the context in which they operate make for circumstances that can be objectively more or less risky. Recognizing this will help extension agents and implementers of projects determine what innovations they should or should not suggest.

  (Economic literature commonly makes a distinction between risk and uncertainty. Risk applies where a probability can be attached to the occurrence of an event, and uncertainty arises where no such probability can be assigned. For example, past experience may have told farmers that rainfall reaches 500 mm four out of every five years, so (if the year-to-year distribution is random) there is a 20% probability that in any given year rainfall will be less than 500 mm. Now, with climate change, farmers may observe that this pattern is less reliable; that is, uncertainty is creeping in where before they could calculate risk. This chapter only refers to risk, effectively presuming that farmers can assign probabilities, either objective or subjective, to different outcomes that are possible in their future.)
- ***Cultural influences are inherent in how farm households perceive and organize themselves and how extension services advise them.*** They are also the most difficult for communities themselves to take into account. It has been said that trying to be aware of one's own culture is like trying to smell one's own breath. Each person's culture seems to be the natural way to perceive the world until he or she notices that other people have different perceptions. Promoters of innovations commonly come from outside the regions where they are working (even extension agents are often from other areas of the country) and must not presume that what seems natural to them will seem natural to local farmers.

It is also easy to show in this diagram how the inner and outer nested systems impinge on the farm enterprise. Field systems are clearly part of the farm, influencing the nature of resources at its disposal. Farm resources are also affected by the watershed system and ecosystem within which the farm is located, while the policy-market system determines the structure and functioning of the output and input markets and other components of the economic and institutional environment.

The following sections in this chapter look more closely at how the nature of the farm enterprise system, the economic and institutional environment, risk, and culture affect management decisions and resource use. As smallholders are so often lumped together as if they were a homogeneous group, data will be presented that illustrate the considerable variability among them. Generally the facts and figures refer to differences among countries, but similar variability also exists within countries and, as extension workers well know, within most villages.

## Farm-Level Resources and Decisions on Natural Resource Management Practices

### Arable Land

While smallholders by definition own only modest amounts of land, there are differences in the size of landholdings among them that are important. Table 1 illustrates this, using figures from Africa. In the left-hand column, average land per household is less than 3 hectares for all countries but varies from 2.76 hectares in Zambia to about one-fourth of that, 0.71 hectares, in Rwanda. Looking at the amount of land per capita (i.e., per household member), the variations within each country are even greater, and the smallest farms have very little land at all. Malawi has the least uneven distribution, with the area per person in the top quartile being only seven and a half times that of the area in the lowest quartile. In Rwanda, which like Malawi is very small and densely populated, and in Ethiopia, people in the highest quartile have about 20 times more land than people in the lowest.

The amount of land plays a role in determining what resource management decisions are appropriate to farmers, and appropriate innovations cannot necessarily be uniform at even the most local level. For one thing, farmers with just enough land to subsist on in a good year are likely to perceive any modification in farm practices as much riskier than farmers who probably will not starve if they suffer some crop failure. Farmers at risk will want to be more certain of a favorable outcome to any change they make. Risks also vary with different forms of land tenure, as a later section of this chapter will show.

Another point is that what kind of innovation is appropriate will vary with the size of a farm's landholding. For example, interplanting maize with beans or other leguminous crops is a common practice that increases yields per hectare. This is a particularly valuable practice where land is

**Table 1. Variations in household access to land in Africa.**

| Country | Avg. land per household (ha) | Household land access per capita by quartile (ha) | | | | | Highest/ lowest raio |
|---|---|---|---|---|---|---|---|
| | | Avg. | Lowest 25% | Low-mid 25% | High- mid 25% | Highest 25% | |
| Ethiopia | 1.17 | 0.24 | 0.03 | 0.12 | 0.22 | 0.58 | 19.3 |
| Kenya | 2.65 | 0.41 | 0.08 | 0.17 | 0.31 | 1.10 | 13.8 |
| Malawi | 0.99 | 0.22 | 0.08 | 0.15 | 0.25 | 0.60 | 7.5 |
| Mozambique | 2.10 | 0.48 | 0.10 | 0.26 | 0.40 | 1.16 | 11.6 |
| Rwanda | 0.71 | 0.16 | 0.02 | 0.06 | 0.13 | 0.43 | 21.5 |
| Zambia | 2.76 | 0.56 | 0.12 | 0.12 | 0.26 | 1.36 | 11.3 |

Source: Extracted from table 3.1 in Economic Commission for Africa, 2004. Original data from Jayne et al. (2001).

scarce, and it is no accident that there is special interest in testing and extending variations of this technique in countries such as Malawi where the average amount of land per household is less than a hectare. Where farmers have more land at their disposal, they are likely to be more interested in improved fallows—for example, covering their land in seasons between food crops with a leguminous shrub such as *Tephrosia vogelii*.

## Pasture and Livestock

Farms in some countries have at their disposal only the land to which members of the household have private title, but in many countries they also have access to common pastureland. Table 2 shows that the amount of pasture available relative to arable land varies immensely. How much pasture a country has depends partly on the density of population, for people plow up pastureland to plant crops when population expands. It also depends on the quality of land. When land is poor in fertility or rainfall is low, the best way to turn the land to economic benefit is to run livestock on it. In Mali the pasture is mainly in the Sahel—the area just south of the Sahara desert where rainfall is uncertain and the land poor. There are similar dry areas where pasture is important in Bolivia (the Altiplano), China (Tibet and Inner Mongolia), and southern Africa (around the Kalahari and Namib deserts).

Pasture gives rise to possibilities beyond simply adding livestock raising, for with animals comes the potential for fertilizing with manure. A number of field trials applying manure to millet were run in the Sahel under Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program Phase II, and a computer model was also developed to simulate the experiment (Badini et al. 2005; Wyeth et al. 2005). According to the latter, applying two tons of cattle manure per hectare could raise millet yield from 505 metric tons (mt) obtainable on an unfertilized field to 991 mt. The impact of manure from sheep and goats was slightly greater. A variation of this practice is to corral animals on fields for several nights after harvest, allowing them to graze on crop residues and, in return, contribute both their manure and their nitrogen-rich urine to the land. It is easy for livestock owners to adopt these practices, and farmers who have no

**Table 2. Availability of pasture and arable land (FAO Statistical Yearbook 2004).**

| Country | Pasture (1,000 ha) | Arable (1,000 ha) | Ratio |
|---|---|---|---|
| Malawi | 1,850 | 2,100 | 0.88 |
| Mali | 30,000 | 4,634 | 6.47 |
| Rwanda | 520 | 900 | 0.58 |
| Zambia | 30,000 | 5,260 | 5.70 |
| Bolivia | 33,831 | 2,928 | 11.55 |
| Ecuador | 5,087 | 1,616 | 3.15 |
| El Salvador | 794 | 640 | 1.24 |
| Guatemala | 2,602 | 1,360 | 1.91 |
| Cambodia | 1,500 | 3,700 | 0.41 |
| China | 400,001 | 137,124 | 2.92 |
| India | 11,040 | 161,785 | 0.07 |
| Indonesia | 11,177 | 20,500 | 0.55 |
| Pakistan | 5,000 | 21,302 | 0.23 |

livestock can come to arrangements with others in the area who do. In the corralling experiment in Mali, the animals came from herders with whom the crop farmers had earlier been in active dispute over access to land and water. In this case researchers and extension workers helped the two groups to see that they could manage their different resources to bring mutual benefit rather than conflict.

## Water and Irrigation

The enormous variation in access to water for irrigation between countries (table 3) is seen also within countries and even villages, depending on proximity to rivers and streams and the depth of the water table. These factors also determine what irrigation methods can be used. Where water can be diverted from rivers or streams that run during the dry season, farmers can irrigate substantial areas to produce relatively low-value staple crops. Paddy rice across all continents is a classic example, and wheat in Afghanistan is another. Where fields are above streams or there is water in shallow wells, farmers can use treadle pumps (small foot pumps) to move it to where they need it.

As the textbox on the following page shows, whether to invest in a piece of equipment even as apparently modest as a treadle pump requires consideration of a number of factors. Further, while the view that irrigation reduces risk is generally true, it is not always so. Risk reduction is sometimes the specific justification for investment in irrigation: to water staple crops when rainfall is below normal, for example, or to reduce dependence on rainfed crops by making it possible to grow other crops during the dry season. However, if the aim is to make money by growing crops for market, as the case in the box indicates, the buyers must be there, and this is not always the case. Irrigation almost inevitably involves some kind of investment, at least in labor time and usually in cash for seed, fertilizer, and other variable inputs in addition to paying for the equipment. This increases the farmer's vulnerability to loss.

**Table 3. Irrigated land as a percentage of arable land (FAO Statistical Yearbook 2004).**

| Country | Irrigated as % of arable land |
|---|---|
| Malawi | 1% |
| Mali | 3% |
| Rwanda | <1% |
| Zambia | 1% |
| Bolivia | 4% |
| Ecuador | 29% |
| El Salvador | 5% |
| Guatemala | 7% |
| Cambodia | 7% |
| China | 37% |
| India | 34% |
| Indonesia | 14% |
| Pakistan | 82% |

### A decision to use a treadle pump depends on more than water

Factors other than the presence and nature of a water source affect ability to profit from a treadle pump. To begin with, $70 to $120 of capital is needed, an amount only some farmers can afford out of household funds. Others will need access to credit, which depends on the governance and policy context; or a gift of a pump from government agencies or nongovernmental organizations.

Farmers also need to be assured of the substantial amount of labor needed to operate the pumps. Clearly this varies according to the nature of the crops to be grown and how well drained the soil is, but one rule of thumb is that about five hours of labor are needed to irrigate 3,000 square meters of land if it is well laid out (Hayes et al. 2002, p. 15), and this is necessary up to three times a week, again depending on the crop, how mature it is, and the soil. Many or most farm households face labor constraints and will find it necessary to make a tradeoff between adopting this technique and taking an opportunity to earn money off the farm or, where the treadle pump can be operated by children (some can, some cannot), sending their children to school.

When deciding whether to irrigate, farers should also take into account how well they understand the technique they want to use, and this turns on the availability of extension advice from government and nongovernmental agencies or other farmers. Where treadle pumps have been distributed without ensuring that farmers learn how to manage them, fields have been unevenly watered, water and labor wasted, stream banks damaged, and yields and profits poor, discouraging their further spread. Similar considerations apply to the drip irrigation systems that are increasingly the irrigation technique of choice for smallholders.

Output markets are also important here. Even when optimally managed, the capital outlay and sheer effort that treadle pumps and drip irrigation require represent a substantial cost to farmers. Consequently, they grow high-value crops to earn a good return, often vegetables to be sold fresh in local markets. Farmers who adopt treadle pumps early and are among the first to produce during the dry season make good profits, but as others in the area follow their example and increase supply, margins decline. At this stage, farmers begin to want advice not only on production but also on marketing. Extension agents typically have no training themselves in how to spot market opportunities and take advantage of them, or even how to calculate profits from crops grown for cash. This is a good example of how progress in developing one part of a farming system can produce a bottleneck in another part of it, and marketing is receiving increasing attention from donors and organizations engaged in agricultural development.

## Livestock and Equipment

Part of how livestock enters into the farm-level system was covered above when pasture was considered. Here, among farm resources, animals are classed with equipment and buildings as capital items. In general, the more diverse or plentiful the capital, the less risky the enterprise. A farm with livestock as well as arable land will be less vulnerable to any particular crop or livestock disease than one with only animals or crops, though diversity will be less protection against serious floods or drought. A farm that has more equipment and buildings of an appropriate kind

and in reasonable condition can produce more than one with less. For example, a farm with good granaries can store its staple crops for later sale or its own use, and a farm with a plow and draft animals can cultivate more land than one without. On the other hand, the other side of a capital asset is debt. When farmers take on a heavy amount to buy capital items, their increased obligations to off-farm creditors place them in a risky situation, for bad weather or an epidemic could leave them unable to pay their creditors.

## Labor and Family Dependents

The household comprises males and females of different ages with varying levels of education and skill. In the context of a farm enterprise, household members can scarcely be considered without bringing in cultural considerations and the influence they have on the roles that men, women, and children are expected to play. More will be said on the age and gender division of labor in the section on culture. Here, the focus is on essentially quantitative considerations: the amount of labor available to the farm and the number of consumers in the household.

The dependency ratio (most generally, the number of people who have to be cared for in a household divided by the number of workers in it) is a good summary statistic that is probably as important to a farm as the amount of land it has available. This figure is bound to vary greatly from household to household, depending especially on the age (and vigor) of household members. Table 4 shows that dependency ratios vary substantially from one country to another, though most are between 1 and 2. Further, in 7 out of the 10 cases in the table the dependency ratio is larger for households headed by females than for those headed by males. Dependency ratios can be significant to extension agents and project implementers for at least two reasons. One is that a higher ratio will generally mean greater vulnerability to crop loss due to adverse weather or innovations that turn out badly. A farm family comprising a recently widowed mother and five young children will not be the best to experiment with an innovation where the outcome is uncertain, such as intercropping millet with a legume in an area where annual rainfall is variable. The second point is that labor is likely to be in shorter supply in a female-headed household. Even if the household has considerable livestock, a

**Table 4. Dependency ratios in male-headed households (MHH) and female-headed households (FHH) (extracted from tables 1 and 2 in Quisumbing et al. 2001).**

| Country | Year of survey | Dependency ratio | | % FHH |
|---|---|---|---|---|
| | | MHH | FHH | |
| Botswana | 1993 | 1.57 | 2.00 | 58.1 |
| Côte d'Ivoire | 1986-1987 | 1.19 | 1.28 | 8.1 |
| Ethiopia | 1989-1990 | 1.66 | 2.03 | 9.4 |
| Ghana | 1987-1988 | 1.10 | 1.63 | 29.3 |
| Madagascar | 1992 | 1.27 | 1.58 | 10.1 |
| Rwanda | 1985-1986 | 1.30 | 1.21 | 11.1 |
| Bangladesh | 1991-1993 | 1.32 | 1.42 | 8.2 |
| Indonesia | 1991-1992 | 0.86 | 0.66 | 6.8 |
| Nepal | 1988-1989 | 1.01 | 0.90 | 8.3 |
| Honduras | 1988-1989 | 1.71 | 2.51 | 9.3 |

Note: Dependency ratio in this table is the number of people younger than 15 or older than 65, divided by those between 15 and 65 years.

single woman with young children will not have time to spread manure on fields at a rate of 2 mt per hectare or commit to the labor involved in alley cropping. To raise soil fertility, she is more likely to prefer a less labor-intensive practice, such as undersowing maize with *Tephrosia* or pigeon peas, or applying microdoses of chemical fertilizer. Such labor concerns will also be much more important in countries where HIV/AIDS is especially widespread. Currently this means southern Africa, where the rate among adults aged 15 to 49 ranges from 32.4% in Swaziland to 14.2% in Malawi (and rates in these countries are much higher among young women than young men).

## Cash Income

Cash income can be from at least three sources: sales of farm produce, wages earned by household members, and remittances from relatives who have migrated elsewhere and send home some of their wages. Cash income can fund purchases of improved seed and fertilizer, additional livestock, or equipment such as better plows or irrigation equipment. It can also permit a farm to take on hired labor, releasing children to go to school. Regular income from off-farm sources is especially important. It can allow some farms to survive that would be too small to provide a living on their own, which must apply to a number of the smallest farms in table 3 above. Off-farm income can also can be an important buffer against the variability of crop and livestock production, for it allows the family another means to provide for its sustenance, reducing the risk of taking a chance on a farming practice that is new to the area.

While there are great disparities among households within any country or village in the amounts of off-farm income received, the statistics do not show as much variation between continents or countries as might be expected. In table 5, the region with the lowest percentage of off-farm income in total rural income is South Asia, at 29%, and the highest in East and Southern Africa, at 45%. The figures for individual countries in Latin America shown in table 6 are rather higher. The fact that the highest figure of 68% is for Haiti shows that a high proportion of income from off-farm sources can be due to low rural incomes rather than to good off-farm employment opportunities.

**Table 5. Share of rural nonfarm income in total rural income (extracted from FAO, The State of Food and Agriculture 1998).**

| | Rural nonfarm income |
|---|---|
| Africa | 42% |
| E. and S. Africa | 45% |
| W. Africa | 36% |
| Asia | 32% |
| E. Asia | 35% |
| S. Asia | 29% |
| Latin America | 40% |

**Table 6. Rural nonfarm income, Latin America (Reardon and Berdegué 1999).**

| Country | Year | Rural nonfarm income |
|---|---|---|
| Argentina | 1997 | 51% |
| Brazil | 1997 | 39% |
| Chile | 1997 | 41% |
| Colombia | 1997 | 50% |
| Costa Rica | 1989 | 59% |
| Ecuador | 1995 | 41% |
| El Salvador | 1995 | 38% |
| Haiti | 1996 | 68% |
| Honduras | 1990 | 38% |
| Mexico | 1994 | 37% |
| Nicaragua | 1998 | 42% |
| Panama | 1997 | 50% |
| Peru | 1997 | 50% |

## Economic and Institutional Environment

The economic and institutional environment has as much bearing on decisions regarding what, when, and how to produce as the farm's physical resources discussed earlier.

### Extension Services

Extension advice and training can not only increase the range of production possibilities by introducing farmers to products and techniques, they can also affect the quality of decision making by improving farmers' understanding of agricultural and market conditions and showing them how best to take advantage of these conditions. Government agencies, nongovernmental organizations, and private companies can all provide extension advice and training, and though the motivations of these entities may vary (private firms can be relied on to recommend their own products over any alternatives), the considerations brought up in this chapter and the conclusions at the end of it apply to all of them.

### Output Markets

Market outlets available to farmers will determine what products they can raise for cash. While this seems an obvious point, it has not always been understood, and the implications are not always fully grasped even now, either by farmers or extension agents and project implementers. It is not simply a matter of ensuring that a market is there before production begins; it is also important to grow the varieties that consumers most like and to time harvest for those seasons when prices are most favorable. Difficulties increase where farmers want to produce for export markets; smallholders do not have the resources to learn much about these markets on their own, and buyers often want to purchase in larger quantities than producers have to sell. With help, however, farmers can adapt. A commonly effective approach is to help producers form associations, either formal cooperatives or informal groups, that permit them both to consolidate their production into bundles large enough to attract buyers and to negotiate good prices. Often donors are willing to support formation and training of such associations.

### Input Supplies and Prices

These will certainly influence whether farmers can adopt practices that require certain inputs. While government policy can encourage or discourage the provision of supplies at good prices, as in the case of output markets, the matter is not entirely out of farmers' control because associations can access sources and negotiate prices that are out of reach for individuals.

### Credit

Farmers often say they need credit. Commercial banks find small loans unprofitable, but a variety of institutional forms such as credit unions have developed that make it possible for rural people, organized in groups, to make loans to one another. Each group accepts collective responsibility for individual loans, and group pressure replaces conventional forms of collateral to encourage repayment. Where formal microcredit institutions do not already exist, it has been found that groups organized informally to receive loans for specific purposes also function well. Sometimes borrowers can repay in kind. A recipient of a cow might repay in the form of a calf that is passed on to another member of the same group. In fact, unless government regulation forbids

any kind of rival to formal financial institutions, steps can usually be taken to make credit available to all but the most destitute.

## Educational Opportunities

The existence of local schools clearly affects farm household decisions concerning which family members work. Furthermore, an important aim in many developing countries is to reduce child labor and increase school attendance. Even where there are effective programs to strengthen schools or build new ones, steps are necessary to reduce the incentive to keep children home to work in the fields. Extension services and projects promoting innovation have to be aware of the impact that farm practices might have on the demand for child labor. For example, working with farmers on growing irrigated crops during the dry season should take account of the fact that using watering cans takes a lot of work and could lead to keeping children out of school. This can be avoided by promoting the use of treadle pumps that can supply the needed water in much less time. Another aim is to encourage families to send their girls as well as their boys to school. In fact, there is a clear positive impact of female education on family nutrition and health (Klasen 1999; Summers 1994). Extension services may not feel that direct encouragement of female education is an appropriate role for them, but they may be able to promote it indirectly. For example, where females spend long hours collecting firewood, projects can increase supply close to home by supporting the planting of trees in woodlots or the borders between fields. They can also show households how to lower their demand for fuel by building simple brick-and-mud stoves that burn much less wood than open fires.

## Off-Farm Employment

Opportunities for work off the farm are largely determined by the level of economic development of the country and how close farms are to urban areas. However, there is increasing emphasis on developing agricultural processing enterprises in rural areas. The aim is often to reach urban or export markets, but the fact is that local markets for items such as dried vegetables and fruit, jams, wines, and groundnut oil also provide worthwhile cash income. Frequently, successful processing enterprises have been cooperatives run by groups of women rather than operations run by an individual or single household.

## Rights to Land and Water

Farmers' rights to land are often based on arrangements such as sharecropping, the local chief's allocation, or cash rent. Writers on development policy have commonly observed, though more so in the past than now, that anything less than the certainty of a clear ownership title reduces farmers' incentive to invest in their land. There is some truth to this, for without clear ownership farmers cannot be certain they will reap the benefits of their investments. However, the need can be exaggerated. Where customary law is important, as in most of Africa, it is frequently forbidden to arbitrarily terminate a farmer's right to use land that he or she has cultivated for years, and most farmers have an incentive to make investments that will pay off in their own lifetimes. In countries such as Afghanistan where land tenure arrangements include shareholding and cash rent agreements, owners have an incentive to see their land well managed and can pay part of the capital costs to encourage it.

(Rights to land in developing countries typically depend crucially on gender, with great variation from society to society. Where descent is matrilineal, women can often own land; but where

descent is patrilineal, their rights are typically much less. In communities that adhere to Islamic *sharia* law, women inherit land that is a specified fraction of what males are entitled to—an inferior right but one that is at least clear and definite. This imbalance in land rights can lead to severe hardships and deserves more attention than it gets. However, its impact on natural resource management at the farm level is not clear.)

As already observed, some resources, in particular pastureland, forests and water, are common property. The difficulty with this is that the decisions that are sensible from the point of view of a single farm enterprise do not contribute to sustainable resource management when all farm enterprises act the same way. For example, an individual gains when he or she acquires more cattle and grazes them on common land, but when many individuals do the same in an unrestricted way, overgrazing and degradation result. Similarly, the more water each household takes from streams or aquifers, or the more trees each cuts from communal forests, the more rapidly the resource depletes.

This phenomenon is referred to as the "tragedy of the commons" after a 1968 article with that title by Garrett Hardin. For some observers the only way to resolve the problem is to divide the common pasture or woodland into private plots, though this would be difficult in the case of, say, river water. For others, the best solution is government-enforced regulation—issuing permits to livestock raisers, for example, up to the total number of cattle that the land can sustain. In some situations this kind of mechanism works, but because it would require individuals to cut back their usage of the commons to the number of permits they are given, it would be unpopular and, in the rural areas of many developing countries, difficult to enforce.

More recent research by Elinor Ostrom and others has noted that there are solutions that users of the commons can enforce themselves and often do. Livestock owners could keep all their animals but, perhaps with help from extension services and project implementers, organize themselves to move their herds in a coordinated way from one part of the pasture to another, establishing a system of rotational grazing that allows areas not being grazed to recuperate. Similarly, communities can agree to rotate tree cutting from section to section of a communal forest, replanting areas after cutting. Where downstream users of water are unhappy with the quantity or quality of water that upstream users allow to flow down to them, they can pay the upstream users in cash or in kind to reduce amounts used or their polluting behavior. The kind of cooperation needed to implement these solutions may not be easy or quick to organize, and a good deal of trial and error may be needed before the best approach is found for each case, but it offers a viable prospect for solving a very old problem.

## Risk and Attitude toward Risk

The discussion of figure 1 made the point that risk should be seen as being determined by objective circumstances at least as much as by psychological factors. To take a simple example, a farm household with many dependents, little or no off-farm income, and limited land is highly vulnerable to drought and crop failure. A farmer in this situation should probably hesitate to try an innovation aimed at enriching the soil by replacing some of his millet with cowpeas if he knows cowpea crops fail 3 out of 10 years in his area because of poor rainfall. A neighbor with enough land to produce a substantial surplus over his family's food needs might or might not be braver, but he would certainly be much better placed to sustain a loss and take a chance on cowpeas.

Table 7 elaborates on this view, taking account of some of the points made in the sections above. The upper part of the table shows how farm-level resources affect risk. The more plentiful on-farm land and water are, the less risky the situation is for the farm enterprise, and so on. The

second section of the table refers to the economic and institutional environment and the bottom section to two aspects of the broader watershed and ecological systems. Strong extension training and advice make for greater security because farmers are better informed about how to make the most of their resources under a variety of conditions. Better rainfall makes for better crops and pasture, and more food and income security.

An interesting point brought out by table 7 is that sometimes it is the level of an item that matters, while in other cases variability is more important. The higher the off-farm income, for example, the less risk a farm faces. In several instances, however, annual variation is at least as important as the absolute level of an item. In general, one might consider low rainfall and high levels of disease to make for high risk, and there is some truth in this. But suppose rainfall were consistently only 350 mm every year, and the same viruses attacked the same fields and same animals to the same degree annually. In this case, farm productivity would be low and costs high, but farmers would know what to do to make the best of these conditions and would see themselves as facing hardship rather than risk. It is because adverse factors come and go with varying intensity that it is difficult to choose which practices will pay off best in any given year.

A further conclusion is that the level of risk can be much affected by the level of training that farmers receive. Unlike the other factors, this is one that extension services and project implementers can do something about. Where farmers are trained inadequately or not at all, consequently adopting new practices poorly, their risk of running a loss and abandoning innovation is high. Governmental and nongovernmental agencies will have to devote more resources to conduct proper training, but the expense is essential to fostering innovation.

**Table 7. On- and off-farm determinants of risks.**

| | Low-risk conditions | High-risk conditions |
|---|---|---|
| **Farm-level resources** | | |
| Land and water on farm | Exceeds subsistence needs | Poor quality, small area |
| Dependency/labor ratio | Few dependents relative to farm workers | Many dependents relative to farm workers |
| Livestock, equipment, buildings | Plentiful, good quality | Limited, poor quality |
| Off-farm income | High and consistent | Low or inconsistent |
| **Economic and institutiuonal environment** | | |
| Extension training and advice | Good training → good adaptation → known returns | Poor training → poor adaptation → unknown returns |
| Rights to land and water | Secure | Insecure |
| Output markets, prices | Competitive markets, steady prices | Low level of competition, highly variable prices |
| Input supplies and credit | Supplies assured, competitive prices or interest rates | Supplies unsure, uncompetitive prices or interest rates |
| **Watershed and ecosystem** | | |
| Annual rainfall | Consistent | Highly variable |
| Crop and livestock diseases | Rare | Frequent |

## Culture and Natural Resource Management Decisions in a Farm Enterprise

When farmers make decisions about what to produce and who should do what in the production process, they are influenced, like all the rest of us, by notions of what is acceptable according to prevailing social and religious norms. Muslim farmers do not raise pigs, and Hindu farmers do not raise cattle for meat. When it comes to crops, what culture has to say is less obvious, and taste seems to come second to what growing conditions allow. For instance, there is an apparent tendency worldwide for farmers to grow maize where there is enough water and warmth, wheat where there is water but inadequate warmth, and sorghum and millet where there is warmth but not enough water. But when it comes to how to produce, in particular who does what and when, culture plays a critical role, especially where the division of labor and decision making within households are concerned.

### Division of Labor

The most significant way in which culture has an impact on farming is through accepted attitudes regarding the proper roles of males and females. Typically, though not universally, men have worked in the fields, herded livestock, and taken farm produce to market. Women have been seen as having primary responsibility for domestic work within the home, feeding the family, cleaning, and caring for the sick. However, they have always done much more. They have worked in the fields when more hands have been needed to weed and harvest, raised kitchen gardens to supplement the family diet with vegetables, fruits, and herbs, and processed farm and garden produce, making bread and cheese and preserving vegetables. They have also raised poultry and dairy animals, and in many parts of Africa they have fattened small ruminants for market. In most developing countries today it also falls to women to collect firewood and water.

There are certainly variations on these themes. For example, while the general pattern just described holds in many communities in Afghanistan, others in that country do not think it proper for women to work outside the extended family's compound. Thus all fieldwork, other than in small gardens within the household compound, is left to men, even in the case of widows (common in that country) who have to rely on male relatives or sharecrop out their land. On the other hand, in African communities where the men have gone off to find work in the cities, women are left to do all the fieldwork.

Whatever the situation, it has been widespread and conventional practice for extension agents and most project implementers to be men and for them to deal with the males in households, though the many women's roles listed above indicate the importance of communicating with women too. There may be a few instances where the usual man-to-man interaction is enough to transfer technology such as building terraces to reduce soil erosion, but in others interaction with women is indispensable. For example, where the crops or livestock are women's particular responsibility, a cooking stove that uses less wood is to be introduced, or nutrition education is an issue. Indeed, it has been found that in some instances women extension agents succeed in circulating information within a village better than male extension agents (Moore et al. 2001).

Where most natural resource management practices are concerned, men and women will each have an interest. For instance, in discussions regarding tree planting for fuel wood, both will have opinions on what species they prefer and where the trees should be planted. When considering alternative practices to improve soil fertility, such as spreading animal manure, applying micro-

doses of chemical fertilizer, rotating traditional grains with legumes or interplanting them with legumes, both men and women will have legitimate considerations to bring to bear.

To interact effectively in these cases, extension agents and project implementers will sometimes have to broaden their own knowledge to take account of the food value of grains and pulses as well as their yields, for example. In many or most situations it will be necessary to hire qualified women to interact with female household members, either because men do not have the necessary expertise or because it is inappropriate for men to speak to women at all if they are not related to them.

### Decision Making within Households

Decision making within the household is harder to investigate than the division of labor. Who does what is often open to observation, but decision making usually takes place in private discussions within families, and questions about these are commonly regarded as intrusive. One way out of dealing with this difficulty is to treat households as if they were single individuals, though very complicated ones. Those who have taken this approach have said that it does not necessarily amount to presuming that the husband makes decisions unilaterally without consulting other family members. Instead, they say, the household head can be presumed to value his or her relationship with other family members and to take account of their preferences when making decisions, so any decision will reflect what the family as a whole wants. This is a convenient formulation, but it is almost certainly more accurate—and effective—to consider that decisions are arrived at through a process of bargaining among family members and that the relative strength of their bargaining positions can vary with the circumstances. For example, women are known to have more bargaining power where they earn some cash income from activities such as selling vegetables, fruit preserves, or clothes that they produce.

Whatever view of household decision making is adopted, it is important that all family members who provide a significant amount of labor to the farm enterprise, especially spouses, be well informed about the relative payoffs and costs of alternative farm practices so they can contribute to informed decisions. How best to inform them and encourage their involvement in decisions will require considerable sensitivity on the part of extension agents and project implementers. The approach will vary from community to community and household to household. In some instances women can be expected to sit with the men in meetings and participate actively and without hesitation in discussions. In others, to insist on meetings that jointly involve men and women will be ineffective if either or both sexes refrain from speaking frankly for fear of upsetting the other. It can be counterproductive when joint meetings run so much against the cultural grain that even suggesting them can result in hostility among both men and women, toward the whole program. Again, the obvious solution is to hire or train enough qualified females to confer effectively with the women.

## Conclusions: Promoting Innovations at the Farm Level

This chapter emphasizes several points:

- The farm enterprise can be represented as a circular system, with resources conditioning management decisions that determine this year's production and its allocation among consumption, sales, and investment in farm resources that will be available for next year.

- In the economic and institutional environment, output markets affect farmers' incentives and ability to convert farm production into cash income. Input markets, credit, land and water rights, and opportunities for off-farm employment and education also condition farmers' decisions regarding how to allocate resources and allow them to supplement resources produced on-farm with additional means acquired off-farm.
- Risk perceptions are not simply a matter of attitude but are also determined by on- and off-farm circumstances and resources.
- How resources are used and management decisions are made also depend on cultural influences.
- Circumstances vary immensely from country to country, district to district, and farm to farm. As a system, each farm is potentially unique. Even where land, crops grown, and livestock raised are the same, household makeup and availability of off-farm income can be different, leading to differences in production possibilities, views of risk, and decisions.

This view of the farming system has significant implications for the promotion of appropriate innovation in farm practices:

- ***Innovations should have a clear payoff to farmers within a fairly short time.*** Often innovations that make farming more ecologically sustainable are promoted without paying attention to how immediately profitable they are to farmers or whether they are profitable at all. Innovations are sustainable from the farmer's perspective if they result in a greater accumulation of resources as one production cycle succeeds another.
- ***Innovations will be viable if output markets, input suppliers, credit, and other aspects of the economic and institutional environment support them.*** In some instances, such as the law governing land rights, what government policy says is crucial, but sometimes institutional support can be created, as when producer groups are formed to funnel credit to farmers and to negotiate with traders in town.
- ***The promotion of innovations must accommodate risk and attitudes to it.*** If farmers are reluctant to think about innovating, it may be because the program proposed does not adequately take account of either the farm's own resources or the economic and institutional environment. In these cases it may be that project implementers and extension agents, rather than farmers, should adapt.
- ***Extension agents and project implementers should involve farm households in the choice of innovations.*** This is not the same as saying that farmers should not receive advice regarding what the innovations should be. They do not know all the technical possibilities that specialists are aware of. Because they know their own household preferences and constraints better than anyone, however, they are well qualified to collaborate in evaluating the relative importance of different alternatives. Going beyond the household and considering possible alternatives in neighborhood groups will raise the level of discussion and also encourage a wider appreciation of all the alternatives being offered.
- ***To involve farm households means to involve spouses. Not all innovations affect all household members, but most do.*** Consulting the head of household alone will result in only a partial appreciation of household preferences on the part of project implementers and extension agents. This will usually mean having to hire and train more females to work with the women of farm households.
- ***The benefits of innovations should be assessed collaboratively for the same reasons that the initial choice should be.*** Farm households understand their own circumstances better than anyone and so are generally better positioned to determine which innovations suit

them and which to reject. Furthermore, when innovations are tested or demonstrated in farmers' own fields with different farmers conducting different innovations, it is important that all farmers in a neighborhood be made aware as a group of all the results so that they have a chance to discuss the pros and cons of alternative practices.

- ***Patience and persistence are more important than expense.*** Experience shows that farms are most likely to innovate and increase their food security and incomes when researchers work with them over long periods of time, such as 10 years and more, which not all development projects permit. Large-scale efforts are less effective than long-term, flexible programs that pursue their own specific priorities as farm households respond to research results and new possibilities.

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## Note

This chapter does not define and examine different categories of farming systems. For this approach see John Dixon and Aidan Gulliver with David Gibbon, *Farming Systems, and Poverty: Improving Farmers' Livelihoods in a Changing World*, FAO and World Bank, 2001.

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