Managing Resources in Erratic Environments

An Analysis of Pastoralist Systems in Ethiopia, Niger, and Burkina Faso

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Foreword

Although 22 percent of land in sub-Saharan Africa is arid or semiarid rangeland, development policies have long been biased toward crop agriculture. In the wake of the Green Revolution, international and national agricultural research institutions focused on crop systems and plant breeding. As a result, the customary tenure arrangements that enabled pastoralists to move their livestock from one grazing ground to another fell out of favor. As climate-related crises and desertification have spiraled, however, research and policy interest in rangeland management issues have been renewed.

As part of its strategy to seek policies for the efficient functioning of global food systems, IFPRI has been in the forefront of this research. In the 1990s, as part of a shared CGIAR initiative on property rights and collective action, IFPRI, in collaboration with the International Livestock Research Institute, began work on a project called "Property Rights, Risk, and Livestock Development," with a focus on rangeland systems in sub-Saharan Africa.

The research on resource management conducted for this report in three drought-prone countries of sub-Saharan Africa—Burkina Faso, Ethiopia, and Niger—is related to that work. This study analyzes the links between risk and the kinds of property rights that have evolved to provide the mobility needed to raise livestock where rainfall fluctuates, and it evaluates the impact of cooperation on resource management in these environments. Three interesting conclusions emerge from the analyses with respect to economic vulnerability and natural resource management in these environments. First, there is little evidence of dramatic misuse of land resources by herders; rather, evidence suggests that overstocking, limited herd mobility, and encroachment of farmland on common pastures vary a good deal both within and across countries. Second, stock densities are lower precisely in areas with very high rainfall variability, whereas herd mobility is strongly related to recent rainfall patterns. Finally, greater cooperative capacity significantly reduces grazing pressure on home resources. While it remains a challenge for policymakers to design and implement mechanisms to increase cooperative capacities, this research points to the scope for such action.

Joachim von Braun
Director General, IFPRI

Summary

People living in semiarid-to-arid regions of the world face a high degree of climatic variability, mostly in the form of rainfall patterns that vary both spatially and temporally. In these regions, livestock is generally the predominant production activity, although cropping can also be important in semiarid regions. The ability to move livestock to different pastures is a key strategy for mitigating exposure to erratic rainfall, and reliable access to a wide range of pasture resources has long been essential to the viability and sustainability of such systems. In addition, various types of common-tenure regimes facilitate herd mobility.

Although the flexibility inherent in such common-tenure systems enables herders to cope with different rainfall patterns and thus limits their exposure to this risk, one potential cost of such systems may be in terms of the use and management of the natural resource base. As is well known, common resources may be subject to externalities; these externalities open up the possibility that resources will not be well managed. Thus, there may be a trade-off in terms of flexible access to mitigate risk and the use and management of common-pool pastures.

In this report, we look at three community-level outcomes that can be affected by both climate variability and by externalities generated when managing the commons is costly. In the second chapter, we develop a theoretical model incorporating variability and costly cooperation. The model generates the following hypotheses: greater variability will lead to lower stock densities, increased herd mobility, and, likely, larger amounts of land allocated to the common pastures. Furthermore, when cooperation is costly, stock densities will be too high, herd mobility will be too low, and pressure will build to encroach on common pasture for private uses. To capture the costs of cooperation, we consider factors that affect cooperative capacity, hypothesizing that greater cooperative capacity reduces the costs of cooperation.

Empirical results indicate that there are some general lessons to be drawn. First, greater cooperative capacity does indeed lead to lower stock densities and increased mobility, as we expect from the theoretical model. Cooperative capacity has a more limited impact on land allocated to private uses vs. common pastures, although its impact is particularly strong in Burkina Faso. Also of interest is the great variability in the capacity of communities to manage pastures and allocate land to its best use, both within and across countries. Factors that are generally associated with greater cooperative capacity include relatively small community size, more equal distribution of wealth, and fewer adults migrating for wage work, all of which should reduce negotiation and enforcement costs of undertaking collective action. Other factors affecting cooperation differ across countries. For instance, external pressure to use community resources appears to have a much greater impact on cooperation in Ethiopia than in Burkina Faso or Niger. Higher productivity rangelands and higher effective livestock prices are associated with greater cooperative capacity in Ethiopia, but have no impact in Burkina Faso. Thus, the evidence suggests that more favorable livestock market conditions either increase cooperative capacity or have no impact; there is nothing to suggest that better market conditions erode this capacity.

Second, there is little evidence to suggest that livestock owners accumulate larger herds to mitigate vulnerability to rainfall shocks in high variability environments. Our results instead indicate that herd sizes do increase with rainfall variability at relatively low variability, but decrease precisely in the higher variability environments. In other words, we would expect that policies and programs that directly "insure" livestock owners—through feed subsidies in response to drought, for instance—would likely lead to larger herds precisely in the environments subject to the greatest variability. We must emphasize that our results are consistent with this hypothesis, but, given the one-period nature of the survey, we did not test the hypothesis directly. This is still a contentious issue, as a wide range of researchers, policymakers—and indeed, herders themselves—believe that holding onto more livestock is a strategy to mitigate the impact of such climate shocks as drought.

Results presented here imply that policymakers designing crises mitigation strategies—including those in many governments that are signatories to the UN Convention to Combat Desertification—must carefully consider insurance and crises mitigation mechanisms that do not lead to dramatic increases in the size of the national herd. Not only do policymakers need to consider the impact of such programs on herd size, but also on herd mobility. Mobility remains an important part of these systems; our results indicate that current rainfall patterns—and thus, locally available feed resources—heavily influence the extent of herd mobility. Given the rather complicated patterns of herd mobility into and out of community areas in Ethiopia, we were not able to gather good enough data to include this variable in the statistical analyses. Still, more than 84 percent of the communities surveyed relied on mobility for at least part of the previous year, and in the 12 communities for which data were quite good, herds were mobile for nearly 40 percent of the year. The number of communities where at least some members engaged in herd mobility is lower in Niger and Burkina Faso, but mobility is still practiced in more than 40 percent of communities in both these countries. And, as noted above, better cooperative capacity within communities supports greater herd mobility. Nonetheless, herders' rights to access traditional grazing areas are generally eroding everywhere. Results indicate that communities with more traditional pastoralists do tend to rely more heavily on herd mobility, but the impact is weak and not robust across specifications. Thus, pastoral land tenure and drought mitigation policies will need to take into account the continued reliance on herd mobility—even by those not considered to be traditionally pastoralist—as well as factors that are either directly or indirectly limiting mobility.

CHAPTER 1

Introduction

The arid and semiarid rangelands located throughout sub-Saharan Africa are estimated to support nearly 60 million people and comprise nearly 22 percent of the total land area of sub-Saharan Africa, an area of more than 550 million hectares (Dixon et al. 2001). Yet, even though these rangelands cover large areas and support many people, the historical record of development policies and paradigms starkly reveals a pervasive bias toward the development of sedentary crop agriculture. There are a number of plausible explanations: sedentarized crop farmers tend to be located closer to urban centers, where infrastructure development is far more advanced; the more isolated and dispersed populations in semiarid and arid areas tend to have more limited opportunities and fewer mechanisms to participate effectively in the national political arena and grab the attention of donors and nongovernmental organizations (NGOs); after the successes of the green revolution, both international and national agricultural research institutions focused largely on crops systems and plant breeding; and urban elites, who often hold important positions in postindependence governments, inherited the view of colonial regimes that the production systems and customary tenure relations prevailing in the semiarid and arid regions were "backward" and would have to be reformed. As stated in Bruce et al. (1995, p. 1): "The new elite who came to power . . . believed that these community-based tenure systems were outmoded and had to be replaced." Despite a history of misunderstanding and neglect, rangeland management issues in sub-Saharan Africa are generating renewed interest and attention in policy circles (Niamir-Fuller and Turner 1999; Kirk 1999). Stronger pastoralist associations; cumulative experience of government ministries, donor agencies, and NGO personnel; and local and national research results have convinced many policymakers that a better understanding of these systems is required to inform policymaking in such areas as land reform, decentralization and devolution for natural resource management, climate-related crises mitigation strategies, and investment in infrastructure.

Perhaps one of the key failures of earlier development strategies was the failure to understand the role and importance of climate variability in shaping production systems and tenure institutions.[1] In highly variable environments, households must adopt mechanisms to manage the variability in production of crops and livestock and to mitigate the impacts of drought when it does occur. Among the many risk-management strategies that have been identified,

[1]It appears that Sandford (1982) catalyzed researchers to seriously consider the importance of mobility and "opportunistic" grazing in the semiarid and arid rangelands, leading to the development of a body of research now referred to as the "new range ecology." The collected volumes by Behnke et al. (1993) and Niamir-Fuller (1999) contain many works highlighting the importance of mobility in these systems.

livestock mobility is often seen as one of the most valuable, as it enables herders to improve mean output as well as decrease output fluctuations associated with both spatial and temporal variability in rainfall (e.g. Sandford 1982; Fleuret 1986; Painter et al. 1994; Swallow 1994; van den Brink et al. 1995). Mobility is facilitated by the common-pool nature of most grazing resources, which significantly reduces the transaction costs associated with mobility (Niamir-Fuller 1999). But the common-pool nature of grazing resources also means that there are potential externalities, which can lead to costs associated with resource management. These externalities, and the extent to which they are managed, will also affect such decisions as stock densities, herd mobility, and land allocation patterns.

It is interesting to note that the flexibility of access to a wide range of grazing resources that generally do not have well-defined boundaries is considered one of the key strengths of traditional pastoral systems, whereas in the literature on common property, "well-defined boundaries" are considered one of the key ingredients to successful cooperation in resource management (Ostrom 1990). The apparent contradiction arises because most of the common-property literature does not explicitly consider the value of flexible access to the individual; rather, well-defined boundaries are considered important to ensure that collective action taken by community members will result in benefits for those who contribute. Thus, flexibility is likely to have both private benefits and collective costs.

In historical assessments of the functioning of these systems, most observers believe that such flexible systems based on mobility were very effective in terms of efficient resource use and support of the herding families dependent on them. Also, the notion that customary tenure relations in these areas was insufficient to guarantee security for the multiple claimants is likely to have been greatly overstated. As we now know, lack of formal, legal title to land does not necessarily imply lack of tenure security; customary tenurial arrangements have often been seen as secure by those operating within those systems (Okoth-Ogendo 1995; Place and Hazell 1993; but note that these studies are often concerned with cropland). Nonetheless, with the advent of high population pressure, increased market activity, and diminished authority of traditional leaders, a need for adapting these property rights regimes to the increased pressure on the finite natural resource base has also been recognized (Bromley and Cernea 1989; North 1994; Pender et al. 1999). Unfortunately, previous attempts at land reform imposed either state ownership or, in a few cases, privatization. Even the simple declaration of state ownership often weakened traditional authority structures, but states rarely then put into place mechanisms to replace the roles and responsibilities previously undertaken by traditional authorities, a situation that often led to open-access situations (Niamir-Fuller 1999). Privatization schemes, loosely based on the "western" ranch model, are considered to have failed primarily because ranch areas were not sufficiently large to support enough livestock units per family, given the high spatial and temporal variation in rainfall and forage. A secondary reason for failure was that, in certain cases, large and powerful pastoralists became the de facto "owners" of the ranch, effectively excluding large segments of the population and capturing rents on the ranches while still using remaining non-ranch-based common pastures (Behnke and Scoones 1993; Niamir-Fuller and Turner 1999). In these cases, the reforms certainly failed in terms of equity, and often in terms of efficiency as well (Swallow and Kamara 1999).

To summarize, mobility and thus access to a relatively large number of rangeland "patches" is required, and such mobility is much more easily accommodated when rangelands are communal (see Behnke et al.

1993; Niamir-Fuller 1999).[2] Nonetheless, pressures to privatize common and open-access grazing lands are likely to increase with increases in population densities, and perhaps in response to market integration and government policies, such as those that promote sedentary crop agriculture. The pressure to restrict access and/or privatize land, in part, will be a function of how productive and profitable pastures are vis-à-vis alternative uses, as well as of other external pressures, local customs and norms, and/or government policies and changes in legislation (van den Brink et al. 1995; McCarthy et al. 1998). Where communities can manage their rangeland resources,[3] different forms of common property may well be the most efficient (and, perhaps, equitable) property-rights structure, and we should observe less pressure to privatize, all else being equal. Private property will only become "optimal" when management of the common rangeland is so poor that it becomes economically beneficial to individually appropriate land (Seabright 1997).

In such situations, it becomes critical to examine what factors affect the use and management of common-pool resources. There are now many hundreds of empirical case studies on common-pool resource management;[4] empirical evidence supports the hypotheses that not all common-pool resources suffer from overexploitation and that at least some communities are capable of attaining a high degree of cooperation in the use and management of the natural resource base (see the case studies in Ostrom 1990; Bromley et al. 1992; Berkes and Folke 1998; Ostrom et al. 2002). However, there is still little consensus on what explanatory variables actually affect the success of collective action, either conceptually or empirically. For instance, many researchers posit that sociocultural heterogeneity will make collective action more difficult, because members will not share the same social norms, or perhaps mutual trust among members will be lower (Ostrom 1990; White and Runge 1994; Seabright 1997 and references therein; Bardhan 2000). Other observers argue that sociocultural diversity increases the stock of knowledge and experience over a range of potential mechanisms to effect collective action and also diminishes the tendency toward institutional inertia (Begossi 1998); indeed, the latter explanation is more consistent with the benefits of diversity often discussed in the context of developed countries. This is but one example of the disagreements that still exist on the impact of such variables as group size, economic heterogeneity, and degree of market integration. One of the key criticisms of much of the earlier work on common-pool resource management has been that too much empirical work focuses on too few communities, with little attempt to put these case studies into a wider context and thus to draw conclusions that can be generalized. In fact, there has been a tendency to both research and publish studies on communities where collective action is working particularly well. These studies have provided invaluable information to help refine hypotheses regarding the impacts of various factors on collective action, and, in

[2]These environments are often termed "nonequilibrial," or "at disequilibrium." Semiarid rangelands with a coefficient of variation of rainfall above approximately .3–.33 are characterized as being nonequilibrial (Scoones 1994).

[3]We use the term "can manage" to imply that external agents recognize their authority to manage and that the community itself is capable of implementing management decisions made internally.

[4]In the bibliography on the CAPRi website (System-Wide Program on Collective Action and Property Rights), there are over 800 references for empirical case studies on collective action and/or property rights (http://www.capri.org/bibliography.asp, accessed September 13, 2004).

particular, to help elucidate the process of decisionmaking and enforcement. But our approach in the empirical work presented in this report has been to collect information on a sufficient number of communities such that we could run regression analyses at the community level to test model hypotheses. A growing number of studies have followed this empirical strategy (Seabright 1997; Bardhan 2000; Dayton-Johnson 2000; Meinzen-Dick et al. 2000; Isham and Kahkonen 2002). There are advantages and drawbacks to each empirical strategy; the strategy taken here, for instance, sheds less light on the processes by which communities reach and enforce decisions than do in-depth case studies, but the benefits are that we can statistically test hypotheses about factors that affect collective action and subsequently evaluate the impact of collective action on natural resource management.

The research presented in this report was undertaken expressly to contribute to the current debate on resource management in highly variable environments, focusing on the impact of climate variability and the role of cooperation in resource management. More specifically, a conceptual framework is developed to analyze the impact of climate variability and cooperative capacity on land allocation patterns (common pastures vs. private uses), stock densities, and patterns of herd mobility. Thus, the primary level of analysis is the community. To test model hypotheses, we collected data in communities located in southern Ethiopia, southwestern Niger, and northeastern Burkina Faso. All three study areas are semiarid regions where livestock production is the dominant activity, but the importance of cropping varies both across communities within countries and across countries.

In Chapter 2, a theoretical framework incorporating the impact of climate risk and cooperation on land allocation, land use, and herd mobility is developed. The framework is based on insights from different theoretical models that capture different aspects of natural resource management, which are then integrated into a unified conceptual framework. We begin by considering a model of the use of common pastures subject to climate variability (output variability) by risk-averse producers. We then extend the model to consider the additional strategic choice of whether to engage in herd mobility. In the third step, we consider the additional decision to allocate land to common pastures vs. individually cropped plots. All three of these steps focus on determining the impact of climate variability on the outcomes of community-level stock density, herd mobility, and land allocation, assuming the two "extreme" assumptions of either noncooperation or joint maximization. The nature of the externalities involved in this system, dependent on access to common pastures, is highlighted by the comparison of outcomes resulting from these two assumptions.

The second section of Chapter 2 then considers the role of cooperation in determining community-level outcomes. We develop a model of cooperation in which the costs of cooperation are a function of individual incentives to deviate—given by the externalities generated under the assumption of noncooperation highlighted in the earlier models—and cooperative capacity at the community level. From this model, we derive first-order conditions and the equilibrium outcomes for stock densities, herd mobility, and land allocation, finishing the section with a system of equations that can be empirically estimated.

Chapters 3, 4, and 5 present the results of econometric analyses using data collected in Ethiopia, Niger, and Burkina Faso, respectively. In each of these chapters, we begin by considering measures of cooperative capacity and the factors affecting this capacity, to obtain proxies of cooperative capacity. After obtaining such measures, we proceed to test the impact of cooperative capacity and climate variability on community-level stock densities and land-allocation patterns. With the exception of Ethiopia, we also estimate herd mobility. Chapter 6 presents a comparative analysis of the three countries. In Chapter 7, we consider the results in terms of broad policy conclusions, as well as those results that are country-specific.

CHAPTER 2

Theoretical Framework

In this chapter, we develop a framework for analyzing community-level decisions on land use and allocation when externalities are generated from the use of common land and when stochastic rainfall causes variability in both crop and livestock returns. Decision variables include stock densities, the extent of mobility, and the proportion of total community land to allocate to common pasture and to individually exploited cropland. The final model developed is a community-level model of land use and allocation that includes the costs of cooperation. This model of costly cooperation is adapted from a simpler model found in McCarthy et al. (1998). As noted in Chapter 1, many authors have noted that, empirically, the actual use and management of many common-pool resources appear to fall somewhere in between the perfect cooperation and complete noncooperation outcomes; Oakerson (1992) stressed the need to account for costs of collective action when evaluating the use of these resources. In the model developed here, these costs are a function of the externalities generated in land use, and their magnitude is determined by the difference between outcomes resulting from a noncooperative game and outcomes arising from a social optimizer who jointly maximizes expected utility over all community members. But, it is difficult to gain intuition into the hypotheses stemming from this final model, so we develop the model in steps to highlight the externalities at each stage as we add additional decision variables.

First, we consider the impact of including variable rainfall on the stock density decision when herders are risk-averse, under the assumptions of either perfect cooperation or noncooperation. We then consider the decision to engage in mobility given stock densities, and subsequently consider the simultaneous decision to choose stock densities and mobility when herders are risk-neutral, and when they are risk-averse. Third, we allow herders to choose the amount of land allocated to cropland and common pastures, although we defer adding the mathematical representation of this decision until the final model. Finally, we consider the role of cooperation. As the model development shows, there are a number of externalities generated by the provision of lands for common pasture and by stock densities realized on home pastures, which themselves are affected by the decision to engage in herd mobility. In this report, cooperation refers to the extent to which externalities are successfully addressed (internalized). Cooperation, however, is costly, and we develop the final model to incorporate costs of cooperation as a function of externalities and the underlying cooperative capacity that exists in the community. Cooperative capacity itself is an abstract construct, and we also digress to consider how we measure this capacity in the empirical chapters. In the final section of this chapter, we develop a system of equations that can be empirically estimated.

Climate Variability and Stock Density Decision

The use of climate variability and/or indicators of climate shocks as explanatory variables in household decisions has been applied in many cases, including studies by Paxson (1992), Rosenzweig and Wolpin (1993), Udry (1994), and Fafchamps et al. (1999). These studies are primarily concerned with the impact of transitory production shocks on savings and consumption smoothing, particularly the use of livestock as a consumption-smoothing mechanism. For the studies undertaken in Africa (Udry 1994; Fafchamps et al. 1999), there is little evidence that livestock, particularly large livestock, are used as a savings mechanism to smooth consumption in the face of generalized rainfall shocks.[5] In other words, there is little empirical evidence to support the hypothesis that livestock are held primarily as precautionary savings for coping with transitory shocks, although the evidence does indicate that small ruminants may to some degree play such a role.

Here, we do not focus on the consumer, but rather, on the effect of climate variability on the producer. Standard noncooperative, one-period game models of use rates of common rangelands indicate that use rates are greater on the commons than would be the case under the social optimum, and that the degree of overexploitation increases with the number of members involved (Dasgupta and Heal 1979). In one of the few articles on risk and common-pool resource use, Sandler and Sterbenz (1990) develop a model incorporating variable returns that results in risk-averse decisionmakers reducing inputs as variability increases. Thus, even with common-pool resources, risk reduces input use. These results mirror the standard results in production theory when all inputs are implicitly assumed to be private.

Contrary to the hypothesis of lower input use resulting from the Sandler and Sterbenz (1990) model, a group of researchers have posited that herders will attempt to hold onto more livestock in high-variability environments. The reasoning here is that increased herd size going into a drought is thought to imply a greater probability of coming out of the drought with relatively more animals (Livingstone 1991; Fafchamps 1998; Niamir-Fuller 1999),[6] which itself would seem to imply that overall herd variability is decreasing in herd size, although it is not at all clear why this would be the case. Similarly, proponents of the "new range ecology" also argue that holding larger herds in areas subject to high climate variability is the best strategy in these disequilibrium environments, particularly because, in these environments, it is thought that forage productivity is driven almost exclusively by rainfall, with limited or no impact of stock densities on future forage productivity (see Behnke et al. 1993). One of the main hypotheses to be tested in the empirical sections is the sign of the impact of rainfall variability on stock densities, and whether there is a different effect in

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[5]As noted above, Udry (1994) and Fafchamps et al. (1999) derive empirical estimates of the importance of livestock's role in consumption smoothing. In both studies, which use data collected in West Africa, the results show no role for large ruminants and a limited role for small ruminants. The authors conclude that livestock plays a limited role as savings. Alternatively, Dercon and Krishnan (1998) investigate the distribution of asset holdings in Tanzania and Ethiopia: livestock holdings and income from livestock both increase with increases in total wealth. They thus conclude that livestock is not likely being used as a risk-coping measure, because otherwise, we would expect that poor households would have a higher share of income from livestock.

[6]This line of reasoning ignores the fact that even though such a strategy might be rational when pasture is either perfectly managed or held as private land, the extent of herd build-up may be significantly greater when pastures are not perfectly managed.

communities with relatively high variability —a coefficient of variation of about .3—as proposed by the new range ecology.

We extend the Sandler and Sterbenz (1990) model to explicitly derive testable hypotheses from a one-period model of the stock density decision. This model implicitly assumes that there is no value to precautionary savings or precautionary asset build-up; we can thus contrast the results from the one-period model with those from the different multiple-period models.

Theoretical Model

To characterize the externalities arising from noncooperation, we derive both the noncooperative and joint-maximization outcomes (see Dasgupta and Heal 1979). Joint maximization implies that a group can perfectly manage its common resources (in the sense that all externalities are internalized, and costs for this management are zero). Conversely, noncooperation implies that each individual is concerned only with his/her own profit maximization; we use the standard Cournot-Nash equilibrium concept to arrive at the equilibrium outcome. To incorporate the impact of risk aversion on producer decisions, we use the mean-variance approximation for expected utility (Hirschleifer and Reilly 1992) and a multiplicative specification for climate risk. We consider that overexploitation occurs if the number of livestock occurring under the noncooperative game is greater than the level associated with joint maximization.

Model results show that, as in Sandler and Sterbenz (1990), the total input level under climate risk is less than the corresponding case under certainty. Furthermore, we establish that over a certain range, average profits are actually higher, but expected utility lower, when there is variability in production and a noncooperative game is played. Higher average profits are possible because as stock densities are reduced, they become closer to joint-maximization levels that obtain under no risk. In contrast, input levels, expected utility, and average profits all decline with increases in risk under joint maximization. Increasing the number of players reduces average profits, and thus reduces the range over which profits are higher under noncooperation vs. joint maximization.

Joint-Maximization vs. Noncooperation: Risk vs. No Risk in Production

We first consider the case in which there are two players, $i = 1,2$. We hypothesize that either a social optimizer jointly maximizes expected utility (EU) of profits (π), $\Sigma EU(\pi)^{JM}$, or that the ith individual maximizes his or her expected utility of profit under a noncooperative game, $EU_i(\pi_i)^{NC}$. In the riskless scenario, we use a standard production function that captures negative externalities, $l_i f(l_i + l_j; \beta)$, where l_i is the number of livestock held by the ith player and $f(l_i + l_j; \beta)$ is the average product function, which is a function of total stock densities. Total profits are $Pl_i f(l_i + l_j; \beta) - cl_i$, where P is livestock output price, β is a vector of technical coefficients, and c is the constant marginal cost of livestock. Under output risk, the mean-variance representation of expected utility is written as

$$Pl_i f(l_i + l_j; \beta) - cl_i$$
$$- \tfrac{1}{2}\sigma_\theta^2 \phi_A [Pl_i f(l_i + l_j; \beta)]^2$$

where σ_θ^2 is variance in rainfall, and ϕ_A is the coefficient of absolute risk aversion, which is assumed to be the same for both players.[7]

The expected utility maximization equations are given here for the following two-

[7]An extension to consider differences either in terms of marginal costs or risk preferences is given in McCarthy (1999).

player scenarios: (1) joint maximization, no climate risk, (2) noncooperative game, no climate risk, (3) joint maximization, climate risk, and (4) noncooperative game, climate risk. Additionally, we assume that under jpint maximization, the social optimizer sets $l_1 = l_2 = l$. Immediately following are the respective first-order conditions.

Scenario 1: Joint Maximization, No Climate Risk

$$\max_{l_1, l_2} \sum EU(\pi)^{JM} \equiv \pi^{JM} = P[l_1 f(l_1 + l_2; \beta) + l_2 f(l_1 + l_2; \beta)] - cl_1 - cl_2 \tag{2.1}$$

Scenario 2: Noncooperative Game, Two Players, No Climate Risk

$$\max_{l_1} EU(\pi_1^{NC}) \equiv \pi_1^{NC} = Pl_1 f(l_1 + l_2; \beta)] - cl_1 \tag{2.2a}$$

$$\max_{l_2} EU(\pi_2^{NC}) \equiv \pi_2^{NC} = Pl_2 f(l_1 + l_2; \beta)] - cl_2 \tag{2.2b}$$

Scenario 3: Joint Maximization, Climate Risk

$$\max_{l_1, l_2} \sum EU(\pi^{JM}) = \left[Pl_1 f(l_1 + l_2; \beta)] - cl_1 - \tfrac{1}{2}\sigma_\theta^2 \phi_A [Pl_i f(l_i + l_j; \beta)]^2\right] + \left[Pl_2 f(l_1 + l_2; \beta)] - cl_2 - \tfrac{1}{2}\sigma_\theta^2 \phi_A [Pl_2 f(l_i + l_j; \beta)]^2\right] \tag{2.3}$$

Scenario 4: Noncooperative Game, Two Players, Climate Risk

$$\max_{l_1} EU(\pi_1^{NC}) = \left[Pl_1 f(l_1 + l_2; \beta)] - cl_1 - \tfrac{1}{2}\sigma_\theta^2 \phi_A [Pl_i f(l_i + l_j; \beta)]^2\right] \tag{2.4a}$$

$$\max_{l_2} EU(\pi_2^{NC}) = \left[Pl_2 f(l_1 + l_2; \beta)] - cl_2 - \tfrac{1}{2}\sigma_\theta^2 \phi_A [Pl_2 f(l_i + l_j; \beta)]^2\right] \tag{2.4b}$$

First-Order Conditions

To simplify notation when writing the first-order conditions, we use f for $f(l_i + l_j; \beta)$, and R for the variance multiplied by the coefficient of absolute risk aversion, $(\sigma_\theta^2 \phi_A)$. Furthermore, we also assume that:

$$\frac{\partial f}{\partial l_1} = \frac{\partial f}{\partial l_2}$$

and

$$\frac{\partial^2 f}{\partial l_1^2} = \frac{\partial^2 f}{\partial l_2^2}$$

These assumptions have been widely made in the theoretical literature and hold that "inputs" are equally productive across producers, so that each producer's share of total output is equal to their share of variable inputs applied.[8] Below, we give the first-order conditions for each scenario outlined above, substituting $l = l_1 = l_2$ in the joint maximization scenarios.

Scenario 1: Joint Maximization, No Climate Risk

$$\frac{\partial EU^{JM}}{\partial l} = P[f + lf'] + Plf' - c + P[f + lf'] + Plf' - c = 0 \tag{2.5}$$

or equivalently,

$$2P[f + 2lf'] - 2c = 0 \tag{2.6}$$

[8]In cases where the common-pool resources (CPRs) are being exploited by a group of people using the same underlying technology (e.g., herders stocking the same breed of livestock or fishermen using the same type of boats), this assumption is justified, as it is in our study sites. However, it would not be justified if we considered a herder who held low-growth, indigenous cattle and who shared common pastures with another herder who held high-growth, improved stock (assuming that both types of animals are otherwise identical), or a community in which some members have adopted a modern fishing technology but others were still using traditional methods.

Scenario 2: Noncooperative Game, Two Players, No Climate Risk

$$\frac{\partial EU_i}{\partial l_i} + P[f + lf'] - c = 0 \qquad (2.7)$$

for $i = 1,2$.

Scenario 3: Joint Maximization, Climate Risk

$$\frac{\partial EU^{JM}}{\partial l} = P[f + lf'] - RP^2 lf[f + lf'] + Plf' - RP^2 l^2 ff' - c + P[f + lf'] - RP^2 lf[f + lf'] + Plf' - RP^2 l^2 ff' - c = 0 \qquad (2.8)$$

or equivalently,

$$2P[f + 2lf' - PRlf(f + 2lf')] - 2c = 0 \qquad (2.9)$$

Scenario 4: Noncooperative Game, Two Players, Climate Risk

$$\frac{\partial EU^{NC}}{\partial l_i} = P\left[f + l_i f' - R_i l_i f[P(f + l_i f')]\right] - c = 0 \qquad (2.10)$$

for $i = 1,2$.

The first two implications of the model are not surprising, and coincide with the general effect of variability and noncooperation on exploitation levels. Comparing the first-order conditions for the variability and no variability scenarios, we see that exploitation levels are lower when there is climate risk under both joint maximization (compare equations [2.6] and [2.9]) and noncooperation (compare equations [2.7] and [2.10]). We can also see the standard result that input levels are higher under noncooperation than under joint maximization, with and without climate risk (see the proof supplied in Appendix 1).

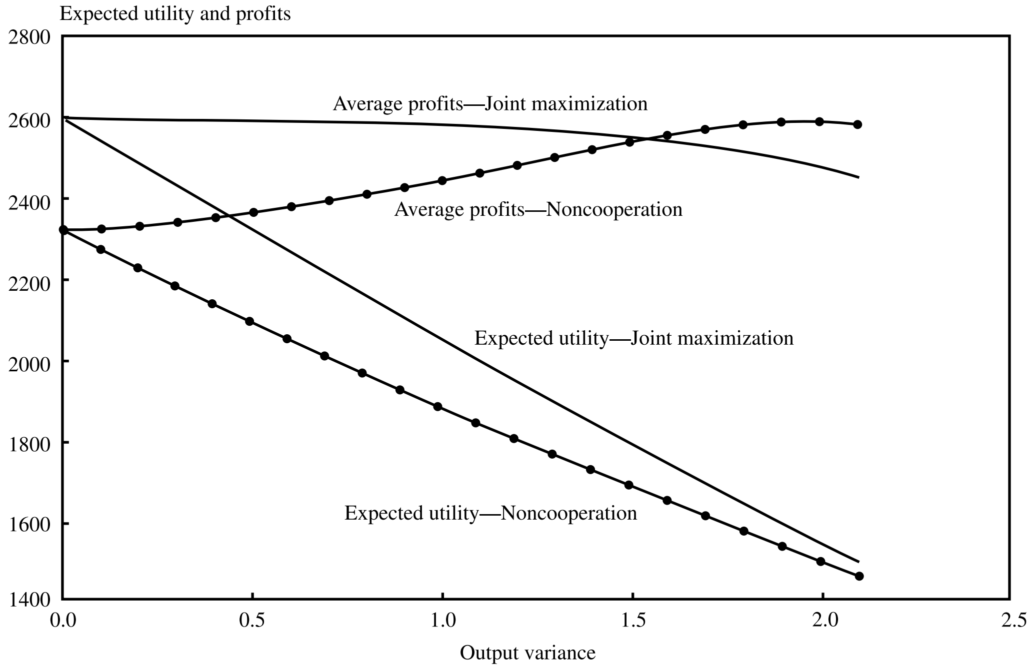
What is more interesting is that input levels under noncooperation and climate risk may be equal to or lower than the levels under no risk joint maximization (proof provided in Appendix 1), which is the basis for the conclusion in Sandler and Sterbenz (1990) that risk mitigates the "tragedy of the commons." Nonetheless, note that to obtain this result, we must make a comparison across two different levels of risk, as well as across two types of management regimes. That is to say, this result depends on using the joint-maximization solution in the absence of variability as the basis for calculating the degree of overexploitation. If instead, we compared the noncooperative outcome to the joint-maximization solution at the same level of climate risk, it is simply not necessary that overexploitation—defined here as the difference between the joint-maximization and noncooperative levels—decreases with increases in climate risk.

Next, we can examine average profits and expected utility accruing under both scenarios as the level of climate risk is increased, as shown graphically in Figure 2.1.[9]

Starting from a point of no variability, as variability increases, both total and individual input levels decline, and average profits under noncooperation increase to the point at which input levels coincide with the optimal stock levels associated with the joint-maximization solution under no climate risk. At this point, further increases in variability will reduce both average profits and expected utility. As also shown in Figure 2.1, increases in variability will always reduce both average profits and expected utility under joint-maximization. In fact, we see that average profits are actually lower under joint-maximization vs. noncooperation over a range of values for output variance; how-

[9]The model is parameterized based very roughly on prices, costs, and productivity parameters from the Ethiopia case study; income is high, because there are only two players in the game, as opposed to the average of 79 households per community in Ethiopia.

Figure 2.1 Expected utility and average profits as functions of variability: joint maximization and noncooperation

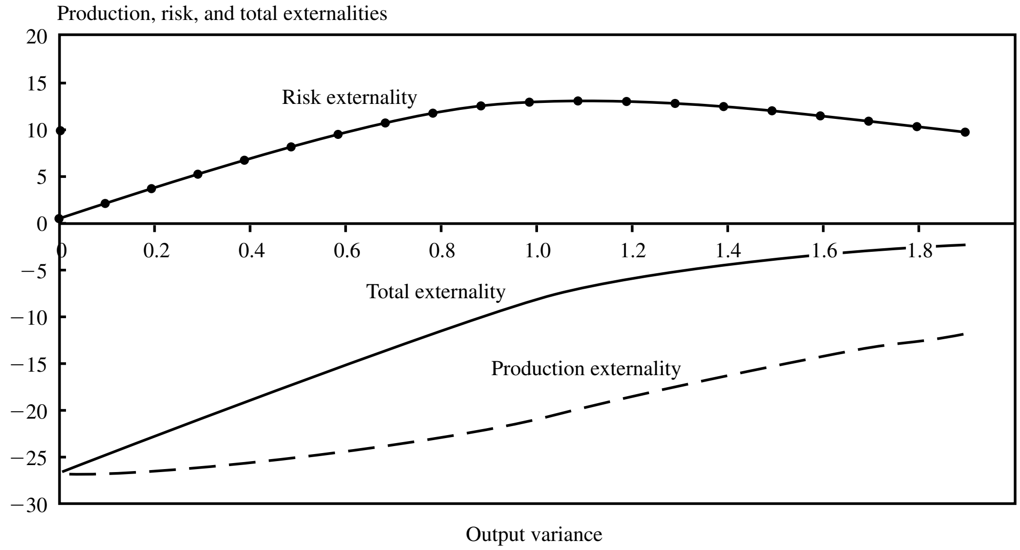


ever, note that expected utility is always lower under noncooperation. Thus, where producers are risk-averse, we may very well observe input levels that produce average profits at—or even above—average profits that coincide with joint maximization.

Another interesting way to highlight the difference between the variability and no-variability situation is to consider how the externality changes as variability increases. The difference between the first-order conditions for joint-maximization vs. noncooperation under certainty is equal to lf' (compare equations [2.5] and [2.6]). This is the standard crowding externality. The difference between the first-order conditions for joint-maximization vs. noncooperation under climate risk is equal to $lf' - RPl^2ff'$, where the second term, $-RPl^2ff'$, is hereafter referred to as the risk externality. Note that whereas lf' is negative, $-RPl^2ff'$ is positive, so that the externalities are offsetting. Using a general functional form for production, the overall change in the total externality (crowding plus risk) as climate risk increases is indeterminate, although the total externality itself will always be negative (the crowding externality is always absolutely greater than the risk externality, regardless of the functional form for production, as long as the production function is concave). However, a sufficient condition for the total externality to increase (become less negative) is that the absolute value of the elasticity of input demand with respect to climate variance be less than 1, the proof of which is provided in Appendix 2. In this case, we might say that the "tragedy of the commons" is indeed reduced in the sense that the associated absolute level of the total externality decreases as variability increases. Figure 2.2 illustrates the case for the linear quadratic production function, in which the elasticity condition holds.

Now consider an increase in the number of players. As shown in Appendix 1, increasing the number of players always increases the difference between the first-order condition resulting from noncooperation and that arising from the social

Figure 2.2 Production, risk, and total externalities as functions of risk aversion



optimum, so that overall stock densities increase with the number of players.

Next consider the impact of other model variables. Any variables positively affecting profitability—greater output prices, shorter distances to market, and lower input prices —lead to higher stock densities, as long as herders are not too risk-averse. Differentiating any of the first-order conditions given above with respect to output prices, for instance, yields a positive term that captures the direct impact on the marginal product of livestock and a negative term that captures the impact of increased prices on the marginal cost of risk. Thus, the overall impact is ambiguous. Note that greater profitability has a similar effect on both the social optimum and the noncooperative game, as is true for other variables. Although fairly obvious, this similarity is often forgotten when discussing the impact of profitability on resource use and management. Better agro-ecological conditions that increase average product will lead to higher stock densities under both management regimes. Finally, consider the impact of outsiders using home pastures. If we take this use as a given—perhaps by custom or tradition—then it simply decreases the average product function, thereby decreasing stock levels held by community members. The latter requires that use by outsiders is not influenced by strategic choice—it is simply a given. Also, note that, to this point, we are only examining the direct impact of various factors on stock densities, assuming either noncooperation or joint maximization. As we develop more fully later in this chapter, many of these variables also have indirect impacts on stock densities through an impact on cooperative capacity. Use of home pastures by outsiders is one such variable: although the direct impact is to reduce community members' stock, such use may make cooperation more difficult and thus have an indirect positive impact on community livestock holdings.

To summarize, we hypothesize that greater rainfall variability leads to lower stock densities, and that cooperation in the use of home pastures also reduces stock levels. An increase in the number of herders increases the size of the externalities under noncooperation, and thus leads to higher stock densities. Greater profitability and better underlying agro-ecological conditions—higher output prices, lower input prices, shorter distances to market, better soils, less field slope—all increase stock densities.

Mobility

In van den Brink et al. (1995), the authors consider the effect of rainfall and variability in rainfall on producer decisions to either engage in mobile livestock production or become sedentary farmers. Their model considers returns to livestock vis-à-vis cropping quite generally; the emphasis is on rainfall variability and the comparative advantage that mobile herds may offer. However, in their analysis, neither traditional externalities associated with the use of common pastures nor the ability of communities to cooperate is explicitly considered, so that the impact of variability on cooperation and land use are not considered.

Furthermore, although many researchers have discussed the benefits of mobility in capturing the value of ex post adjustments to actual rainfall realizations for the individual herder (Thompson and Wilson 1994; van den Brink et al. 1995), few economic models have considered the incentives for individual herders to engage in mobility when one's own choice on mobility is affected by the choices of others who share access to the same pastures at home. Schoonmaker-Freudenberger and Schoonmaker-Freudenberger (1993) discuss patterns of mobility observed in the Ferlo region of Senegal. They argue that the individual's decision to engage in mobility depends on how many other individuals choose to remain at home. The description implies that the structure of incentives to engage in mobility resemble a "chicken game," in which the best response to another herder's action is to do the opposite. Under normal rainfall conditions, each herder would prefer to stay at home while at least a certain fraction of others migrate, but a herder also prefers to move in the case in which no others do so. Under other rainfall conditions, however, all community members may prefer to be mobile or all stay at home, so that the fraction moving in any given period will depend on relative rainfall realizations across the region of potential mobility. Mobility will also be a function of relative differences in pasture productivity, the transactions costs of mobility, and the number of members within a community.

With respect to economic heterogeneity, it is quite possible that wealthier herders may have as a dominant strategy to always move, whereas poorer herders may tend to remain at home, as discussed in Ruttan (2000). As the number of members in the community increases, the probability that wealthier herders now find it profitable to move increases, because profits on the home area will decrease with increasing community population, but profits accruing to the herder engaged in mobility do not change when the number of members increases.[10] Thus, the fraction of herders moving in any period will also be a positive function of the extent of economic heterogeneity.

Below, we develop a game-theoretic model of stock densities and herd mobility, in which herders all use community pastures in the first period, but face a discrete decision whether or not to migrate to non-community pastures in the second period. The model is similar to those developed to analyze oligopolistic behavior, in which firms choose to invest in the first period (see Mas-Colell et al. 1995) and play a quantity-choice game in the second stage, although in our model, both the first and second stages are characterized by different games.

Returning to our particular case of herd size and mobility, the decision on mobility results in outcomes in which either both

[10]This is the case when the available pasture in the "rest of the world" is not subject to the same negative externalities that characterize the use of home pastures.

migrate, neither migrates, or one (or a fraction) of the herders migrate in equilibrium, and relative rainfall realizations plus transaction costs of mobility largely determine the extent of mobility. We then extend the model to allow herders to choose stock densities in the first period and mobility in the second period. As shown below, results indicate that noncooperation is likely to lead to higher stock densities and lower mobility, although it is also possible that stock densities increase to the extent that more mobility is undertaken. It is also possible, if home pastures are very productive but higher stock densities have a large impact on the crowding externality, that both stock densities and mobility will be lower under noncooperation. In any case, returns are lower than those that accrue under the social optimum. As is often the case, incorporating risk-averse behavior leads to ambiguous results. Risk aversion increases the value of mobility vis-à-vis the case in which mobility is not an option and likely leads to both greater mobility and higher stock levels, although the latter is by no means certain. The lower the covariance between rainfall realized at the two sites, the greater will be the mobility and, potentially, the stock densities.

In the next section, we develop a simple, two-period model of stock densities and mobility, assuming herders are risk-neutral. We posit that herders use home pastures in period 1, but have the choice to stay at home or engage in mobility to outside pastures in period 2. The second period decision is discrete: either a herder must migrate with the entire herd, or remain at home with the entire herd.[11] We then consider the impact of risk aversion, and conclude by presenting testable hypotheses stemming from the model. We start by specifying the following maximization problem:

$$\max_{l_1} \; E(\pi_1^{NC}) = E(P\theta^{H1} l_1 f(l_1 + l_2; \beta) - cl_1 + V^2) \tag{2.11}$$

subject to

$$V^2 = \max\left(E(P\theta^{H2} l_1 f(L^H; \beta^H) - cl_1), E(P\theta^{A2} g(l_1; \beta^A) - cl_1 - c_{Mob} l_1)\right) \tag{2.12}$$

where $E(\cdot)$ is the expectations operator, and $g(\cdot)$ is the total product obtained on array pastures. Rainfall is specified to have a multiplicative impact on total returns, captured by the terms θ^{H1}, θ^{H2}, θ^{A2}, where the letters in the superscripts refer to the location of pastures—*H* signifies home pastures, *A* signifies away pastures—and the numbers in the subscripts refer to either the first or second period. The quantities β^H and β^A are productivity parameters for home and away pastures, respectively; *c* is the per unit costs of holding livestock; L^H is the number of animals remaining on home pastures during the second period; c_{Mob} represents per unit costs of mobility, and all other variables are as defined earlier in the chapter in the stock density decision model. Suppressing the productivity parameters in the production functions, setting the output price equal to 1, and taking expectations, we can rewrite the maximization problem as:

$$\max_{l_1} \; E(\pi_1^{NC}) = E(\theta^{H1} l_1 f(l_1 + l_2) - cl_1 + V^2) \tag{2.13}$$

subject to

$$V^2 = \max\left(E(\theta^{H2} l_1 f(L^H) - cl_1), E(\theta^{A2} g(l_1) - cl_1 - c_{Mob} l_1)\right) \tag{2.14}$$

[11]This is done for expositional simplicity: results do not change if a fraction of an individual's herd can be moved, except when different animals have different marginal costs of herding. Even in this case, the proportion of cattle that migrate at the community level does not depend on which animals actually move (in the different-cost case, there will be a fraction of different types engaged in mobility at the community level). So, for instance, if there were two "types" of animals, then there would be two subgames. The same holds if different types are subject to different shocks; although, in this case, the analysis is more complicated. Nonetheless, the qualitative results remain; equilibrium outcomes continue to resemble a chicken game.

After taking expectations, we subsitute the mean realization of these variables in the maximization problem, $\bar{\theta}^{H1}$, $\bar{\theta}^{H2}$, $\bar{\theta}^{A2}$. Returns on home pastures realized in the second period are a function of L^H, β^H, and the mean rainfall on home pastures. Returns on away pastures are a function of the individual herder's stock levels, l_1, and not on anyone else's stock levels. Returns to away pastures are also a function of β^A and c_{Mob}. Lower c and higher output prices, P_l, increase returns to stock levels whether animals are home or away.

Consider the second-period problem, in which the herder must choose whether to stay at home or migrate with the herd. Initially, we assume that there are only two herders. The player has two potential strategies in his strategy set $S_i = \{s_i^H, s_i^A\}$. There are thus four potential payoffs that player 1 might receive, $\pi_i^{s_1^H, s_2^H}$, $\pi_i^{s_1^H, s_2^A}$, $\pi_i^{s_1^A, s_2^H}$, $\pi_i^{s_1^A, s_2^A}$, where:

$$E(\pi_i^{s_1^H, s_2^H}) = \bar{\theta}^{H2} l_1 f(l_1 + l_2) - cl_1$$

$$E(\pi_i^{s_1^H, s_2^A}) = \bar{\theta}^{H2} l_1 f(l_1) - cl_1$$

$$E(\pi_i^{s_1^A, s_2^H}) = \bar{\theta}^{A2} g(l_1) - cl_1 - c_{Mob}$$

$$E(\pi_i^{s_1^A, s_2^A}) = \bar{\theta}^{A2} g(l_1) - cl_1 - c_{Mob}$$

Note that the expected profits from migrating are the same for player 1, irrespective of whether player 2 stays at home or also migrates. Next, we can determine player 1's best response to a strategy undertaken by player 2; this choice is easily seen in the typical 2×2 representation of the normal form game.

If player 2 stays at home, player 1 will also stay at home if

$$\bar{\theta}^{H2} l_1 f(l_1 + l_2) > \bar{\theta}^{A2} g(l_1) - c_{Mob}$$

otherwise, he chooses to move. If player 2 migrates, then player 1 will remain at home if

$$\bar{\theta}^{H2} l_1 f(l_1) > \bar{\theta}^{A2} g(l_1) - c_{Mob}$$

First note that if

$$\bar{\theta}^{H2} l_1 f(l_1 + l_2) > \bar{\theta}^{A2} g(l_1) - c_{Mob}$$

then surely

$$\bar{\theta}^{H2} l_1 f(l_1) > \bar{\theta}^{A2} g(l_1) - c_{Mob}$$

because

$$\bar{\theta}^{H2} l_1 f(l_1) > \bar{\theta}^{H2} l_1 f(l_1 + l_2)$$

That is, if player 1 chooses to stay home when player 2 stays home, then clearly the former will also choose to stay home when player 2 is away. Given alternative parameter values, the game might be fully privileged, in the sense that either both players stay at home or both players engage in mobility; these Nash equilibria are also the social optimums. Or, the game might resemble a chicken game, with two pure-strategy Nash equilibria, in which one player migrates and the other stays at home. This happens when

$$\bar{\theta}^{H2} l_1 f(l_1) > \bar{\theta}^{A2} g(l_1) - c_{Mob} > \bar{\theta}^{H2} l_1 f(l_1 + l_2)$$

	Player 2—Home	Player 2—Away
Player 1—Home	$\bar{\theta}^{H2} l_1 f(l_1 + l_2) - cl_1$, $\bar{\theta}^{H2} l_2 f(l_1 + l_2) - cl_2$	$\bar{\theta}^{H2} l_1 f(l_1) - cl_1$, $\bar{\theta}^{A2} g(l_2) - cl_2 - c_{Mob}$
Player 1—Away	$\bar{\theta}^{A2} g(l_1) - cl_1 - c_{Mob}$ $\bar{\theta}^{H2} l_2 f(l_2) - cl_2$	$\bar{\theta}^{A2} g(l_1) - cl_1 - \bar{c}_{Mob}$, $\bar{\theta}^{A2} g(l_2) - cl_2 - c_{Mob}$

As with the fully privileged equilibria, the Nash equilibria are also socially optimal, for given l_1 and l_2. Because we have set up the game as a one-period game (one period in which mobility is a choice), we write the expected value of V^2 in terms of the mixed-strategy Nash equilibria:

$$EV^2 = \tfrac{1}{2}[\bar{\theta}^{H2} l_1 f(L^H) - cl_1] + \tfrac{1}{2}[\bar{\theta}^{A2} g(l_1) - cl_1 - c_{Mob}] \quad (2.15)$$

Note that it is not possible for the game to resemble an assurance game, characterized as having two Nash equilibria, one in which both remain at home and the other with both migrating. An assurance game would require

$$\bar{\theta}^{H2} l_1 f(l_1 + l_2) > \bar{\theta}^{A2} g(l_1) - c_{Mob}$$

and

$$\bar{\theta}^{A2} g(l_1) - c_{Mob} > \bar{\theta}^{H2} l_1 f(l_1)$$

which is not possible. Also, the game can never resemble a prisoner's dilemma, because a prisoner's dilemma would require not only

$$\bar{\theta}^{H2} l_1 f(l_1 + l_2) > \bar{\theta}^{A2} g(l_1) - c_{Mob}$$

and

$$\bar{\theta}^{H2} l_1 f(l_1) > \bar{\theta}^{A2} g(l_1) - c_{Mob}$$

but also that

$$\bar{\theta}^{A2} g(l_1) - c_{Mob} > \bar{\theta}^{H2} l_1 f(l_1 + l_2)$$

which obviously contradicts the first requirement. The latter holds because the returns to player 1 from migrating are not a function of the other player's decision.

Mobility will be chosen when

$$\bar{\theta}^{A2} g(l_1) - c_{Mob} > \bar{\theta}^{H2} l_1 f(l_1 + l_2)$$

and it is easy to see that this inequality is more likely to hold the greater the mean rainfall at away pastures and the more productive those pastures relative to home pastures. We noted above that the Nash equilibria to the mobility game are the same strategies that would be chosen by a social optimizer, *for given* l_1 and l_2. However, to the extent that

$$[\bar{\theta}^{H2} l_1 f(l_1 + l_2)]^{NC} < [\bar{\theta}^{H2} l_1 f(l_1 + l_2)]^{JM}$$

then it is more likely that mobility is undertaken. In other words, if returns to home pastures are driven down by noncooperation at home, then mobility is promoted. This result gives insight into the more sophisticated game developed below, in which the proportion of herds engaging in mobility under noncooperation may be greater than or less than that proportion under the social optimum.

We now extend the game to consider N players and consider that each player has two choice variables: the number of animals to hold and the proportion of a season spent at home. We can write the individual's maximization problem as:

$$\max_{l_1} \; E(\pi_1^{NC}) = \bar{\theta}^{H1} l_1 f\Big(l_1 + \sum_{j \neq 1} l_j\Big) - cl_1 + \bar{\theta}^{H2}\Big[d_{H1}\Big(l_1 f\Big(\sum_i l_i d_{Hi}\Big) - cl_1\Big)\Big] + \bar{\theta}^{A2}(1 - d_{H1})[g(l_1) - cl_1] - c_{Mob} \quad (2.16)$$

such that

$$d_H + d_A = 1$$

where d_H is the proportion of days in the second season that herders remain at home, and $d_A = 1 - d_H$ is the proportion of days spent in migration. Taking the derivative of the above problem with respect to the number animals and the number of days in migration yields:

First-Order Conditions: Noncooperation

$$\mathrm{FOC}_{l1}^{NC} = \bar{\theta}^{H1}\left[f + l_1 \frac{\partial f(L)}{\partial l_1}\right] - c + \left[\bar{\theta}^{H2}\left(d_{H1}f + d_{H1}l_1 \frac{\partial f\left(\sum d_{Hi}l_i\right)}{\partial l_1}\right) - c\right] + \left[\bar{\theta}^{A2}(1-d_{H1})\frac{\partial g(l_1)}{\partial l_1} - c\right] \quad (2.17)$$

$$\mathrm{FOC}_{d_{H1}}^{NC} = \bar{\theta}^{H2}\left[l_1 f + d_{H1}l_1 \frac{\partial f\left(\sum d_{Hi}l_i\right)}{\partial d_{H1}}\right] - \bar{\theta}^{A2}g(l_1) \quad (2.18)$$

Again assuming that the social optimizer jointly maximizes over all individuals and suppressing the arguments in the average product function for use of home pastures, *f*, the first-order conditions for individual $i = 1$ are as:

First-Order Conditions: Joint Maximization

$$\mathrm{FOC}_{l1}^{JM} = \bar{\theta}^{H1}\left[f + l_1 \frac{\partial f}{\partial l_1} + \sum_{j\neq 1} l_j \frac{\partial f}{\partial l_1}\right] - c + \left[\bar{\theta}^{H2}\left(d_{H1}f + d_{H1}l_1 \frac{\partial f}{\partial l_1} + \sum_{j\neq 1} d_{H1}l_1 \frac{\partial f}{\partial l_1}\right) - c\right] + \left[\bar{\theta}^{A2}(1-d_{H1})\frac{\partial g}{\partial l_1} - c\right] \quad (2.19)$$

$$\mathrm{FOC}_{d_{H1}}^{JM} = \bar{\theta}^{H2}\left[l_1 f + l_1 d_{H1}\frac{\partial f}{\partial d_{H1}} + \sum_{j\neq 1} l_j d_{Hj}\frac{\partial f}{\partial l_1}\right] - \bar{\theta}^{A2}g(l_1) \quad (2.20)$$

Under both noncooperation and the social optimum, the first-order condition with respect to herd size has three terms. The first term represents the marginal impact of adding an additional animal on revenues deriving from the use of home pastures during the first period. The second term is the marginal impact on returns from using home pastures the second period multiplied by proportion of the season that the individual will stay at home. The third term is the marginal impact of an additional animal on returns from engaging in mobility during the second period multiplied by the proportion of the season that the individual engages in mobility. The first-order condition with respect to days is composed of the marginal returns to remaining on home pastures and the marginal returns to migrating.

Comparing the first-order conditions (FOCs), we see that $\mathrm{FOC}_{l1}^{NC} > \mathrm{FOC}_{l1}^{JM}$ when evaluated at the same l_i, d_{Hi} pair, as FOC_{l1}^{JM} contains two additional terms:

$$\sum_{j\neq 1} l_j \frac{\partial f(L)}{\partial l_1}, \sum_{j\neq 1} d_{Hj}l_j \frac{\partial f\left(\sum d_{Hi}l_i\right)}{\partial l_1}$$

both of which are negative. Also, $\mathrm{FOC}_{d_{H1}}^{NC} > \mathrm{FOC}_{d_{H1}}^{JM}$, because $\mathrm{FOC}_{d_{H1}}^{JM}$ contains the additional term

$$\sum_{j\neq 1} d_{Hj}l_j \frac{\partial f\left(\sum d_{Hi}l_i\right)}{\partial l_{H1}}$$

which is also negative. The former is the conventional negative externality arising from adding an additional head of livestock, the latter externality captures the negative effect of remaining at home on all other players.

Thus, either $l_1^{NC} \neq l_1^{JM}$ and/or $d_{H1}^{NC} \neq d_{H1}^{JM}$ in equilibrium. Either increasing l_1^{NC} or increasing d_{H1} would reduce FOC_{l1}^{NC}, $\mathrm{FOC}_{d_{H1}}^{NC}$, as required; thus $l_1^{NC} > l_1^{JM}$ and $d_{H1}^{NC} > d_{H1}^{JM}$ is a possible equilibrium outcome. Unfortunately, any combination, $l_1^{NC} > l_1^{JM}$, $d_{H1}^{NC} \gtreqless d_{H1}^{JM}$ is possible, as is $l_1^{NC} < l_1^{JM}$, $d_{H1}^{NC} > d_{H1}^{JM}$. The only combination that we can rule out is $l_1^{NC} < l_1^{JM}$, $d_{H1}^{NC} > d_{H1}^{JM}$. We can consider under what circumstances each outcome is likely to arise. First, note that $l_1^{NC} < l_1^{JM}$ would lead to an increase in all three terms in FOC_{l1}^{NC} whereas increasing d_{H1} would only lead to a decrease in the second two terms. Also, d_{H1} is bounded by

1, so there is a limit to which d_{H1} can be increased.[12] Thus, this outcome is not likely unless marginal returns to away pastures are very large but diminish slowly, and the average product of home pastures is relatively high but returns decline quickly. Given $l_1^{NC} > l_1^{JM}$, d_{H1}^{NC} is more likely to be greater than d_{H1}^{JM} when marginal returns to home and away pastures are relatively similar and diminish at a similar rate; d_{H1}^{NC} is more likely to be less than d_{H1}^{JM} when stock densities have a large impact on externalities at the margin, and away pastures are of relatively high productivity. That is, when home and away pastures have similar characteristics, which is quite likely in the semiarid agroecological environments where case studies were undertaken, we expect $l_1^{NC} > l_1^{JM}$ and $d_{H1}^{NC} > d_{H1}^{JM}$.

Finally, we consider the implications of combining this model of mobility with the model of the stock density decision by risk-averse herders detailed in the previous section. Letting $\bar{R}_i^{H1}$, $\bar{R}_i^{H2}$, $\bar{R}_i^{A2}$ represent the mean returns realized during the first and second periods from home and away pastures, $\sigma_{\theta^H}^{H2}$, $\sigma_{\theta^A}^{A2}$ represent the variance of returns on home and away pastures during the second period, and assuming, for simplicity, that rainfall on home pastures in the first period is nonstochastic ($\sigma_{\theta^H}^{H1} = 0$), we can write the following maximization problem:

$$\max_{l_1,d_1} EU(\pi^{NC}) = \Big[\bar{R}_1^{H1} + d_{1H}\bar{R}_1^{H2} + (1 - d_{1H})\bar{R}_1^{A2} - \tfrac{1}{2}\phi_A([d_{1H}\bar{R}_1^{H2}]^2\,\sigma_\theta^{H2} + [(1 - d_{1H})\bar{R}_1^{A2}]^2\,\sigma_\theta^{A2} + 2[d_{1H}\bar{R}_1^{H2}]\,[(1 - d_{1H})\bar{R}_1^{A2}]\,\mathrm{cov}\,(\sigma_\theta^{H2}, \sigma_\theta^{A2}))\Big] \quad (2.21)$$

Although it is difficult to compare much without the aid of a simulation model and empirical parameter estimates, we can still easily note that the lower the covariance, the greater will be either stock levels or mobility, or both. Because mobility reduces the variance of returns, however, we expect that under most parameter values, risk-averse herders will choose a greater level of herd mobility.

In our empirical work, we do not have long time-series data on mobility, only observations on the extent of mobility undertaken during the 12 months previous to the survey. Actual mobility will adjust to current rainfall realizations relative to long-term values. The higher the rainfall realizations on home pastures (relative to long-term mean rainfall and rainfall occurring on away pastures), the lower will be the mobility in this period. For other parameters, we note that comparative statistics of this four-variable system with risk aversion are, in general, ambiguous, but as long as risk aversion is not too great and strategic effects not too large, then the lower the costs of mobility and the lower the relative productivity of home vs. away pastures, the greater will be mobility. Higher output prices and lower costs per animal are expected to increase stock densities and thus, mobility.

Land Allocation

The ultimate decision to be made is on the allocation of land between usufruct (de facto private) cultivation by individual households and common pastures. The decision by community members on stock rates on home pastures determines the marginal productivity of land allocated to pastures. This productivity will be equated to that arising from cultivation. Thus, to the extent that noncooperation reduces the productivity of home pastures, there will be pressure for land to be reallocated to individual crops. In

[12]Furthermore, if we had modeled the choice as a two-stage game, where days away are chosen for any given stock densities in the second stage, and stock densities are chosen in the first stage, then we can rule out $l_1^{NC} < l_1^{SO}$, $d_{H1}^{NC} > d_{H1}^{SO}$.

addition, even if there is perfect cooperation over stock densities on community pastures, there will be a tendency to underprovide land to the commons, so that the number of members has both a positive direct effect on land allocated to crops and an indirect positive effect via stock densities, to the extent that the latter are overexploited (de Janvry et al. 1998). Put differently, allocating land to the common pool is similar to providing a public good, and, as such, there will be a tendency to underprovide that good, irrespective of how the land is used. If members know that the common-pool pastures will subsequently be overexploited, then there will be a tendency to reduce the allocation of land to the common pastures. These are two distinct effects, often referred to as provision and appropriation (de Janvry et al. 1998). Following this model, below we assume that under a noncooperative game, the *i*th individual decides how much of his/her share of total land, which we assume to be A/N will be allocated to crops, ac_i, and to pastures, ap_i, with the constraint:

$$ac_i + ap_i = A_i = A/N$$

With respect to the addition of rainfall variability in this model, given that livestock herding is less subject to the vagaries of climate than is crop production, it would seem trivial to show that more land would be allocated to livestock than to crops in higher variability environments. However —as so often happens with models incorporating multiple covariate risks—the effect is actually ambiguous (McCarthy 1999). This comes about as a result of externalities generated by the use of common pastures that do not arise under individual crop farming. The presence of both crowding and risk externalities has a positive impact on the proportion of land allocated to individual crops vs. common pastures, because of individuals' incentives to minimize this externality, ceteris paribus. Nevertheless, because our empirical work has been undertaken in relatively marginal semiarid regions, we hypothesize that the overall impact of rainfall variability on cropland allocation is negative, whereas the impact of higher rainfall on cropland is positive.

To summarize, we make the following hypotheses: greater negative externalities generated on common pasture lead to a greater proportion of land allocated to crops, and larger membership in the community also leads to more land allocated to crops, because the provision externality increases. Other factors will also affect cropland allocation. We hypothesize that population density will lead to more land in crops when density-driven intensification favors productivity improvements in crops vs. livestock, that higher relative ratios of crop:livestock prices increase cropland, that more crop-specific assets held within the community and more infrastructure increase cropland, and finally, that higher mean rainfall leads to more cropland, whereas greater rainfall variability reduces cropland.

Cooperation

Given that formal rules and regulations on stock densities and land allocation do not exist in any of the communities studied, then following the noncooperative model, overexploitation should be captured solely by the number of members. However, there is a large body of empirical evidence to support the notion that communities are unlikely to either fully cooperate or completely not cooperate (Ostrom 1990; Baland and Plateau 1996); instead, outcomes are likely to be between the two extremes, because achieving collective action is likely to be costly (Oakerson 1992). In other words, observed outcomes in a community are not likely to be the result of a binary choice between perfect cooperation and absolute noncooperation, but rather a function of variables often posited to affect the "successfulness" of cooperation that have an impact at the margin.

Nonetheless, theoretical models of cooperation and how such cooperation can affect equilibrium outcomes are fairly rare. In a theoretical model of costly cooperation developed in McCarthy et al. (1998), equilibrium use levels are directly affected by agro-ecological conditions and demographic and market characteristics, but an indirect effect also arises via an impact through community-level capacity to cooperate, which shifts equilibrium use rates. Here, we develop a simplified representation of this model. In the model as developed thus far, the choice variables are the total herd size at the community level, the number of days the livestock migrate to away pastures, and the amount of land allocated to crops and pasture. For each of these choices, we assume that the social optimizer maximizes the sum of each individual's utility. Thus, the externalities not internalized under noncooperation are additive. For instance, in the mobility game without risk for player 1,

$$\mathrm{FOC}_{l1}^{NC} - \mathrm{FOC}_{l1}^{JM} = \sum_{j\neq 1} l_j \frac{\partial f(L)}{\partial l_1} + \sum_{j\neq 1} d_{Hj} l_j \frac{\partial f\left(\sum d_{Hi} l_i\right)}{\partial l_1}$$

let

$$Ext_{l1} = \sum_{j\neq 1} l_j \frac{\partial f(L)}{\partial l_1} + \sum_{j\neq 1} d_{Hj} l_j \frac{\partial f\left(\sum d_{Hi} l_i\right)}{\partial l_1}$$

where Ext_{l1}^{P} indicates the production externality generated by player 1 with respect to the choice of herd size, l. The above expression can be rewritten as:[13]

$$\mathrm{FOC}_{l1}^{NC} = \mathrm{FOC}_{l1}^{JM} = Ext_{l1}^{P}$$

Letting $\sigma_Y^{R_1}$ equal the complicated income variance term, ap_i equal the allocation of hectares allocated to pasture, and assuming that the total land endowment constraint

$$ac_i + ap_i = A_i$$

is binding, we can write the individual's maximization problem as:

$$\max_{l_1,d_1,ap_1} EU(\pi^{NC}) = [\bar{R}_1^{H1}(l_1,d_1,ap_1) + d_{1H}\bar{R}_1^{H2}(l_1,d_1,ap_1) + (1-d_{1H})\bar{R}_1^{A2}(l_1) - \tfrac{1}{2}\phi_A\sigma_Y^{R1}] \qquad (2.22)$$

which yields the first-order conditions for player 1:

$$\mathrm{FOC}_{l1}^{NC} = \mathrm{FOC}_{l1}^{SO} + Ext_{l1}^{P} + Ext_{l1}^{R} \qquad (2.23)$$

$$\mathrm{FOC}_{d1}^{NC} = \mathrm{FOC}_{d1}^{SO} + Ext_{d1}^{P} + Ext_{d1}^{R} \qquad (2.24)$$

$$\mathrm{FOC}_{ap1}^{NC} = \mathrm{FOC}_{ap1}^{SO} + Ext_{ap1}^{P} + Ext_{ap1}^{R} \qquad (2.25)$$

where the superscripts P and R refer to production and risk externalities, respectively. From the development of the model's constituent parts above, we note that Ext_{l1}^{P}, $Ext_{d1}^{P} < 0$, capturing the standard crowding externalities, whereas Ext_{l1}^{R}, $Ext_{d1}^{R} > 0$, because higher stock densities and greater herd mobility actually reduce overall variability of returns for other players. However, $Ext_{ap1}^{P} > 0$, capturing the public goods nature of allocating more land to common pastures, but $Ext_{ap1}^{R} < 0$, because increasing the size of the pastures will reduce variability for all players, an effect not taken into account by the individual.

Finally, we consider the social optimizer's problem. Following McCarthy et al. (1998), we posit that social optimizer jointly maximizes members' utility functions, subject to the cost of ensuring cooperation,

[13] Note that these externalities are exactly the Pigouvian tax required needed to induce the socially optimal stock levels (see Dasgupta and Heal 1979).

C_{Coop}, which is a function of the externalities generated under noncooperation

$$C_{Coop} = f(Ext,\ \lambda^{Coop})$$

A very simple cost function is:

$$C_{Coop-i} = (1 - \lambda^{Coop})\left(\sum_{j\neq 1}\bar{R}_j^{H1} + d_{iH}\,\bar{R}_j^{H2} + (1 - d_{iH})\,\bar{R}_j^{A2} - \tfrac{1}{2}\phi_{abs}\,\sigma_{\theta}^{R_i}\right)$$

which posits that individual-specific costs of cooperation will be a linear function of the capacity to cooperate, λ^{Coop}, and the utility function of all other individuals. We write the "costly" social optimizer's problem (*SOCst*) as:

$$\max_{l_1,d_1,hp_1} \sum EU(\pi^{SOCst}) = \Big[\bar{R}_1^{H1} + d_{1H}\bar{R}_1^{H2} + (1 - d_{1H})\bar{R}_1^{A2} - \tfrac{1}{2}\phi_{abs}\sigma_{\theta}^{R_i} + (1 - \lambda^{Coop})\Big(\sum_{j\neq 1}\bar{R}_j^{H1} + d_{iH}\,\bar{R}_j^{H2}] + (1 - d_{iH})\bar{R}_j^{A2} - \tfrac{1}{2}\phi_{abs}\sigma_{\theta}^{R_i}\Big)\Big] \quad (2.26)$$

such that

$$0 \leq \lambda^{Coop} \leq 1$$

Representative FOCs for player 1, are:

$$\text{FOC}_{l1}^{SOCst} = \text{FOC}_{l1}^{SO} + (1 - \lambda^{Coop})\,(Ext_{l1}^{P} + Ext_{l1}^{R}) \quad (2.27)$$

$$\text{FOC}_{d1}^{SOCst} = \text{FOC}_{d1}^{SO} + (1 - \lambda^{Coop})\,(Ext_{d1}^{P} + Ext_{d1}^{R}) \quad (2.28)$$

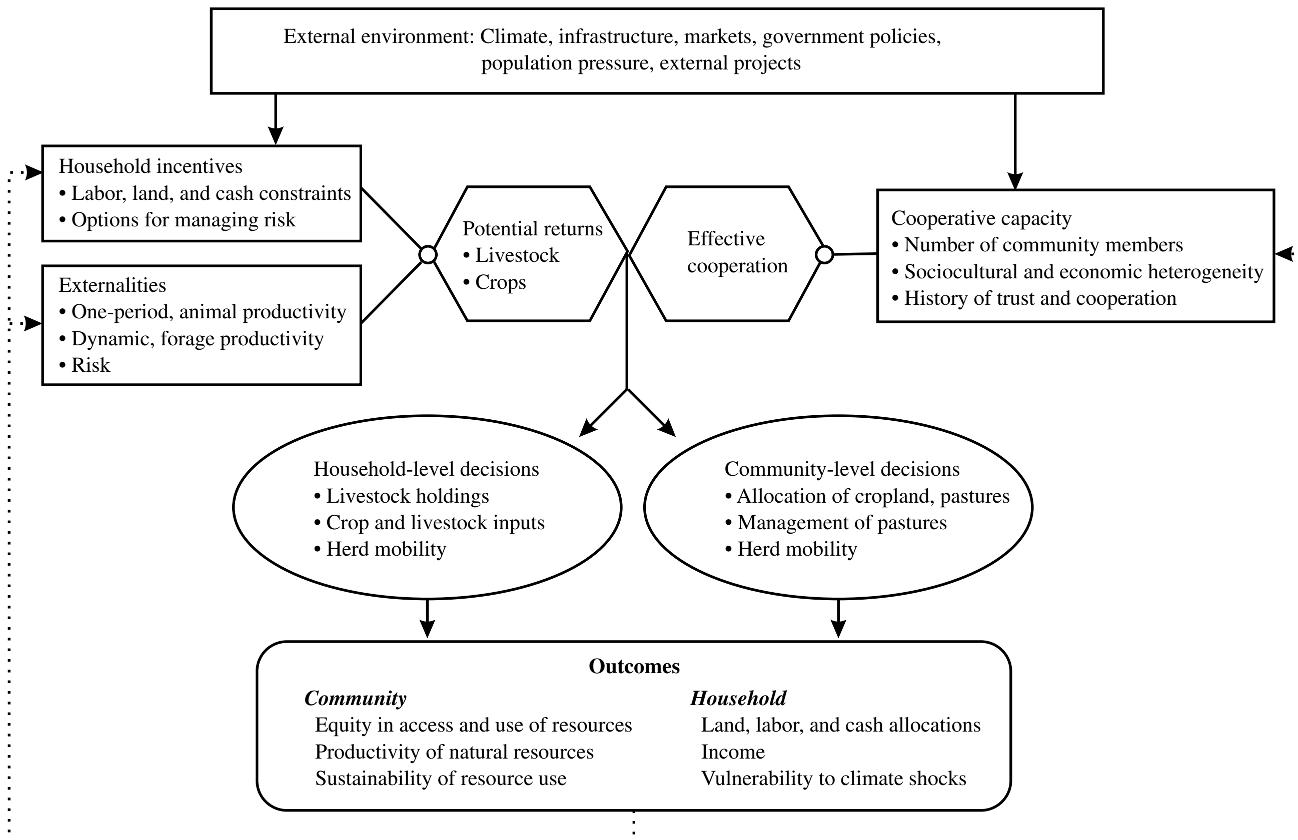
$$\text{FOC}_{hp1}^{SOCst} = \text{FOC}_{hp1}^{SO} + (1 - \lambda^{Coop})\,(Ext_{hp1}^{P} + Ext_{hp1}^{R}) \quad (2.29)$$

Note that λ^{Coop} is bounded below by 0 and above by 1; when cooperative capacity equals zero, the cost of cooperation will be such that the noncooperative solution is reproduced, when capacity equals one, all externalities will be internalized and the "costless" social optimum will be reached.

Variables expected to influence λ^{Coop} include the size of the group, sociocultural and economic heterogeneity, the extent and nature of interactions with external organizations or government agencies, whether certain resources are shared with noncommunity members, and "exit" opportunities (the opportunity cost of labor dedicated to undertaking collective action). An increase in the number of members at first reduces the cost of cooperation because of lower fixed costs per member, but at some point, higher transactions costs of making and enforcing agreements coupled with greater marginal costs (due to greater cumulative incentives to cheat) lower the relative gains to cooperating and thus lead directly and indirectly to higher stock densities (Sandler 1992; de Janvry et al. 1998; Bardhan 2000). Heterogeneity in terms of different marginal costs, wealth levels, cash constraints, and the like, reduces the scope over which mutually beneficial agreements might be made, thereby making cooperation more costly (Johnson and Libecap 1982; Alesina and La Ferrara 1999). As discussed in Chapter 1, social heterogeneity is almost always hypothesized to have a negative effect on cooperation, because different social norms may make creating and enforcing decisions more costly (Ostrom 1990; White and Runge 1994; Seabright 1997 and references therein; Bardhan 2000). However, at least some researchers posit that sociocultural homogeneity may lead to a stagnation of ideas and foster institutional inertia, thus leading to lower overall institutional capacity relative to communities with greater sociocultural diversity (Begossi 1998).

Distance to market centers and/or towns where local government offices are located may either increase or decrease community-level capacity. To the extent that proximity to population centers increases opportunities to learn about different organizations and their structures and functioning, then proximity should lead to greater cooperative

Figure 2.3 Conceptual framework



capacity (Meinzen-Dick et al. 2000). The presence and density of external non-government organizations (NGOs) may also affect cooperative capacity. NGOs may increase capacity by actively helping community members develop cooperative efforts (Chopra and Gulati 1998; Khwaja 2000); however, NGOs may erode cooperative capacity by substituting their activities for community-based collective action (Pender and Scherr 1999; Gebremedhin et al. 2004). In our particular case, whether or not outsiders regularly use home pastures will be an important indicator of the degree to which community members can be assured that benefits to decisions made by community members accrue to them, and/or signifies increased negotiation and enforcement costs. Capacity is also hypothesized to be negatively affected by higher opportunity costs of labor; for instance, engaging in outside wage work increases the opportunity costs of engaging in collective action at home (Bardhan 2000).

Conceptual Framework and Empirical Model Development

At this stage, we can summarize our insights from the theoretical model development in a diagrammatic representation of the framework to be used to analyze land use (stock levels and mobility) and allocation patterns observed in communities, illustrated in Figure 2.3. Underlying demographic, market and infrastructure, and agro-ecological characteristics determine the relative profitability of crops and livestock production, and also determine the nature and extent of externalities in land use and allocation. These characteristics essentially form the scope for collective action in resource management activities. Thus, the cooperative capacity of the community can be brought to bear on the mitigation of these externalities by lowering the costs of cooperation.

Operationalizing the Theoretical Model

Rewriting the first-order conditions found in equations (2.31)–(2.33), we can write the reduced-form optimal stock densities, mobility, and land allocated to crops as:

$$\sum l_i^* \equiv L^* = f(\lambda^{Coop}, AgEcol, Comm, Mkt)$$

$$\sum d_i^* \equiv D^* = f(\lambda^{Coop}, AgEcol, Comm, Mkt)$$

$$\sum ap_i^* \equiv AP^* = f(\lambda^{Coop}, AgEcol, Comm, Mkt)$$

We note that the explicit representation of the externalities drops out of the reduced form equations, as they are a function of the same variables as expected utility; we defer a discussion of the implications for the econometrics until the next subsection. Higher λ^{Coop} reduces costs of cooperation, and is thus expected to lead to lower stock densities, more mobility, and more land in pastures. Agri-ecological characteristics, *AgEcol,* include average rainfall or current relative rainfall, long-term rainfall variability, and land quality. For instance, greater rainfall is expected to increase stock densities and reduce land allocated to pastures (as crops are considered to have a greater marginal response to higher rainfall than do livestock). Greater relative rainfall this period is expected to decrease mobility. Higher land quality is expected to increase stock densities and decrease mobility; the impact on land allocated to crops vs. pasture is ambiguous. Community characteristics, *Comm,* include such things as community infrastructure (schools, health clinics, transportation), population density, ethnic traditions, experience with livestock vs. crop production, and the land endowment of the community. More infrastructure and higher population densities are hypothesized to lead to greater inventiveness and productivity, and perhaps reduced transaction costs of purchasing inputs and selling products; both are expected to lead to greater stock densities, but the impacts on mobility and crops are ambiguous. Greater relative experience with livestock than with crops, often captured in whether or not the major ethnic group in the community is considered traditionally pastoralist, is expected to lead to higher stock densities, more mobility (by lowering the costs of mobility), and more land allocated to pastures. A greater land endowment is expected to reduce mobility, but to have an ambiguous impact on stock densities and land allocated to pastures. Finally market variables, *Mkt,* include relative livestock:grain prices and the distance to market. Higher relative livestock prices and lower distances to market are hypothesized to increase stock densities, mobility (via the impact on higher stock densities), and land allocated to pasture.

Measuring Cooperative Capacity

Theoretically, it is simple enough to define cooperation as the actions taken to internalize externalities. As previously noted, however, we do not observe explicit rules on stocking rates or land allocation adopted by the community. We also have limited information on the resource-specific transaction costs of cooperation. Instead, in the empirical case studies presented later in this report, we attempt to recover indicators of cooperative capacity. We posit that the capacity of a community to cooperate on managing externalities can be recovered by observable indicators of cooperation in other activities. In recent years, many such indicators have been described as comprising "social capital,"[14] although some observers have noted that a community also requires the capacity to draw on this social capital (see Krishna 2001). There is less agreement on how to construct measures of social capital, although one of two avenues is usually followed. Factors hypothesized to affect cooperative capacity, such as ethnic or economic heterogeneity, can be entered directly as regressors (McCarthy et al. 1998; Bardhan 2000; Dayton-Johnson 2000). Alternatively, direct measures of social capital or cooperative capacity can be used, such as the extent of disputes or political feuding (Seabright 1997) or the density of networks (Pender and Scherr 1999; Berhanu et al. 2003).

A less common approach to measuring social capital is to construct indices of social capital or "agency" (Krishna 2001; Isham and Kahkonen 2002; McCarthy et al., in press). We follow this approach, constructing indicators of cooperative capacity based on such characteristics as the number of meetings held, active participation by members in various collective activities, density of networks, rules, activities, and violations of rules. This empirical strategy is followed because a direct measure of cooperative capacity enables us to separate the direct and indirect impacts of such variables. Often, factors thought to affect collective action also have a separate direct impact on land use and allocation outcomes at the community level. For instance, more favorable land quality and higher output prices are hypothesized to increase cooperative capacity, which should reduce stock densities, all else being equal. But the direct impact should be to lead to higher stock densities, because stock levels increase with higher pasture productivity and higher output prices under both the social optimum and the noncooperative game. There are a wide variety of measures that might be used to measure

[14]The World Bank has produced a number of documents useful for operationalizing the concept of social capital, including a working-paper series from the Local Level Institutions Study, which are available from Social Development Family, Environmentally and Socially Sustainable Development Network and the Environmentally and Socially Sustainable Development Division; and the papers prepared for the Social Capital Initiative (www.worldbank.org/poverty/scapital/scindex.htm). Also, see Dasgupta and Seregeldin (2000).

cooperative capacity, although the effect of many measures is still debated in the wider literature. For instance, meeting attendance can be high if members are dedicated or if there are many conflicts; many groups might imply that members are focusing on taking advantage of different opportunities or that the community is socially splintered, and the like. Thus, we hypothesize that communities' scoring consistently on a wide range of indicators across many different groups/institutions is a better proxy for underlying cooperative capacity than relying on one indicator alone. And, to test whether these indicators actually measure cooperative capacity, we regress them on exogenous factors thought to affect cooperative capacity.[15]

Econometric Model

Using the categories of variables for simplicity, and using the subscript k to denote the community, the econometric equations of land use and allocation to be estimated in the following country studies are:

$$L_k = \alpha_L + \beta_1\lambda_k^{Coop} + \beta_2 AgEcol_k + \beta_3 Comm_k + \beta_4 Mkt_k + e_1$$

$$D_k^* = \alpha_D + \gamma_1\lambda_k^{Coop} + \gamma_2 AgEcol_k + \gamma_3 Comm_k + \gamma_4 Mkt_k + e_2$$

$$AP_k^* = \alpha_{HP} + \delta_1\lambda_k^{Coop} + \delta_2 AgEcol_k + \delta_3 Comm_k + \delta_4 Mkt_k + e_3$$

where the αs are the intercept terms, β, γ, and δ are the coefficients to be estimated, and the es are error terms. As noted earlier,

$$Ext = f(\lambda^{Coop}, AgEcol, Comm, Mkt)$$

so that it is not possible for us to separate out the direct production impacts from the externality impacts. Although it is quite restrictive to assume that there are no cross effects between cooperative capacity and variables affecting externalities and cooperative capacity, empirically, this specification is chosen for parsimony.[16]

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[15]Such an index could only be constructed for Ethiopia and Burkina Faso; in Niger, we directly include exogenous factors hypothesized to affect collective action.

[16]Consider the following structural input-demand equation:

$$L = aX^b e^{(1-c\lambda^{Coop})} lX^m$$

Taking logarithms gives:

$$L = \ln a + b \ln X + 1 - c\lambda^{Coop} + \ln l + mX$$

or

$$L = \ln a + \ln l + 1 + (b + m) \ln X - c\lambda^{Coop}$$

Substituting A for the first three constant terms gives:

$$L = A + (b + m) \ln X - c\lambda^{Coop}$$

This is essentially the form of the equations we estimate in the following chapters, with all the assumptions this form entails on cross effects.

CHAPTER 3

Ethiopia

In this chapter, we examine resource use and management, using community-level data collected in southern Ethiopia.[17] These semiarid southern rangelands support the livestock that are highly valuable to Ethiopia for direct consumption and income for the Borana people, for the provision of draft power, and for export to generate foreign exchange. Despite the consensus on the region's high ecological potential for livestock production, the area is seen as one that has chronically been in and is still in crisis today, mostly due to pressure on the common rangelands, high population growth rates, and increased privatization for both cultivation and grazing (Coppock 1994; Kerven and Cox 1996; Hogg 1997).

The Borana Rangelands are located on the southernmost part of the Ethiopian lowlands, occupying a total land area of about 95,000 km^2. They are located in the area 4–6° N and 36–42° E, sloping gently from 1,600 meters altitude in the northeast to about 1,000 meters in the extreme south, bordering on northern Kenya. The area is still predominantly in pasture and is mainly comprised of flat plains. There are occasional mountains, massive valleys, and depressions. Occupied almost entirely by pastoral populations, natural resources are largely communal, although individual crop cultivation and private enclosures appear to be increasing in recent decades. The area exhibits a bimodal pattern of precipitation, with the long rains falling between March and May, and the short rains between September and November. Spatial and temporal variability in both the quantity and distribution of rainfall renders the area semiarid, with an average annual rainfall varying from 353 to 873 mm/year, and coefficient of variation of rainfall (CoV) ranging from .2 to .6.

A field survey was conducted in 40 rural communities in the six districts of the Borana rangelands from September 1997 through March 1998. A community in this study consists of two or more pastoral settlements having common access to pastures and water resources, to which they bear a common claim, called an *arda.* The communities were selected to represent different rainfall patterns (level and variation). Rainfall data from 11 weather stations[18] located across the area were used to classify the communities into four different rainfall categories: high mean with high variation; high mean with low variation; low mean with high variation; and low mean with low variation. A list of all communities within approximately 50 kilometers of each rainfall station was collected, with the aid of district agricultural officers and chairmen of peasant associations. Between two and five communities were randomly selected.

[17]This chapter is based on empirical results presented in McCarthy et al. (2003).

[18]For eight of the stations, rainfall data were complete for the period 1982–1996; for the remaining three stations, data were missing for some years between 1982 and 1996, and so values for mean rainfall and *CoV* were generated based on eight to 11 observations for these three stations.

The first phase of the data collection employed a combination of standard questionnaires and rapid rural appraisal techniques. Respondents included community elders, heads of encampments, or other key informants, responding in a group setting. Social mapping was used to assess the proportion of land under different types of land uses—different types of common-property grazing areas, transhumance routes, cultivated area, private enclosures, and the like. This phase was followed by a wealth-ranking exercise and the implementation of a close-ended questionnaire capturing total livestock holdings, the proportion of members engaged in nonfarm income-generating activities, rules and regulations regarding the various resources, and basic information on demographics and infrastructure. The physical boundaries of the *arda* were obtained by use of a global positioning system (GPS) instrument that determined the coordinates of community border points. These data were later digitized and analyzed to generate community maps and land areas. Finally, a range condition score was developed for each community by a range specialist from the International Livestock Research Institute, Addis Ababa; information was collected on such measures as dry matter and crude protein content along transects within an arda, slope measurements, and the area covered by barren land.

Descriptive Statistics

The communities studied consist of more than 200 settlements and/or pastoral encampments, with an average of five settlements per community. These constitute a total of 3,141 households, with an average of 79 households per community and seven people per household. The total human population of all the communities is 21,637 people, with a mean of 541 people per community. About 26 percent of the households are headed by women. The majority of the households are classified as poor (67 percent), about 21 percent as middle class, and only 12 percent as wealthy.[19]

Cattle are by far the most important livestock species held by the Borana pastoralists and account for more than 90 percent of the tropical livestock units (TLU). This amounts to about 50,000 TLU or 64,470 head of cattle.[20] The remaining 10 percent consists of small ruminants, camels, and equines. The mean number of livestock per community is 1,249 TLU, with a minimum of 82 and a maximum of 5,900 TLU. Average livestock holdings at the household level vary between 2 TLU for poorer households to above 100 TLU for wealthier ones, with an aggregate mean of 19 TLU.

Current Land Use Patterns and Property Rights

About 84 percent of the total land area is allocated to livestock production, and 16 percent is cropped. However, land allocated to livestock production is managed under different forms of common property, including *warra, fora,* communal enclosures, and individual enclosures. *Warra* grazing is by far the most common form of common property in the area, constituting nearly half of the total land area. These are communal grazing areas for milking cows, calves, and sick or weak animals during the year, and are generally used by dry herds during the rainy seasons. They are accessible to all

[19]This is based on the wealth stratification criteria suggested by the respective communities according to their definitions and perceptions of wealth.

[20]The tropical livestock unit is a unit of parameterization for livestock of different sizes and species to facilitate aggregate computation. The TLU is taken to be the equivalent of an animal of 250 kilograms liveweight. Following Jahnke (1982), we used a conversion factor of .7 for cattle and donkeys, .1 for sheep and goats, and 1 for camels.

members of a community, usually at specified periods of the year and for specified types of animals, but may be used by outsiders during some times of the year upon obtaining permission from the community. Thus, *warra* areas largely fit the definition of a common property resource with a well-defined membership.

Communal enclosures for calves and sick or weak animals account for about 9 percent of the total land area; these enclosures may be accessible to the entire community, or in many cases, to only a subset of households in one encampment. Unlike *warra* areas, they are rarely open to non-*arda* members. Community-level enclosures and *warra* areas are present in 83 percent of the sample communities and hence, constitute the most important forms of common property resources. *Forra* areas are unrestricted communal grazing areas for dry herds—nonlactating livestock—for all members of the Borana pastoral ethnic group. Spatial and temporal access to such areas is unregulated at all times. *Forra* areas generally constitute the largest communal grazing areas in Borana, but because they are generally unsettled, they largely fall outside the boundaries of the communities under investigation, and thus comprise only about 1.22 percent of the total land area. The remaining noncropped land is mostly comprised of transhumance corridors and areas around major wells and other water sources, and we include this land in the land available for grazing when constructing stock densities. Individual holdings account for 24 percent of the total land area, allocated mainly to crop production (16 percent), partly to enclosed private grazing (4 percent), and partly to enclosed areas for draft animals grazing around cultivated fields (4 percent). Privatization of common pastures is negotiated by individuals with community elders or representatives of the government-sponsored local peasant associations, or both; privatization is thus a complex process that differs across communities and is not easily observed by outsiders. Private enclosures for grazing are relatively new phenomena, illustrating a new dimension in the dynamics of property rights in the area. Such trends were observed in nearly 20 percent of the communities under investigation. Finally, we note that the quality of herd mobility data did not enable us to estimate separately the proportion of the herd migrating in any of the four seasons. We simply have information on whether any herds migrated out of the community during the rainy and dry seasons. Thus, we could not separately estimate herd mobility at the community level, but we do return to this issue in the Niger and Burkina Faso case studies. The dependent variables in our analysis are stock densities, the proportion of land allocated to private crops, and the proportion of land allocated to private pasture enclosure. Stock densities are calculated as total TLU divided by total grazing land available, including the rangeland, transhumance corridors, and areas around wells. Stock densities are high at 1.03, although the median density is .79; when calculated over the total land endowment, densities are .91, with a median of .62.[21] The proportion of land in crops, PA_{crops}, and in private pastures, PA_{pvtpas}, are as described earlier in the chapter.

Appendix 3 contains descriptive statistics of the remaining variables used in the subsequent analysis, for the whole sample and by four categories determined by rainfall and variability of rainfall characteristics.

Model Development

Here we develop an empirical model based on the conceptual framework outlined in

[21]Our stock densities are higher than those previously reported. This is because we took the land area for a particular community to be only that falling within the *arda* boundaries. Densities over the entire plateau are lower because of the larger *forra* areas to which all Boran have access.

Chapter 2, but incorporating site-specific information. As noted, we do not have good enough information on community-level herd mobility, so we cannot estimate this equation. Instead, we estimate stock densities, the proportion of land allocated to crops, and the proportion of land allocated to private pastures. The reduced-form input demand equations are:

$$SD = f(Coop, Rain, CoV_{Rain}, RangeQual, InMig, PopDen, Hay, YCyult, TotalHa, P_l/P_g, MktDist) \quad (3.1)$$

$$PA_{crops} = f(Coop, Rain, CoV_{Rain}, RangeQual, InMig, PopDen, Hay, YCult, TotalHa, P_l/P_g, MktDist) \quad (3.2)$$

$$PA_{pvtpas} = f(Coop, Rain, CoV_{Rain}, RangeQual, InMig, PopDen, Hay, YCult, TotalHa, P_l/P_g, MktDist) \quad (3.3)$$

All three input demands are functions of the capacity of the community to cooperate, represented in the above equations by the variable *Coop;* we develop an empirical estimate of this capacity later in this section. We hypothesize that greater cooperative capacity reduces stock densities and reduces land allocated to private activities, both cropland and private pastures. Alternatively, greater cooperative capacity increases land in common pasture, the omitted category.

To capture the underlying agro-ecological characteristics, we include mean rainfall, the coefficient of variation of rainfall, and a range quality index. Higher mean rainfall, *Rain,* is expected to increase stock densities and land allocated to crops. Also, because higher rainfall is expected to reduce the need for mobility in any given year (as distinct from the rainfall variability effect), we expect higher mean rainfall to also increase land appropriated as private pastures. As previously discussed in detail, we expect the coefficient of variation in rainfall, CoV_{Rain}, to lead to lower stock densities. We also allow for a nonlinear impact of the coefficients of variation by including a square of the coefficient of variation of rainfall, to capture potential differences in impact in the "equilibrial" vs. "nonequilibrial" environments. It is more difficult to predict the effect of rainfall variability on land allocation in the absence of specific information on the variance of crops, livestock outputs, and the covariance between these activities. Land in the study area is fairly marginal land (except key points), and the rainfall distribution is bimodal, resulting in short growing seasons. Under these conditions, it is likely that crop output is more variable than livestock output, as livestock production is more mobile and flexible. Even so, the greater relative variability of crops vs. livestock is not sufficient to determine the sign of the direct impact of rainfall variability. Nonetheless, under plausible assumptions on variability and covariance across activities, we expect that land allocated to crops will be a negative function of rainfall variability. Greater range quality, *RangeQual,*[22] is expected to

[22]*RangeQual* is an index of rangeland quality based on the extent and degree of slopes in the *arda,* on soil water retention characteristics, and on crude protein content of forage species taken from samples; for a complete description of the range data collected, see Kamara (2001). Given that we have cross-sectional data, the empirical model is based on factors affecting current period animal production. As developed thus far, noncooperation is hypothesized to lead to negative crowding externalities that are not internalized, and which thus reduce profits from the current-period animal production. However, it is possible that certain range quality characteristics are themselves a function of past stock densities, so that we would have potential endogeneity problems if these characteristics were used, because we do not have the data to estimate a dynamic system incorporating the impact of current stock densities on future forage productivity. We did not use data on dry matter production and the extent of bush encroachment to construct the range quality index, for instance, precisely to avoid problems of endogeneity. Instead, we have used only those range quality characteristics that we have reason to believe are less subject to change due to human use.

lead to higher stock densities. Although the impact on land allocation is ambiguous, we expect that better range quality will lead to less land allocated to crops but more to private pastures, to the extent that range quality improves the relative profitability of livestock vs. crops and increases the incentives to appropriate private pasture.

In terms of community-specific characteristics affecting relative profitability of livestock and crop production, we include a dummy variable capturing whether or not community lands are accessed by nonmembers, *InMig,* a dummy variable capturing whether or not haymaking has been adopted in the community, *Hay,* the number of years that cultivation has occurred in the community, *YCult,* population density, *PopDen,* and the total land constraint, *TotalHa.* The variable *InMig* is hypothesized to increase stock densities and land allocated to private pastures, since in-migration by outsiders increases competition for scarce grazing resources. Given increasing population densities, households may intensify either agriculture or livestock production or both, following the standard Boserupian hypothesis of density-driven intensification. We noted earlier that although some cropping has long been undertaken in certain key areas of the plateau, for many Borana households, it is a relatively new activity undertaken on what appears to be a more permanent basis. We did not specifically gather information on intensification of agricultural activities at the community level; based on our experiences and pilot-testing, there is little apparent intensification of either crop or livestock production. Nonetheless, greater population densities may still be driving unobserved changes in livestock or cropping production, leading to higher optimal stock densities or more land allocated to crops, and so we include population density in all three equations. We did gather information on whether any member in a community undertook haymaking activities to capture technological change, and we include a dummy for this variable in the stock density equation and private grazing land equations.

The number of years that the community members have been cultivating is included to capture learning-by-doing effects, *Cult.* The total land constraint enters the land allocated to crops and private pasture equations, though *a priori,* we do not have enough information to sign the impact of the land constraint.

Stock densities are a positive function of market variables captured in relative livestock to crop prices, P_l/P_g, and distance to livestock markets, *MktDist.* We hypothesize that being farther from the market increases the transaction costs associated with crop markets more than those associated with livestock, thereby decreasing the percentage of land in crops, which seems reasonable, given that livestock are more mobile. The impact of relative price on land allocation is less certain; to the extent that crop-livestock interactions are important, higher livestock prices may actually increase land allocated to crops.

Developing a Measure of Capacity to Cooperate

We return now to the actual measurement of cooperative capacity. Theoretically, it is simple enough to define cooperation as the actions taken to internalize externalities, and cooperative capacity as the ability to undertake those actions. In the communities studied, we did not observe explicit rules on stocking rates or land allocation. As discussed in Chapter 2, however, we posit that the capacity of a community to cooperate to manage externalities can be recovered by observable indicators of cooperation in other activities; to recover such indicators, we perform a factor analysis on these variables.

Variables in the factor analysis include the number of meetings per year and the percentage of the community members attending, as we expect that both will be higher for increased capacity to cooperate. The sum of rules pertaining to grazing, water, settlement, and cultivation are also hypothesized to be positively correlated with cooperative capacity, whereas the number of violations of these rules occurring in the past five years is considered to reflect a lower level of cooperative capacity. We note that collecting data on violations proved relatively easy, whereas collecting data on enforcement mechanisms and whether stated punishments were actually enforced proved more difficult. Thus, we include only data on violations, but stress that information on violations is distinct from information on enforcement. Grazing rules mostly referred to restrictions on types of animals using various parts of the range, seasonal restrictions on access, and the use of calf and draft animal enclosures. Water rules are largely related to maintenance activities and seasonal restrictions. Settlement and cultivation rules mainly consisted of fence maintenance for cultivated areas and certain zoning rules regarding settlement patterns.

Results from the factor analysis show that three components had eigenvalues greater than 1, together accounting for a cumulative loading of .7, which indicates that the variables jointly exhibited only a rather modest degree of correlation. We chose to retain only the first factor when creating the cooperative capacity index, which has scoring coefficients as shown in Table 3.1.

Table 3.1 Scoring coefficients

Variable	Scoring coefficient
Number of meetings per year	0.035
Members attending (%)	0.288
Sum of grazing rules	0.140
Sum of water rules	–0.044
Sum of settlement and cultivation rules	0.074
Violations: grazing rules	0.622
Violations: water rules	0.122
Violations: settlement and cultivation rules	0.412

The scoring coefficients are relatively low but still positive on many of the variables thought to represent cooperative capacity. However, loadings on violations are all positive and relatively high. We thus hypothesize that this factor actually captures lack of cooperative capacity, reflecting noncooperation. To construct a measure of cooperation, we normalized the factor to lie in the [0,1] interval, and then transposed the index to create our index of cooperative capacity, *Coop.*

To test whether the index indeed captures cooperation, we estimate the determinants of this index using variables often hypothesized to affect collective action and group management, as described earlier in the report. Cooperative capacity is hypothesized to be at first increasing and then decreasing with increases in the total number of households. As the number of households increase, sharing fixed costs of cooperation decrease, which decreases incentives not to cooperate, but at some point, increased numbers of households leads to increased transactions costs of negotiating, monitoring, and enforcing agreements, which eventually overwhelm the benefits of sharing fixed costs. Greater heterogeneity in wealth is hypothesized to lead to differences in income diversification strategies and levels of risk aversion; the greater these differences, the more difficult it will be for members to find agreements that leave all members better off, which results in lower capacity. Capacity is also hypothesized to be a negative function of whether outsiders regularly come into the *arda,* because negotiating and enforcing agreements among this expanded set of resources will be more costly. Members engaging in seasonal migration outside the community may represent less pressure on resources—and is, in fact, one mechanism to reduce grazing pressure, as previously discussed—but its direct impact on cooperative capacity is hypothesized to be negative, because it may make it more difficult to make and enforce rules. Outside wage work is hypothesized to be associated with greater opportunity costs of participating in cooperative activities and meetings, and thus reduced cooperative capacity. Favorable

Table 3.2 Factors affecting cooperative capacity, Ethiopia

	Cooperative capacity	
Parameter	**Coefficient**	***t*-statistic**
Demographic		
Size of community	–0.06	1.99*
Size of community squared	1.90×10^{-4}	2.03**
Heterogeneity in cattle holding	–0.08	3.24**
Percentage of adults migrating	0.002	1.5
Agro-ecological characteristics		
Coefficient of variation, rainfall^	0.06	0.41
Range quality index	0.05	1.8*
Markets and infrastructure		
Distance to livestock market^	0.09	1.73*
Relative livestock:grain price^	0.31	1.47
External pressure		
Dummy, out migration	0.33	4.08**
Dummy, outsiders use home pastures	–0.22	2.31**
Constant	–1.46	4.29**
Number of observations		37
R^2		0.66

Notes: ^ Indicates variables in natural logs.
* Significant at the 10% level.
** Significant at the 5% level.

relative livestock prices, shorter distances to markets, and range quality are all hypothesized to positively affect cooperative capacity. As profitability increases, individual incentives to cooperate and to not cooperate both increase, but incentives to cooperate increase more rapidly than to do incentives not to cooperate. Thus, the overall effect should be to favor cooperative capacity (see McCarthy et al. 2001). Finally, rainfall variability is also hypothesized to increase capacity, because the increased variability results in greater gains to cooperation relative to the gains obtained from cheating (McCarthy 1999). The regression results are reported in Table 3.2.

Estimated coefficients generally support the interpretation of the *Coop* index as capturing cooperative capacity. One oddity is that the impact of total households is negative but increasing; the turning point is at 200 households. As discussed, we hypothesize that increasing the number of households will at first lead to greater capacity, but at some point, will reduce it. We thus reject the hypothesis that *Coop* has an inverted U-shaped relationship with total number of households. Instead, increasing the number of households decreases cooperative capacity; the marginal impact is negative for all but two communities. High prices, shorter distances to market, and greater range quality all positively affect cooperative capacity, as hypothesized. In-migration negatively affects *Coop,* giving support to the hypothesis that the use of community resources by others reduces incentives for community members themselves to cooperate. At the same time, when community members use outside pastures, cooperative capacity actually increases. Instead of capturing additional costs of monitoring and enforcing agreements within the community when members are absent, outmigration may relieve pressure on community grazing and water resources, thereby contributing to easier management of core resources. A higher percentage of members engaged in outside wage work has a negative impact on the index, but is not significant. Finally, the greater the degree of heterogeneity in wealth, the lower is *Coop.* We used the coefficient of variation in cattle holdings, based on the minimum, maximum, and median cattle holdings of households in the community, to proxy heterogeneity in wealth. Overall, regression results are consistent with the main hypothesis regarding factors influencing the degree of noncooperation.

Stock Density and Land Allocation Equations

Here, we present results for the stock density and land allocation equations. Initially, we intended to collect data on 40 communities, but were only able to complete data collection for 38 of the communities. Additionally, in one community, land allocated to private grazing areas accounted for nearly 90 percent of the total land area; whereas the distribution of private grazing land is quite continuous from 0 to 50 percent for the remaining 37 communities. We chose to eliminate this observation. Furthermore, there are six communities in which no land is allocated to crops, and three that have no land allocated to private pastures. Thus, we present both generalized least squares and censored regression results for the land allocation equations.[23]

Stock densities in TLU were constructed from information on community-level stockholdings of different species,[24] and transformed into natural logarithms, divided by the area of grazing land measured in hectares.[25] Survey respondents identified the major livestock markets that community members predominantly used; data on cattle and grain prices were then collected in these markets. Because cattle are sold standing and unweighed, data were collected on condition score, and height and girth of 3- to 4-year-old males—the most common type of cattle sold. Unit values were then estimated to form the prices used in the regression analysis. Distance to market is based on the distance from the community to the major market. Range quality scores, rainfall data, the haymaking dummy variable, and years of cultivation are as defined above; the natural logarithm of rainfall is used in the estimations.

There is also a potential for the cooperative capacity indices to be endogenous in the land use and allocation equations. We tested for statistical exogeneity using the Hausman-Wu test for the stock density ordinary least squares regression, and the similar Smith-Blundell test for the censored land allocation regressions (Greene 2000); results support statistical exogeneity in all three cases. However, to facilitate comparison with the Niger case study in particular, we also present results for each equation using the exogenous explanatory variables used in the *Coop* equation. Note that certain variables are included in both cooperative capacity and the land use and allocation equations;

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[23]Estimations were performed using STATA. Breuch-Pagan tests indicate heteroskedasticity in all three equations. We used the robust command, which provides the Huber/White/Sandwich estimator of the variance-covariance matrix. For the censored regressions, we use the interval regression command in STATA, along with the robust command; this is a standard tobit model corrected for heteroskedasticity.

[24]Stockholdings at the household level were animals held or managed by the household, regardless of whether the animals were actually at home at the time of the survey.

[25]Because cropland is used by grazing animals at least part of the year, we tried a number of specifications for the stock density variable, including dividing by total hectares, or dividing by total grazing areas plus a weighted cropland area, where the weights were based on the number of months that cattle grazed cropland post-harvest and before preparing for the next crop season. All three of these divisors worked very similarly in all three country studies; we thus chose to use the area in grazing land, as it follows the model most closely.

thus, in this second specification, the coefficients on these variables will be made up of both the direct impact on land use and allocation variables, as well as the indirect impact via cooperative capacity. In certain cases, the hypothesized direct and indirect impacts are of opposite signs, and we can examine whether the estimated coefficients in the two different equations are consistent with these hypothesized impacts. For instance, higher relative livestock prices should directly increase stock densities, but should also increase cooperative capacity, thereby leading to lower stock densities. Similarly, rainfall variability, distance to market, and range quality all have offsetting impacts, so that when entered into the equations directly, the estimated coefficients should be lower than those obtaining in the first specification.

Finally, we address the issue raised by drought cycles and the use of stock densities and land allocation in the single period of observation as choice variables. Immediately after a drought, it is generally assumed that stock levels will be below long-term desired levels and, perhaps, that land allocated to crops will be greater if cropping is generally a short-term coping strategy. Given our dataset, however, we argue that observed stock densities and land-use patterns are actually at long-term desired levels, because of the "position" of the communities in the drought cycle. We base this argument on two data series. The first is an examination of average rainfall at eight of the stations for which rainfall data are most complete. We computed the percentage deviation from average rainfall for each station to facilitate comparison across sites. The data series depicted in Figure 3.1 clearly highlight the 1984/1985 and 1991/1992 droughts. All of the 21 simple correlation coefficients between the seven rainfall series are positive, and more than half are over 40 percent, indicating a fair degree of similarity in rainfall patterns. Note, too, that we expect idiosyncratic rainfall events to be managed largely by herd mobility, meaning that the impact of any one period's rainfall should not affect stock densities unless rainfall is uniformly low, which was not the case for the period covered by the surveys. Furthermore, Desta (1999) estimated that livestock numbers on the plateau had recovered to pre-1984/1985 drought levels by 1990; we believe that the similar rainfall patterns from 1986–1990 and 1993–1996 indicate that recovery levels should be similar in 1997/1998 to those observed in 1990. We also collected data on the normalized division vegetation index (NDVI) (Clark Labs 2000) at stations during 1982–1997. Figure 3.2 presents the percentage deviation from average annual NDVI.[26] The pattern is quite similar, though deviations are much smaller. Deviations from average are generally positive following both drought episodes, though they are lower in the second post-drought recovery period for both series.[27]

Regression results are presented in Table 3.3. First, consider the impact of agroecological variables. In the stock density equation, the coefficient on mean rainfall is

[26]It is difficult to know, a priori, what would be the best NDVI indicator. We present results here for an annualized average NDVI index; but we also ran the same regressions using NDVI for one of the driest months, January, and the wettest month, May, as well as two-month averages for January–February and May–June. Results do not differ substantially no matter what NDVI index is used.

[27]We could simply test whether adjustments to previous rainfall events affected current stock densities by including lagged rainfall variables, but rainfall data for three of the weather stations are not available for the two or three years previous to the survey year, and the dataset is simply too small to drop the communities in the vicinity of these stations. Instead, we use lagged values of NDVI for which complete data are available. Coefficients on these lagged NDVI indices under different specifications are generally insignificant; specification tests lead us to retain equations with no lagged variables.

Figure 3.1 Proportional deviation from average annual rainfall, Ethiopia

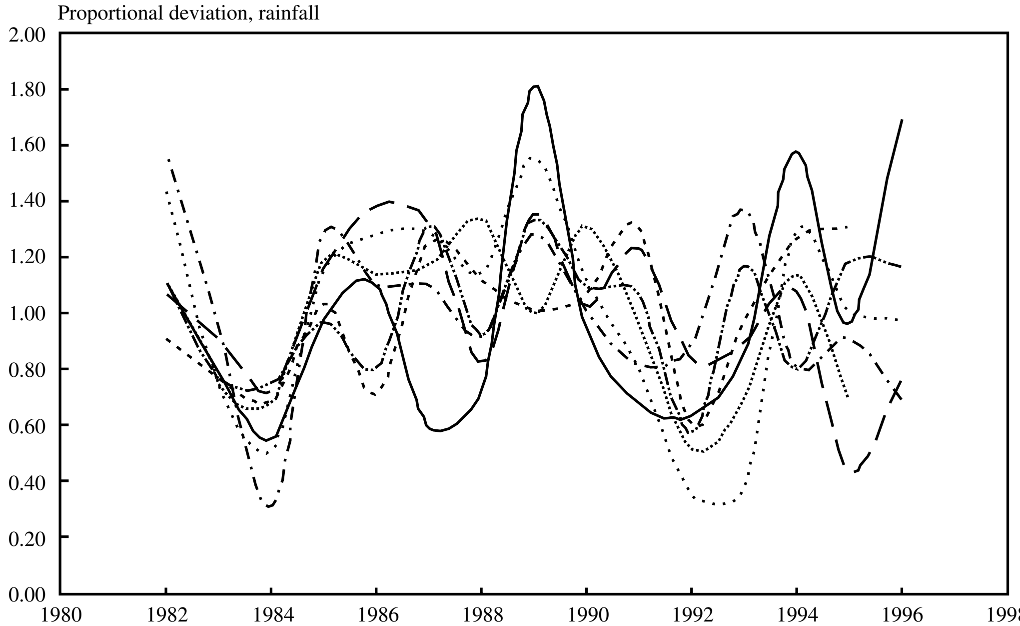
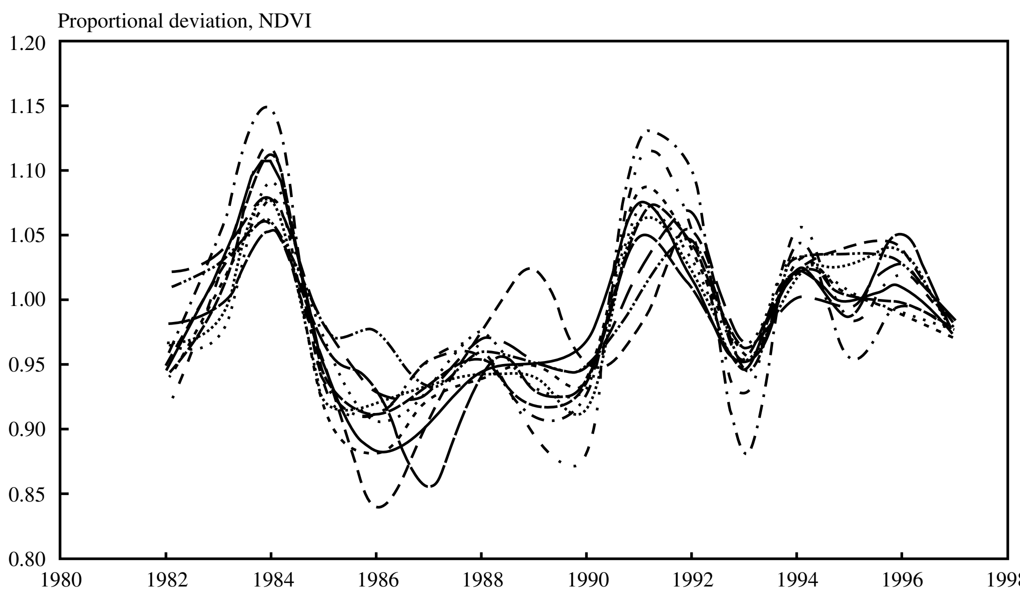


Figure 3.2 Proportional deviation from average NDVI, Ethiopia



negative and significant, whereas the estimated coefficients on the coefficient of variation and its square are positive and negative, respectively, and significant. In fact, the estimated turning point is at .38, which is the sample mean. This result indicates that, whereas increasing stock densities may be used as a strategy to manage higher risk in the relatively low-variability areas, it is precisely in the high rainfall variability

Table 3.3 Determinants of land allocation, stock densities, and herd mobility, Ethiopia

	Stock density				Percentage land cropped				Percentage land private pasture			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
Parameter	**Coefficient**	***t*–statistic**	**Coefficient**	***t*–statistic**	**Coefficient**	***z***	**Coefficient**	***z***	**Coefficient**	***z***	**Coefficient**	***z***
Cooperation indexes/determinants												
Index of cooperation	–0.87	–1.95			–2.82	–0.27			–17.24	–1.66*		
Heterogeneity of livestock holdings			0.19	3.18***			0.47	0.42			1.97	2.03**
Percentage households migrating for work			0.01	2.00			0.05	0.57			0.08	0.92
Dummy, out migration			–0.01	–0.05			4.54	1.00			–0.31	–0.08
Agro-ecological												
Mean rainfall^	–1.00	–2.64**	–1.38	–3.08***	7.67	0.52	3.18	0.19	–0.04	–3.78***	–0.05	–3.3***
Coefficient of variation, rainfall	10.74	2.36**	11.53	3.09***	0.68	0.01	18.10	0.17	–18.50	–0.29	–16.94	–0.26
Coefficient of variation, rainfall, squared	–14.45	–2.29**	–14.90	–3.14***	43.39	0.32	13.98	0.10	48.26	0.65	33.40	0.41
Range quality index	0.16	2.30**	0.08	1.21	0.93	0.50	0.85	0.43	–0.71	–0.46	–1.34	–0.87
Community characteristics												
Population density	0.91	7.61***	0.96	7.95***	–0.88	–0.26	–1.18	–0.32	3.92	1.51	4.56	1.73
Hay	0.02	0.07	–0.11	–0.47	6.27	0.79	5.94	0.71	–5.11	–1.26	–5.56	–1.42
Years cultivating	–0.01	–0.82	4.34×10^{-4}	0.05	0.65	3.71***	0.71	3.83***	0.17	0.97	0.25	1.39
Dummy, outsiders using home pastures	0.26	1.29	0.61	2.40**	–6.87	–1.60	–6.63	–1.20	8.30	1.61	11.78	2.14**
Total size of community land	0.42	2.26**	0.46	2.40**	0.50	0.09	–0.02	0.00	4.23	1.01	4.33	1.07
Market and infrastructures												
Relative livestock: grain price^	0.93	1.69*	0.97	1.75*	14.92	1.00	18.17	1.10	–7.28	–0.63	–8.66	–0.73
Distance to livestock market^	–0.27	–1.97*	–0.10	–1.04	–3.13	–1.20	–2.60	–0.87	–2.09	–1.01	–0.41	–0.22
Constant	3.54	1.28	3.68	1.12	–40.38	–0.43	–20.21	–0.18	29.48	1.11	8.80	0.34
ln(Sigma)					2.40	15.7	2.38	15.66			2.19	14.9
Number of observations	37		37		37		37		37		37	
R^2	0.71	0.76										
Probability ($\chi^2 > 0$)					0.0001		0.0000		0.0002		0.0000	

Notes: ^ Indicates variables in natural logs. *, Significant at 10% level; **, significant at 5% level; ***, significant at 1% level.

areas that stock densities decrease as variability further increases.

In the cropland equation, none of the rainfall variables have statistically significant coefficients. Regarding mean rainfall, we note that the correlation between rainfall and years cultivating is quite high. As highlighted in Appendix 3, the average number of years cultivating in the low-rainfall communities is about 4, but is more than 18 in the high rainfall communitites, so that the dataset may simply be too small to handle the correlation between these variables. For land allocated to private pastures, there is a very strong negative impact of mean rainfall on land allocated to private pasture. This result is interesting, since a priori we expected that more land would be privatized in the higher rainfall areas; in a wider context, many other empirical studies have shown that privatization is more likely to occur for the most productive land resources in the most productive areas. Here, we do not know whether the land privatized is of better quality; however, more land is being appropriated in communities with lower mean rainfall, which is generally associated with lower overall productivity. Theoretical results indicate that the impact is ambiguous, however; in this case, the strategic incentives to underprovide common land at low rainfall realizations appear to dominate. The rainfall variation measures, however, are not significant in this equation. Finally, as hypothesized, the coefficient on range quality index is significant and positive in the stock density equations and negative in the land allocated to private pasture, although it is not significant in the latter case. Range quality has no estimated impact on land allocated to crops.

In terms of community characteristics, we first note that stock densities are a positive function of household density, although the coefficient on the haymaking dummy variable is not significant. These results indicate that some innovations in response to population density may have been introduced to augment livestock feed resources, even though there were no apparent innovations in the communities studied besides haymaking. Neither variable has a statistically significant impact on land allocation, which is particularly surprising for cropland. The number of years that a community has been cultivating has a positive and significant impact on the cropland allocation. This result suggests that there is a structural shift toward cropping, and calls into question the assertion that cropping is a crisis-related response. The years of cultivation variable is negative in the stock density equation, hinting at a substitution effect between crops and livestock, but the coefficient is not significant.

The coefficient on the dummy variable for outsiders using home pastures has no impact on any of the land use or allocation equations in the first specification. This is a surprising result; we would expect that the greater use of home resources by outsiders should increase incentives to privatize land at any level of cooperative capacity. Interestingly, the land constraint has a positive impact on stock densities but no significant impact on land allocation. In fact, population density and landholdings are negatively correlated, so we are cautious about interpreting these results. Nonetheless, the evidence here suggests that stock densities increase in communities with relatively large landholdings. Regarding market factors, the estimated relative livestock price is positive and significant; stock densities have a nearly unitary elasticity with respect to relative prices of livestock. The coefficient on the distance to market variable in the stock density equation is significant and negative, as expected. Neither relative livestock prices nor distance to market affect the land allocation decisions.

With respect to the cooperative capacity index, *Coop,* the coefficient on this variable is negative and statistically significant in the stock density and the land allocated to private pasture censored regressions. This indicates that, in communities with low cooperative capacity, overexploitation of common pastures and overappropriation of common land is occurring, to the extent that our measure captures the inability of community members to internalize externalities. However, although cooperative capacity appears to mitigate incentives to enclose pastureland, it does not appear to impact the expansion of cropland. When we exclude the index and, instead, include the exogenous explanatory variables in the stock density equation, the proportion of households migrating for wage work and the heterogeneity in livestock holdings are statistically significant and positive, and heterogeneity in livestock holdings is statistically significant in land allocated to private pasture. None of the exogenous factors hypothesized to lower cooperative capacity affect the cropland equation, mirroring the insignificant coefficient on *Coop.* In the stock density equation, relative livestock price is now significant and positive, but market distance is no longer significant. The coefficient on outsiders using home pastures is now significant and positive. In this specification, we expect that the coefficients on variables affecting livestock productivity will be lower than in the first specification, because the coefficients will be picking up both direct and indirect effects on cooperative capacity. The coefficients on pasture productivity and distance to market both decrease, as expected, but relative livestock prices increase and are now statistically significant. Similarly, the dummy variable for outsiders using home pastures remains positive but is now statistically significant—this variable should be picking up both direct and indirect positive effects, which, together, are statistically significant. Finally, the coefficients of variation of rainfall variables have the same sign as in the previous equation, but the turning point is now .37, indicating that stock densities begin declining more quickly when calculating the direct and indirect impacts on higher cooperative capacity. For the private pasture equation, outsiders using home pastures now has a statistically significant and positive coefficient.

As can be seen, the stock density equations have good explanatory power with most variables significant, but the land allocation equations are rather poorly estimated. The stock density equations provide strong evidence that cooperative capacity does reduce pressures to overstock home pastures, and that stock densities are lower in areas subject to high rainfall variability. With respect to land allocation, as discussed earlier in the chapter, the institutions through which household members effectively privatize common resources are complex and differ across communities in subtle ways; factors affecting this process are difficult to quantify. Nonetheless, the econometric results suggest that cooperative capacity does affect incentives to privatize pasture; heterogeneity in livestock holdings and pressures by outsiders to access home resources appear particularly important.

CHAPTER 4

Niger

In Niger, the government began implementing a new rural code in 1993 that attempted to redefine the access, use, and management of natural resources (Comité National du Code Rural, Secrétariat Permanent 1993, 1997), although it is generally acknowledged that implementation had stalled, at least up through the time of our fieldwork (Ngaido 1996; Gado 1996; Kirk and Ngaido 2001). At present, village and canton chiefs remain the principal authority regarding land allocation decisions de facto, meaning that customary tenurial arrangements still prevail in most areas of the country (Gavian and Fafchamps 1996). Although it is widely recognized that climate variability is an important characteristic underlying the logic of the agropastoral system, a legal framework that addresses the need for flexible access while maintaining incentives to use and manage the resource has yet to be developed. Results from our research should help shed light on these wider issues.

The study area is located in south-central Niger, with communities located in the area 12.7–4.5° N and 2.1–4.0° E. The study area includes both the more arid Sahelian belt in the north and the Sudano-Sahelian belt, considered primarily suited for livestock production but with important opportunities for crop production, particularly in the communities located farther south. Rainfall is unimodal, with an average of 498 millimeters, ranging from 335 to 650 millimeters. Although rainfall on average is lower than in Ethiopia, the unimodal distribution is more favorable to crop production.

The sample selection process and survey design were very similar to that for Ethiopia. Rainfall stations were first identified and data collected to generate a list of potential communities to survey. Monthly rainfall data were collected at 17 rainfall stations for 1985–1996, and a list was made of all communities within a 50-kilometer radius of each station. Forty community names were randomly drawn from this list. Data were collected at the village level, the primary contact was the village chief, and at least one of the authors was present at every interview. The data were collected during the middle to the end of 1997. As in Ethiopia, a global positioning system instrument was used to georeference key points and boundaries, generate a community map, and to derive information on total land area and land allocation patterns. In the Niger case, aerial photographs (1/50,000) were also available for all communities, which enabled researchers to more easily generate a base map. Range assessments were also undertaken; data included species composition for the herbaceous and tree layers, slope, drainage characteristics, and the like. Finally, grain and livestock price data—including height and girth measurements and animal condition scores—were collected at markets identified as the primary markets used by community members.

Descriptive Statistics

There is a good deal of variation in the total number of households within each community, ranging from 20 to 307, with an average of 100 households. Total landholdings range from 121 to over 4,000 hectares, with an average of nearly 1,800 hectares. Population densities range from about two to 42 households per 100 hectares, with an average of nine households per 100 hectares. Compared with the study area in Ethiopia, ethnic diversity within and across communities is more important in this region. Four major ethnic groups form the large majority in the study communities, including traditionally pastoralist Peuhl and Bella, and traditionally agriculturalist Zarma and Houssa. Nonetheless, on average, there are less than two ethnic groups per community, indicating a relatively homogeneous ethnic composition within villages. Certain ethnic groups, such as the Peuhl, are considered to be traditionally pastoralist, whereas other ethnic groups (e.g., the Dzarma) are considered to be traditionally crop farmers. In our sample communities, the ethnic majority in 12 communities are traditional pastoralists. Additionally, the proportion of the population coming from a traditionally pastoralist ethnic group is approximately 20 percent for the sample as a whole.

Households in this area of Niger hold a mix of cattle, sheep, and goats, unlike those in Ethiopia, in which cattle strongly dominate. On average, there are 880 sheep, 1,480 goats, and 946 cattle per community, which translates into approximately 10 sheep per household, 17 goats per household, and nine cattle per household. Using the same definition of tropical livestock units (TLU) as used in Ethiopia, there are 10 TLU per household, compared to 17 in Ethiopia. However, there is a great deal of variation in livestock holdings within communities. The mean coefficient of variation in livestock holdings is 1.18. Also, far more households are permanently engaged in crop activities than was the case in Ethiopia; the average cropland per person is nearly 9 hectares, three times the figure for Ethiopia. As with livestock holdings, household millet harvests vary within villages, but not nearly as much as livestock holdings, the mean coefficient of variation being .33.

Average stock densities on home pastures are high at 1.08; seven communities have densities greater than 1.2, but the median density is .48. Various estimates of carrying capacity in “normal” years in the Sahel vary between .13 and .25 for the ranges falling on the 400-millimeter rainfall isohyet (de Leeuw and Tothill 1993, p. 78); we suppose that such estimates of normal year carrying capacity would be somewhat higher in the study area, because average rainfall is somewhat higher. This density is measured in TLU/ha in home pastures without adjusting for mobility. Estimates of grazing pressure (stock days per unit of grazing area) yield an average of .86 and a median of .38, but with wide variation across communities. In sample communities, the proportion of herds that were mobile during the year 1996/1997 ranged between 0 and 53 percent, with an average of 14 percent. As shown later in an NDVI graph (see Figure 4.2), 1997 was a very poor rainfall year. However, mobility figures are for the year preceding the survey, starting in the beginning of the rainy season 1996 through the beginning of the rainy season in 1997; that is, it did not reflect the very poor rainfall of 1997. On average, the communities received 90 percent of their long-term average rainfall in 1996, with a wide range between 70 percent and 117 percent. Rainy season mobility was 26 percent on average, ranging from 0 to 86 percent. However, dry season mobility was just 7 percent on average, ranging between 0 and 44 percent. Combined with the relatively high stock densities, the relatively small extent of mobility suggests that overstocking may be problematic in certain communities.

Current land use can be categorized broadly as being either individually managed cropland or common-access pastureland; unlike Ethiopia, in Niger, we did not observe enclosures of pastures at the subgroup or individual level. Cropland accounts for 33 percent of the total community land on average, ranging from about 10 to 42 percent in sample communities; conversely, current pastureland accounts for 67 percent of community land. Community members also have access to neighboring grazing areas, but for the purpose of this survey, we consider the "community's pastureland" as only that land which community elders (including the chief) considered to form part of the community proper. Although there is certainly scope for the "fuzziness" of boundaries, in practice, agreement on the distinction between community and shared pastureland was reached fairly quickly. As in Ethiopia, non-community members also accessed community pastures; in the case of Niger, we distinguish between use by neighbors and use by transhumants. During the previous rainy season, neighbors used home pastures in 11 communities; for the dry season, 13 communities had neighbors using home pastures. Transhumant herds generally arrive at the end of the harvest season and remain into the dry season, although in some cases, transhumant herds moved quickly through a community. Transhumant herd sizes were estimated to be quite large, ranging from 35 to 10,000 TLU with an average of about 2,400 TLU. Full descriptive statistics are found in Appendix 3.

Model Development

Following the model developed in Chapter 2, we write the following equations for stock densities (*SD*), land allocated to crops (Pl_{crops}), and mobility (*Mob*):

$$SD = f(Coop, PopDen, EthPas, CAssetInf, InMig - N, InMig - T, TotalHa, Rain, CoV_{Rain}, RangeQual, P_l/P_g, MktDist) \quad (4.1)$$

$$PA_{crops} = f(Coop, PopDen, EthPas, CAssetInf, InMig - N, InMig - T, TotalHa, Rain, CoV_{Rain}, RangeQual, P_l/P_g, MktDist) \quad (4.2)$$

$$Mob = f(Coop, PopDen, EthPas, CAssetInf, InMig - N, InMig - T, TotalHa, Rain, CoV_{Rain}, RainDev, RangeQual, P_l/P_g, MktDist) \quad (4.3)$$

The stock density and proportion of land allocated to crops equations are nearly the same as those for Ethiopia, with the exception that here we have included information on whether the dominant ethnic group is from a traditionally pastoralist tribe, *EthPas,* and the stock of agricultural assets and community-level infrastructure, *CAssetInf.* We constructed the agricultural assets value by summing over all plows, transport carts, draft and transport animals (equine and bovine), and crop-storage facilities and divided this figure by the number of households, and added this to the number of schools, shops, motorcycles, and vehicles. We expect that greater infrastructure and agricultural assets indicate greater productivity in all activities and in reduced market transactions costs; with an expected increase in stock densities and mobility and an increase in cropland. We have also distinguished between use of home pastures by neighbors, *InMig – N,* and by transhumants, *InMig – T.* We expect that where the dominant ethnic group is from a tribe traditionally associated with pastoralism, less land will be allocated to crops and stock densities will be higher, because we expect that the stock of knowledge and experience favors livestock production relative to crops; furthermore, we expect herd mobility to be greater to the extent that such mobility depends on networking and negotiation among pastoralists (Niamir-Fuller and Turner 1999).

With the data collected in Niger, we can also estimate the mobility equation, *Mob,* where mobility is the proportion of the total community herd migrating to outside pastures during the rainy and dry seasons, weighted by length of season (4 months rainy season, 8 months dry season; the dry season includes the cold and hot dry seasons). In the mobility equation, we include an indicator of relative rainfall deficit, constructed as the rainfall accruing at the relevant rainfall station during 1996 divided by mean rainfall. As discussed in Chapter 2, mobility during the current year should be a function both of the actual rainfall relative to the long-term mean and actual rainfall received in the community relative to rainfall received at all potential sites to which community members might migrate with their animals. We therefore constructed another index of relative spatial rainfall by dividing rainfall received in 1996 by the average rainfall received across all rainfall stations. As noted later, these two measures are highly correlated; thus, later in the chapter, we give two specifications of the equations using each of these two indicators.

As before, all three input demands are a function of the capacity of the community to cooperate, represented in the above equations as *Coop;* however, we were not able to recover a latent estimate of community capacity to cooperate, and instead rely only on exogenous factors thought to impact that capacity.

We also need to consider the time of our data collection relative to the drought cycle, which is more difficult to establish than was the case in Ethiopia. In the region where the study communities are located, the last well-publicized, major generalized drought event occurred in the 1980s; but during 1990–1996, many communities experienced very low rainfall, particularly in 1993. The dramatic shortfall in 1993 was preceded by two years of relatively average rainfall, and, most communities experienced better than average rainfall in 1994. However, 1995 and 1996 were quite erratic years, with four areas receiving above or near average rainfall, but three falling below; as the longer-term NDVI series show, even 1995 and 1996 were rather poor years from a longer-term standpoint (see Figure 4.2). In Figures 4.1 and 4.2, we present percentage deviations of rainfall for the shorter rainfall station time series and NDVI indices. As for Ethiopia, we ran the stock density regression with various lagged rainfall and/or NDVI indices to test whether a lagged effect was driving current stock densities. Different

Figure 4.1 Proportional deviation from average annual rainfall, Niger

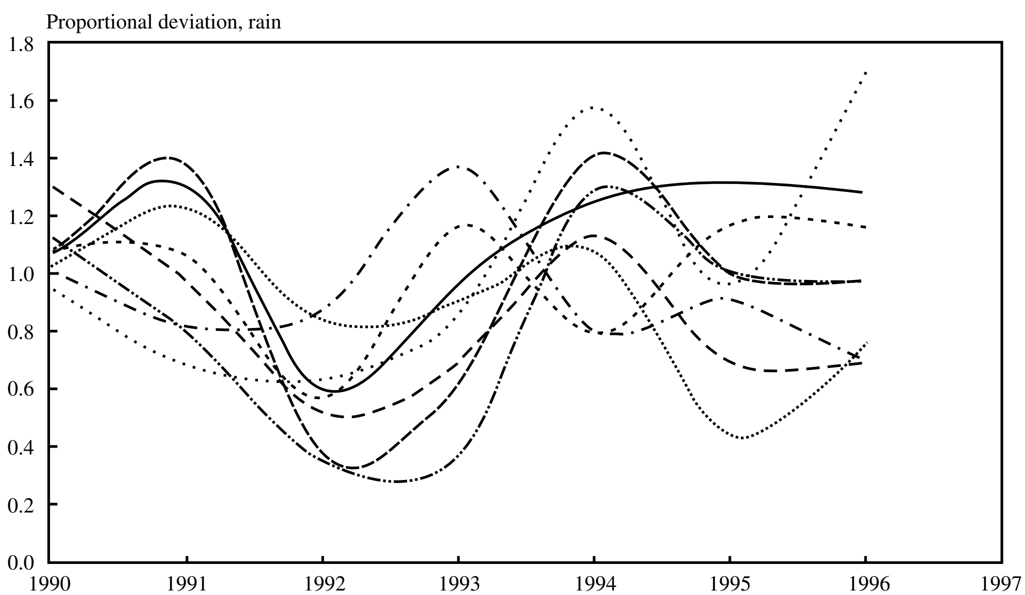
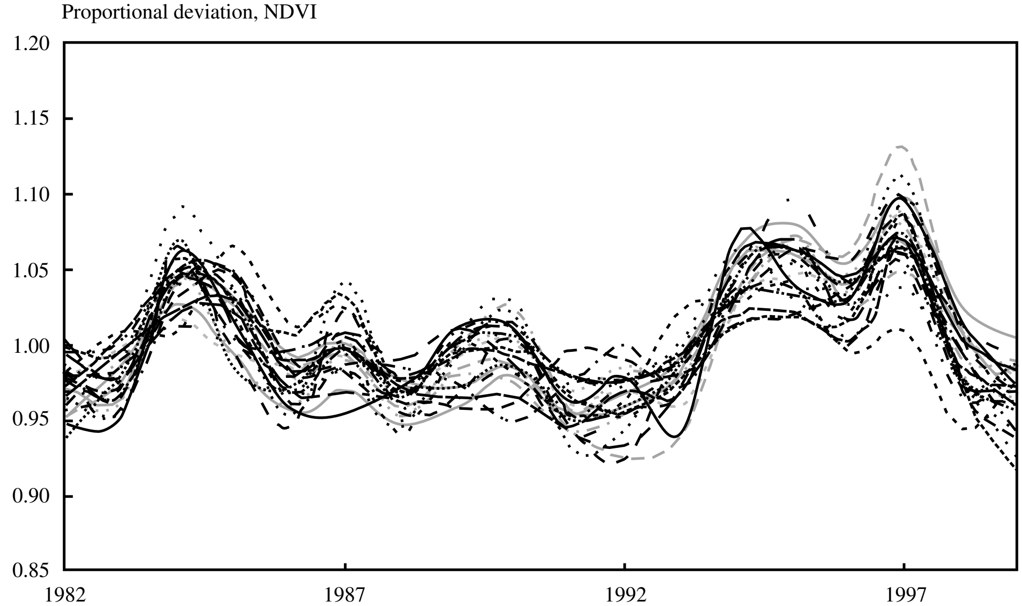


Figure 4.2 Proportional deviation from average NDVI, Niger



specifications included measures of the relative rainfall deficit for 1993, an average of the 1992–1994 deficit, and 1995–1996 deficit. Variables capturing rainfall deficits in the 1990s were never significant in any of the equations, except for rainfall deficits during 1996 in the herd mobility equation, in which the deficits were to be included in any case. Thus, previous rainfall measures are only included in the mobility equation.

Measuring Cooperation

Before proceeding to the econometric estimations, we consider how to capture cooperative capacity. As in the Ethiopian case, in none of the study communities were there explicit rules on maximum stock levels held by households, total stock densities at the community level, or mobility. However, unlike Ethiopia, and as we shall see Burkina Faso, there were few direct indicators of cooperative capacity; nearly all communities had cooperatives with very similar rates of membership, so that variability across communities was small, but little consistent and comparable information was gleaned on active participation, rules, or violations. Thus, for this case, we include only those variables hypothesized to affect cooperative capacity, including heterogeneity in livestock holdings and the proportion of community members engaged in wage work. Additionally, we include an indicator of ethnic heterogeneity, captured by the number of ethnic groups within a community. As before, we expect that other included exogenous variables will now be picking up the direct and indirect effects on cooperative capacity; particularly, pressure on home resources by outsiders (neighbors and transhumants).

Empirical Model Results

We now return to the model developed earlier and attend to some practical difficulties in estimating the model. Following test results, we corrected for heteroskedasticity in all three equations. Although all communities had at least some land allocated to crops, mobility was not undertaken in 15 of the 37 communities, and so we estimate this equation as an interval regression model.

Table 4.1 Estimated land allocation, stock densities, and herd mobility, Niger

	Stock density			
	Model 1		Model 2	
Parameter	Coefficient	*t*–statistic	Coefficient	*t*–statistic
Cooperation indexes/determinants				
Percentage households migrating for work	1.38	1.33	–0.41	–0.43
Heterogeneity of livestock holdings	0.42	2.98**	0.32	1.68*
Number of ethnic groups	0.34	1.85	0.30	1.47
Agro-ecological characteristics				
Mean rainfall^	3.66	3.51**		
Rainfall 1996/long-term mean				
Spatial deviation of rainfall				
Community/areawide rainfall				
Coefficient of variation, rainfall	33.79	2.39**	33.79	2.00**
Coefficient of variation, rainfall, squared	–56.28	–1.83	–63.70	–1.68
Range condition score	0.45	1.22**	0.58	1.31*
Community characteristics				
Population density^	0.65	1.63**	0.64	1.33
Dummy, traditional pastoralist majority	1.69	3.23**	1.23	2.02**
Infrastructure and agricultural assets	4.55×10^{-3}	0.02	-9.39×10^{-3}	–0.04
Dummy, neighbors use home pastures	-9.69×10^{-4}	–1.38	-8.87×10^{-4}	–1.07
Transhumants use home pastures (×1000)	-2.58×10^{-5}	–0.38	-4.58×10^{-5}	–0.54
Total Land Endowment^	0.25	0.72	0.10	0.24
Market				
Relative livestock:grain price^			1.81	1.92*
Distance to livestock market^	–0.83	–2.68**	–0.71	–2.34**
Constant	–30.12	–3.97**	–6.38	–2.01**
ln(Sigma)				
Number of observations	37			
R^2	0.71		0.64	
Probability ($\chi^2 > 0$)				

Notes: ^ Indicates variables in natural logs. *, Significant at 10% level; **, significant at 5% level; ***, significant at 1% level.

We also note that there is a very strong correlation between average rainfall and both relative livestock:grain price ratios and absolute livestock prices (.59 and .58, respectively). The correlation with revenue per head—unadjusted for animal condition and size—is higher still at .67. Thus, even though we have derived unit prices precisely to overcome likely problems of collinearity between revenue per head figures and local climate and range conditions (as well as potential endogeneity problems), there remains a great deal of correlation between the two measures. The correlation may be because markets located in higher rainfall areas subsequently face lower transportation costs for getting the animals to the next destination point. However, it is interesting that no such correlation exists in Ethiopia. Nonetheless, given this correlation, we report results for the stock density and cropland equations run with either the rainfall variable or the price variable. Because the price variable is not correlated with measures of current relative temporal and spatial rainfall, we include price in the mobility equation along with the current rainfall variables. We also present two specifications for the mobility equation: one using current rainfall relative to the long-term mean, and

Percentage land cropped				Herd mobility			
Model 1		Model 2		Model 1		Model 2	
Coefficient	*z*	Coefficient	*z*	Coefficient	*z*	Coefficient	*z*
–0.14	–0.79	–0.15	–0.95	0.10	0.58	–0.20	–0.87*
–0.04	–1.61	–0.03	–1.13	7.97×10^{-2}	1.56	0.04	1.06
–0.03	–1.08	–0.04	–1.17	3.87×10^{-2}	0.82	0.02	0.45
-4.99×10^{-3}	–0.03						
				–0.84	–1.86*		
						–0.55	–1.81
–0.80	–0.36	–0.72	–0.34	7.97	3.50**	8.72	2.84**
1.55	0.3	1.24	0.24	–17.48	–3.63	–20.00	–3.26
0.04	0.76	0.04	0.74	4.01×10^{-2}	0.62	0.06	0.9
–0.07	–1.06	–0.08	–1.21	0.12	1.73*	0.13	1.71*
0.02	0.2	1.16×10^{-2}	0.14	0.08	0.77	–0.01	–0.11
1.38×10^{-2}	0.6	1.45×10^{-2}	0.6	–0.02	–0.88	–0.03	–1.22
2.6×10^{-5}	0.34	3.07×10^{-5}	0.4	5.72×10^{-5}	0.45	8.72×10^{-5}	0.66
1.20×10^{-5}	0.81	1.02×10^{-5}	0.69	2.19×10^{-5}	1.67*	1.98×10^{-5}	1.25
-5.67×10^{-3}	–0.07	-1.16×10^{-2}	–0.16	7.47×10^{-2}	1.27	0.07	1.08
		0.14	0.88	9.22×10^{-2}	0.5	0.43	1.67*
9.47×10^{-3}	0.23	3.83×10^{-3}	0.11	-3.95×10^{-3}	–0.11	0.03	0.62
0.64	0.51	0.62	1.48	–0.57	–1.10	–0.98	–1.8
				0.16		0.16	
37				37.00		37	
0.38		0.41					
				0.0000		0.0000	

the other using current rainfall in the community relative to rainfall received across the area as a whole (Table 4.1).

Looking first at the climate variables, we note that the coefficient of variation of rainfall does indeed have a nonlinear relationship with stock densities, first increasing and then decreasing, as was the case in Ethiopia. Higher variability initially leads to greater stock densities, but the marginal impact becomes negative for coefficients greater than about .3 for both specifications. If it were rational to accumulate herds in anticipation of a drought, particularly in the high-variability areas in which long-term forage productivity is posited to be relatively unaffected by stock densities, then we would expect higher stock densities, particularly in high-variability areas, ceteris paribus. As in the Ethiopian case, our data do not support this hypothesis. Rather, regression results are consistent with the hypothesis that the gains from shifting out of cropping and into livestock as variability increases are eventually outweighed by greater livestock production variability generated from the use of common-pool pastures, as rainfall variability increases still further. Rainfall variability has a similar impact on mobility: mobility at first increases and then decreases with increases in variability. In this reduced-form model, rainfall variability should be picking up the effect of stock densities on mobility; higher stock densities lead to greater mobility, as predicted. Furthermore, communities in areas that received high rainfall relative to long-term means and relative to average rainfall across the area had lower mobility, as expected. Finally, higher mean rainfall leads to higher stock densities, but is not statistically significant in the cropland equation.

Of the cooperation variables, heterogeneity in livestock holdings and ethnic heterogeneity both have statistically significant and positive impacts on stock densities in the first specification, and livestock heterogeneity is statistically significant in the second specification. These results indicate that when cooperation is more costly to negotiate and enforce, stock densities are higher. Coefficients for these variables are not statistically significant in either the cropland or mobility equations. The percentage of total households with at least one member migrating for wage work does not affect stock densities or cropland, but has a negative and significant coefficient in the herd mobility equation, in the second specification that uses relative spatial rainfall. Thus, evidence suggests that more costly cooperation leads to higher stock densities and, to a lesser extent, reduced herd mobility. Consistent with results from Ethiopia, there is no impact of the variables proxying costs of cooperation on cropland. Pressure on community resources stemming from their use by outsiders, captured in the variables representing use by neighbors and by transhumants, have no statistically significant impact on either stock densities or cropland allocation. However, higher use by transhumants does have a positive impact on herd mobility.

With respect to community characteristics and infrastructure, household density has a positive and statistically significant impact on stock densities and mobility, but a negative, although not significant, impact on land allocated to crops. Although the usual presumption is that increasing population density will increase the pressure to open up marginal lands to cultivation, this does not appear to be the case in the communities in the study region in Niger. This result is all the more surprising, given that government and nongovernment organization technical projects tend to support intensification of cropping activities. If increasing household density does indeed capture intensification, the intensification in this system appears to be occurring with respect to livestock, inducing greater stock densities and increased mobility.

The stock of agricultural assets per household and community infrastructure has no statistically significant impact on any of the dependent variables. Whether the ethnic majority is traditionally pastoralist has a statistically positive and significant impact on stock densities, but somewhat surprisingly, no impact on herd mobility. We tried other proxies besides whether or not dominant ethnic group was traditionally pastoralist, such as the percent of the population that is from a pastoralist group, but all performed similarly to the dummy variable.

Range quality has a positive and statistically significant impact on stock densities, and also has a positive impact on mobility and land allocated to crops, but it is not significant in either of the latter equations. Relative livestock:millet price ratios have a significant and positive impact on stock densities, and is also positive and significant in one specification for mobility; the impact on mobility should be an indirect impact through higher stock densities. Distance to market has a negative impact on stock densities, but no further impact on cropland or mobility.

To summarize, there is evidence that the variables hypothesized to increase the costs of cooperation do indeed lead to higher stock densities and less herd mobility. Furthermore, stock densities and consequently, herd mobility, are lower precisely in those communities located where rainfall variability is highest. Both of these results are consistent with results from Ethiopia, although the indicators for cooperation are less well developed in Niger. Relative livestock prices and distances to market appear to have a stronger direct influence in Niger than in Ethiopia; greater relative livestock prices and lower transportation costs increase stock densities. Also, the cropland equation is not well estimated; indeed, none of the variables are statistically significant. In striking similarity with the Ethiopian case, this type of modeling exercise has limited value in helping us to understand land allocated to cropping in areas where livestock production should have a relatively strong comparative advantage. Also similar is the impact of population density, which leads to higher stock densities and more herd mobility. More specific to Niger, we note that ethnic heterogeneity appears to increase the costs of cooperation, at least in terms of pastures use. Interestingly, whether or not the ethnic majority is from a traditional pastoral tribe has little impact on stock densities and land allocation; the only significant impact is a somewhat surprising negative impact on herd mobility in one specification.

CHAPTER 5

Burkina Faso

Like Niger, Burkina Faso is an agropastoral Sahelian country, where livestock production has always been a very important component of agricultural activity. However, a number of factors led to a decline in livestock activity through the 1970s and particularly the 1980s. These included major droughts, which were estimated to induce large losses of livestock; the importation of cheap livestock products from the European Union (EU) during the same period (Economic Commission for Africa 2000); and an overvalued exchange rate. However, in the 1990s, conditions improved for livestock producers because of a reversal of all three factors: the currency (FCFA) was devalued in 1994, leading to a 78 percent increase in producer prices for live animals between 1993 and 1996 (Economic Commission for Africa 2000); rainfall was generally more favorable; and antidumping restrictions reduced importation of unfairly priced livestock products from the EU. The contribution of livestock products to the country's gross domestic product is currently about 12 percent, and these products also account for 25 percent of export income. In fact, it is the second most important source of export income (24 percent) after cotton, according to the International Monetary Fund.[28]

The area of study is located in northeastern Burkina Faso, in the area .02–.76° E and 13.67–14.83º N. The agro-ecological conditions are very similar to those in Niger, with a Sudano-Sahelian climate and a 3- to 4-month rainy season. Average rainfall ranges between about 400 millimeters and just over 550 millimeters. The vegetation is of steppe type, dominated by acacia trees. Surveys were administered in 48 communities of four administrative regions of the provinces of Séno and Oudalan during the end of rainy season (August–October) of 2000. Unlike the studies undertaken in Ethiopia and Niger, the sampling framework is not based on local rainfall characteristics. Because the study was undertaken in collaboration with the Programme Sahel Burkinabe (PSB) supported by the German Technical Cooperation (GTZ), one of the objectives of the research was to measure the impact of the various projects and programs on natural resource management and household livelihood strategies. Thus, four categories of all communities falling in the administrative regions were created, based on the length of participation of the community in various PSB/GTZ programs, as follows: villages working with PSB/GTZ before 1996 (13), villages that entered the program between 1996 and 1999 (12), new PSB/GTZ villages (9), and a group of control villages that have never worked with GTZ (14). With respect to rainfall characteristics, we relied exclusively on rainfall data from a secondary source, and used the Hutchinson (2001) rainfall database to generate long-time–series information on the mean and variability of rainfall. As already noted, such data

[28]See www.imf.org/external/NP/PFP/1999/Burkina/INDEX.HTM#IVB.

series tend to underestimate rainfall variability, and to smooth variation spatially. Basically, this leads to high correlations between mean rainfall and the coefficient of variation, with a simple correlation coefficient of –.94 in our sample. Thus, we chose to use only the coefficient of variation in our analyses, but it must be stressed that the interpretation is different from that of the other two countries studied, because we are not holding the mean rainfall constant. We will not be able to test whether stock densities are lower in high-variability environments; but we can test whether stock densities are lower in low rainfall, high-variability environments.

Data Collection

As in Ethiopia and Niger, data were collected at a number of levels. Unlike those two cases, however, there were many more institutions involved in natural resource management, and a good deal more data were collected at the institution/organization level. The next three sections provide more detail on community-, institution- and market-level data collection.

Community-Level Questionnaire and Resource Mapping Exercise

Data on the main characteristics of the community were collected, such as basic demographic data (e.g., number of households by ethnicity, number of households headed by women, number of quarters within the community), resources shared with other communities, herd demography and mobility, community infrastructure, and identification of major markets used by community members. Collection of data on large and small ruminants was largely accomplished by considering the number of cattle, goats, and sheep of each individual household, usually counted by quarter in the larger villages. Information on herd mobility, following a 12-month calendar, was also elicited in this manner. In addition, aerial photographs were used to construct resource maps for every community and to identify community boundaries—including identification of areas in which resources were shared with other communities. Boundary coordinates were also obtained with global positioning system units. Hand-drawn maps, overlaying the aerial photographs, included information on land use and soil types, key resources (e.g., water points and sand dunes), and the locations of villages, hamlets, and roads.

Institutional Questionnaire

This questionnaire was administered to key representatives of each major natural resource management (NRM) institution. Three broad types of data were collected. First, a census was taken of all institutions and organizations in charge of any aspect of NRM, and detailed information was recorded regarding the structure of management, how the organization was created, who or what group founded the organization, the number of members, frequency of meetings, attendance at those meetings, and the like. This section was followed by an enumeration of all activities related to NRM in the community, with detailed information on the activities, the institution or organizations responsible, methods of monitoring and enforcing participation, and actual participation rates. This part of the survey was structured to gather information by resource: common pastures, water sources, soil, and tree resources. Information gathered by activity and resource could then be cross-referenced with the institutional data gathered in the first section. The final section of the survey gathered information on rules and regulations, following a similar format to that for the activities section.

Market Questionnaire

Data on prices for 3- to 5-year-old male bovines, cereals, and dairy products were collected in six markets during three separate months during the year: August 2000, November 2000, and March 2001. Of the six markets, three were major markets

(Djibo, Gorom, and Dori) and three were minor markets (Bombofa, Markoye, and Gorgadji).

Descriptive Statistics

The number of households in sample communities ranges from 14 to 280, with an average of 91 households. As in Niger, the communities are composed of different ethnic groups, although it appears that ethnic diversity within a community is greater in Burkina Faso than in Niger. Ethnic groups considered traditional crop farmers include the Rimaibe, Mossi, and Mallebe, whereas the Fulbe are considered as traditional pastoralists. On average, there are more than three different ethnic groups per community, ranging between one and eight. Furthermore, the ethnic majority in 25 of the 48 communities are traditional pastoralists, or just over half of sampled communities. As in Niger, wage work is important for households in this region of Burkina Faso; in the sample, on average, 25 percent of households in a community rely on locally available and/or short-term wage work outside the community, ranging from 0 to 60 percent. However, on average, only 6 percent of households migrate for wage work, defined as leaving the homestead for more than three months per year. The range is quite large, from 0 to 40 percent. The destinations for migrant wage workers include the major cities and more heavily cropped southern regions in Burkina Faso, as well as Cote d'Ivoire.

Households also tend to hold a mix of livestock species, and, like Niger, small ruminants form a substantial portion of the total tropical livestock units (TLU) held. On average, households hold about nine head of cattle and 15 small ruminants, and very few households hold camels. Using the conversion rate to TLUs as in Chapters 3 and 4, households hold an average of just over 8 TLU. At the community level, herd size varies between 50 and 9,000 head of cattle, with an average of 800, and mean stock densities are .71 TLU/ha, but median stock densities are just .35, indicating a few outliers with very high stock densities. As in the previous cases, these outliers are found in communities with very small land endowments.

There are four broad categories of land uses/types: cropped land (including land in short-term fallow), pastures, denuded land that is considered to be not arable and of very limited or no use for animals, and areas in *bas-fonds.* About 33 percent of community land is dedicated to cropping, 44 percent to pastures, 8 percent in denuded lands, 10 percent in *bas-fonds,* with residences and lakes occupying the remaining 5 percent. Population density is about four households per 100 hectares, substantially below levels in Niger and Ethiopia, although it must be recalled that access to noncommunity pasture resources is very important, particularly in Ethiopia.

Detailed information on monthly herd mobility indicates that herders practice both short- and long-distance transhumance, and that the cycle of mobility differs among communities, depending on underlying agro-ecological conditions. Among the villages in which herders engaged in mobility, herders in nine villages practiced short-distance transhumance (movement inside the province, 5–100 kilometers), herders in five villages practiced long-distance transhumance (outside the province, greater than 100 kilometers), and herders in 10 villages undertook both short- and long-distance transhumance. In fact, no mobility was undertaken in 15 villages in the historically driest province, Oudalan; this, we hypothesize, is mainly due to very good rainfall occurring during the previous rainy season. The general calendar for cattle movement is:

November–December (harvest, or cold dry, season): herds are largely on village cropland, grazing crops residues.

January–June (dry season): transhumance to the "plateau Mossi" (Namentenga, Fada

N'Gourma) in the central part of Burkina Faso, south of most of the study area.

July–October (rainy season): herds utilize community pastures or move to the north; in our sample, many of the more southern communities in the Seno province moved herds to Ouadalan province, the northernmost part of the study area. As noted above, little herd migration was undertaken in Oudalan itself, because rains were very good. Herders in Oudalan noted that, historically, they move into Mali and even Niger, but this practice was diminishing, because it was becoming more difficult to cross national borders. Given our one-period dataset and the limited mobility during that period, however, we cannot pursue this issue further.

A full table of descriptive statistics discussed is presented in Appendix 3. More so than in our other case studies, in Burkina Faso we have a richer dataset on the institutions involved in natural resource management. In particular, we have information on the structure of decisionmaking, and monitoring and enforcement mechanisms for each institution. In this chapter, we present descriptive statistics on the institutional environment.

Institutions, Activities, and Rules of NRM

In the study area, we observed the provision and maintenance of public goods via such activities as soil erosion control, employment of agroforestry techniques, and maintenance of water points. There were also rules and restrictions on the use of some agroforest and pasture products. We also collected data on time and money allocated to these activities by household, the proportion of households actually contributing, and details on violations of rules and regulations.[29] In the 48 communities surveyed, there were 200 NRM institutions, with an average of 4.5 institutions per village. We group these institutions into six types:

General administration: the chief and/or an administrative delegate (RAV) to the local government, which are bodies that deal with NRM as one of many activities.

Consultation committees: organizations that coordinate NRM activities across several villages; these committees are almost exclusively linked to the PSB/GTZ project, which has been promoting supracommunity resource management since 1996.

Men's, women's, mixed gender, and youth groups: these are officially recognized and are based on traditional age- and gender-specific mutual aid institutions. These groups undertake a wide range of activities, of which a subset directly relates to NRM.

Herders' and farmers' groups: as with the organizations named in the previous entry, these are officially recognized groups that focus on production and marketing activities, and usually support certain specific NRM activities directly associated with production issues.

Water management committees: these are generally formal but not officially recognized local groups.

Tree management committees: these are generally formal and often officially recognized groups, many linked to NGOs and/or government agencies.

In Table 5.1, we present the number of institutions observed in the sample, the percentage of all institutions falling under a specific category, the number of villages in

[29] Survey results indicated very few violations of rules and regulations. Team members discussed the process of gathering this information, and it was determined that the way in which the questions regarding violations were asked basically elicited information only on those violators who were actually punished.

Table 5.1 NRM institutions

Type of organization	Institutions		Villages	
	Number	Percentage	Number	Percentage
General administration	48	24	48	100
Consultation committees	5	3	5	10
Men's, women's, mixed, or youth groups	38	19	29	60
Herder's or farmer's groups	21	11	16	33
Tree management committees	13	7	11	23
Water management committees	75	38	43	90

which at least one institution falling in a specific category is present, and the percentage of villages in which a specific type of institution is represented.

Although either a chief and/or an administrative delegate is present in all communities, consultation committees—which are supracommunity-level committees—are not widespread. Note that this type of organization is relatively new and is being promoted by a specific nongovernmental organization (NGO) working in the area. The men's, women's, mixed gender, and youth groups are present in 60 percent of the communities, and make up 30 percent of all institutions dealing with NRM issues. Herders' or farmers' groups are only present in one-third of the villages, and tree management committees are present in 23 percent of villages. Water management committees, however, are present in 90 percent of the villages, and make up 37.5 percent of all NRM institutions captured in the survey.

Details on membership in institutions as a percentage of the total community members, meetings, and participation in meetings are presented in Table 5.2. All community members are typically considered to belong to the chief/RAV institutions, in the sense that any member may attend meetings organized by the chief and/or the RAV. However, membership of at least one household member in other NRM organizations or institutions typically accounts for between 40 percent (women's groups) and 80 percent (tree management committees) of the total households on average.[30] The number of meetings averages about six per year. The highest frequency of meetings occurs for women's groups, which are typically held monthly; the least-frequent meetings occur for tree and water management committees. The level of participation of members at meetings is rather homogeneous. Participation is 80 percent on average for all institutions, always exceeds 70 percent, and assumes a maximum of 91 percent for herders' groups.

The various institutions and organizations in a community have different management structures. Whereas the chief is often the head of various groups, there are also instances of executive committees, presidents, vice presidents, secretaries, and the like, as well as such combinations as the chief plus an executive committee or secretary. In some cases, the members of the management committee are elected. Nonetheless, it is difficult to argue that nominations—say, to the executive com-

[30]Participation was defined by household, so that households with more than one member attending meetings or actively participating in the organization were not distinguished from those with only one participating member. Also, membership in water management committees at the community level appears to be relatively low; this is because in many communities, water committees are organized at a subcommunity level (i.e., by quarters). Nearly every household belongs to one water committee.

Table 5.2 Membership, meetings, and participation

	Membership (% of total households)	Number of meetings per year	Meeting participation (%)
General administration	100	6.1	81
Supracommunity committees	55	5.4	73
Men's groups	56	9.3	84
Women's groups	39	12.1	83
Adult groups	63	7	78
Youth groups	59	5.9	79
Farmers' groups	66	5.8	77
Herders' groups	48	6	91
Tree committees	80	4.3	74
Water committees	60	4.6	84
Total	69	6	79

Note: Numbers are averages per institutional categories.

Table 5.3 Management structure of NRM institutions

Structure	Number of institutions	Percentage of institutions
Chief	68	34
President, nonelected	29	15
President, elected	38	19
President plus others	36	18
Executive committee	18	9
Others	7	5

mittee or as president—reflect less democratic means of determining leadership than elections, because nominations may well have come from consensus in community meetings. We also collected information on those responsible for making rules, monitoring users to make sure rules are followed, and enforcing rules through punishments or social sanctioning. In most cases, respondents considered that it was the responsibility of all members to monitor and make sure rules were followed, so there was limited variation across groups on this measure. Decisions on creating rules and deciding on activities were generally considered to be either the responsibility of the management or of the management in consultation with general membership. The chief or administrative delegates are responsible for creating 50 percent of all rules, collective rule-making accounts for 16 percent of rules, rules made without the chief account for 32 percent, with the remaining few percent being rules made and enforced by outside agencies. Table 5.3 gives the structure of management for the different types of groups.

The chief or administrative delegate form the basic administrative structure for 34 percent of all institutions involved in NRM. A president alone, or with vice president, secretary, or other officer, is the most prevalent structure, accounting for nearly 52 percent; elected presidents are present in 19 percent of NRM groups. An executive committee is in charge of 9 percent of institutions, with various other types of management structures accounting for the remaining 5 percent.

Next, we consider the type of activities undertaken by the different institutions. We have grouped activities according to those pertaining to erosion control, reforestation or agroforestry measures, fence maintenance

Table 5.4 NRM activities

Activity	Pasture	Crop zone	Total number of activities	Total number of villages	Work days per person	Members contributing (%)
Water			42	36	4.4	72
Erosion control	15	21	36	31	13.3	90
Reforestation	23	13	36	26	2.9	80
Fences	9	5	14	14	3.8	101
Total			128	48	6.2	82

between crop and pasture zones, and water-point maintenance activities. Table 5.4 shows the number of activities occurring in the pastoral zone, which can largely be described as activities to provide pure public goods, and those occurring in the agricultural zone, the benefits of which are both private and public. The collective maintenance of water sources is the most widespread activity, taking place in 75 percent of study communities. Soil erosion control occurs in 65 percent of the communities. Erosion control includes the strategic construction of half-moon barriers (demi-lunes) and diguettes, which are stone lines laid along the contours of fields that catch rainwater and reduce soil erosion. Such measures are more likely to be undertaken on individual fields, but some erosion control also occurs in the pasture areas; unfortunately, we have no further information on the density of activities in either zone. Reforestation activities occur in 54 percent of the villages, in both the pastoral and agricultural zones, although the number of activities is higher in the pastoral zone. One-third of the villages collectively organized the maintenance of fences to protect crops zone from animals and to give well-defined boundaries to passage corridors.

Table 5.4 shows that soil erosion control mobilizes by far the most labor, with 13 days of work for each member household per year, whereas other activities mobilize 3–4 days per member per year. The percentage of total members who actively contribute labor is 82 percent for all activities, with 90 percent in soil erosion control, 80 percent in reforestation, and just 72 percent in water maintenance. Participation rates are just over 100 percent for fence maintenance; the rate is greater than 100 percent because this activity mobilizes labor beyond the members of the institutions charged with implementing fence maintenance activities.

Finally, we consider the rules and regulations implemented by different community groups. We have grouped these as follows: rules setting dates for the entry and removal of livestock from the crop zone; prohibitions or limits on tree cutting, slash-and-burn activities, hay cutting, and use of common pastures by sick animals; and rules regulating livestock use of water points. Figures for the number and percentage of villages with various rules are presented in Table 5.5. Almost all villages have rules regarding the date of entry and exit, and prohibitions on tree cutting and slash-and-burn activities. Whereas fixing dates can be considered a traditional rule, the rules prohibiting or limiting various activities have largely been implemented since 1984.

Rules regulating the use of the land in the crop zone are the most important, being present in nearly all communities. Prohibitions on tree cutting and slash-and-burn activities—rules that have been promoted by various government ministries and their local officials during the past 25 or more years—are also important in a majority of the communities. Limits on cutting grasses found on common pastures are more likely to have been internally devised, and operate in 42 percent of communities. Livestock

Table 5.5 Rules and regulations

	Number of villages with rules	Percentage of villages with rules
Dates for using crop zone	47	98
Prohibitions on tree cutting	44	92
Prohibition on slash and burn	42	88
Limits or prohibition of hay cutting	20	42
Water-point use rules for livestock	12	25
Prohibition of use of pastures by sick animals	6	13

regulations apply in a much smaller subset of communities.

Indices of Observed Cooperation

Although the richness of detail of the institutional data is extremely valuable for different purposes, for our analysis, we are concerned with developing a measure of underlying cooperative capacity found in the community as a whole. Thus, we have aggregated institution-level data to the community level. Variables used in the factor analysis include network variables, such as the density and active membership in NRM and non-NRM institutions, and variables capturing implementation of activities and/or rules. Both types of variables capture institutional capacity at the community level, networks being a traditional measure of social capital, and implementation being a measure of capacity to translate effectively good intentions into concrete actions (Krishna 2001). There are four network variables: the density of NRM institutions, the sum of the percentage of households participating in each institution across NRM institutions, the density of non-NRM institutions, and the sum of the percentage of participating households across non-NRM institutions.[31] To capture implementation capacity, we used the following variables: the average number of meetings per year for all NRM institutions, the average attendance by members, the total number of rules and regulations, the total number of NRM activities (water point maintenance, zoning, reforestation, and soil erosion control), the total number of labor days allocated to collective activities per year, and the average percentage of members who actively contribute labor.

Scoring coefficients resulting from a factor analysis[32] of these variables are presented in Table 5.6 for the first two factors, which both had eigenvalues greater than 1. The first factor exhibits high and positive scoring coefficients on the network variables. We refer to the index generated from this factor as the index of network capacity (INC). The scoring coefficients for the second factor are relatively high on the implementation variables, and quite low—and usually negative—on the network variables. We refer to the index generated from this factor as the index of implementation capacity (IIC).

[31]In each community, the density of institutions is defined as the total number of institutions divided by total number of households. The membership variable for NRM and non-NRM institutions is the sum across institutions of the percentage of households participating in each type of institution. Because the percentage of total households participating in any one institution declines as the number of institutions increases, we use the sum of the average number of households participating in different institutions as a measure to capture “density” of participation.

[32]All statistical analyses performed using STATA 7.0.

Table 5.6 Scoring coefficients

Variable	Index of network capacity	Index of implementation capacity
Network NRM	0.241	–0.065
Membership NRM	0.355	0.087
Network others	0.300	–0.291
Membership others	0.168	–0.175
Number of meetings	0.032	0.071
Number of activities	0.058	0.207
Number of rules	–0.013	0.101
Participation in meetings	0.028	0.091
Participation in work	0.132	0.422
Number of days of work	0.087	0.223

As in the case of Ethiopia, we are also interested in determining which factors affect cooperative capacity as captured in the indices derived from the factor analysis. Here, we examine the determinants of the estimated indices of cooperative capacity. This is done to test whether the explanatory factors are consistent with the theory, although there remains wide disagreement on the theoretical impact of many variables on cooperative capacity. As before, we include the total number of households and the square of that number to test the hypothesis that cooperation becomes more difficult both with too few households and with too many households. We include two measures of social heterogeneity, the number of quarters within a village, and the number of ethnic groups. Heterogeneity in cattle holdings is used to proxy wealth differentiation; we again use the coefficient of variation of cattle holdings constructed from data on minimum, maximum, and mean cattle holdings. To capture the opportunity costs of engaging in collective action, we again use the percentage of households with at least one member engaged in migration for wage work. We also include variables that may affect returns to collective action, including distance to market, the coefficient of variation in rainfall, and relative livestock:millet price ratios. The extent to which community resources are shared with either neighboring communities or with transhumant herders may also reduce cooperative capacity by making communication and enforcement more costly. Unlike our study of Niger, we do not have detailed information on the size of transhumant herds, only whether transhumance generally uses community pastures, so we use a dummy variable to capture this external pressure. For neighbors, however, we use the number of neighboring villages whose members generally use community pastures.

The abovementioned variables are similar to those used in the case studies of Ethiopia and Niger. However, we have additional information to use for this case study. Schools are more prevalent and have been so for a longer time in Burkina Faso, so that we can use the proportion of adults who have attended public school as an explanatory variable in the cooperative capacity equations. Education in general is hypothesized to favor cooperative capacity by increasing the individuals' capacity to acquire information and transform such information into useful knowledge.

We also consider a set of variables capturing the structure of the organizations in the community. Roughly following the structure, conduct, and performance literature, we hypothesize that the structure of organizations can either enhance or diminish cooperative capacity. We propose that more participatory forms of decisionmaking mean that more decisions will be made, monitored, and enforced. We created a variable called "chief dominant" by using information on the proportion of organizations in which the chief has sole responsibility for making, monitoring abidance, and enforcing rules, as well as information on whether the general administration was under the chief (as opposed to an administrative delegate). The proportion of organizations/institutions in which the chief plus others (e.g., members of an executive committee) jointly make rules (collective rule-making) and, finally, the proportion of organizations in which the rules are made by an executive committee or elected (or nominated) president, but without any involvement of the chief (members-only rule-making). Because of potential problems of multicollinearity between the proportion of rules made with vs. without the chief, we only include one or the other in the regressions reported here. Finally, we include a variable to capture the costs of negotiating with regional government officials, captured by the distance to the regional capital. On the one hand, greater distance to the capital may reflect higher costs of learning about other instances of collective action in the region and reduced spillover benefits from examples of other successful interventions, thereby leading to lower cooperative capacity. On the other hand, the greater this distance, the less likely that the activities of noncommunity government officials will interfere with the authority and activities of local organizations. As with other variables, then, the hypothesized impact of this variable is ambiguous.

Finally, we take into account the presence of external programs or projects (mainly those of international NGOs) and the duration of these programs to test the effect on cooperative capacity. We have divided the number of programs into three categories: those in existence since before 1986, those beginning during 1987–1993, and those beginning after 1993. As already noted, our study was undertaken in conjunction with PSB/GTZ, and the coordinator of PSB/GTZ delineated three distinct conceptual frameworks guiding project implementation and noted that the change in frameworks leading to a change in development paradigms affected many projects in the region (Grell, pers. comm.). In general, most programs or projects beginning before 1986 had an overwhelming focus on technical solutions to crop production and NRM, whereas those beginning in 1987–1993 largely adopted the *terroir* approach, with a focus on specific resources within given boundaries. Many projects or programs beginning after 1993 expanded on the *terroir* approach to consider the system as a whole, including community members' use of noncommunity resources and vice versa. It is generally supposed that projects begun after 1993 should increase cooperative capacity the most, followed by the second period and finally the earliest period. Regression results are presented in Table 5.7.

The estimated equation for network capacity has fairly good explanatory power, although of the significant coefficients, quite a few are opposite in sign to those predicted by theory. For instance, the impact of the number of households is U-shaped and significant, whereas we hypothesized an inverted-U shape. Although of the wrong shape, the impact of households is negative until the turning point at about 180 households. Interestingly, the number of quarters and heterogeneity in livestock holdings positively impact network capacity; migration for wage work has a positive, but not significant, impact. Although it makes a good deal of sense that having many distinct neighborhoods, heterogeneity in wealth, and (perhaps) many income sources all increase the value of networks, this result highlights why network capacity per se may not improve the capacity of community members to undertake collective action. Education is positively related to network capacity in the first specification, as expected. Communities in which a larger number of projects began before 1986 have greater network capacity, as do those closer to the regional capital. Finally, communities with relatively low rainfall but high rainfall variability also have greater network capacity. In summary, it

Table 5.7 Determinants of cooperative capacity, Burkina Faso

	Index of network capacity				Index of implementation capacity			
	Specification 1		Specification 2		Specification 1		Specification 2	
	Coefficient	***t*-statistic**	**Coefficient**	***t*-statistic**	**Coefficient**	***t*-statistic**	**Coefficient**	***t*-statistic**
Demographic								
Size of community	–4.77	–2.97**	–4.20	–2.43**	1.35	0.65	1.00	0.35
Size of community squared	0.01	2.43**	0.01	1.71**	0.00	–0.27	0.00	–0.07
Number of quarters	33.68	2.18**	35.28	2.70	8.23	0.48	9.63	0.53
Number of ethnic groups	–7.35	–0.44	–7.63	–0.42	32.47	1.22	31.38	1.18
Heterogeneity in cattle holding	16.38	3.27**	11.62	1.91**	–15.66	–1.89*	–15.99	–1.89*
Percentage of adults migrating	578.05	1.30	576.03	1.19	–1083.70	–2.19*	–1099.62	–2.20**
Percentage of households w/ public education	325.47	1.91*	267.01	1.29	404.69	1.37	411.43	1.36
Institutions structure								
Chief dominant	25.09	0.45	11.34	0.21	–5.46	–0.08	–5.395116	–0.08
Percentage of rules made in collaboration	276.41	3.11**			10.41	0.04		
Percentage of rules made without chief			45.35	0.45			–28.35712	–0.19
Number of projects								
Before 1986	37.65	2.22**	39.63	1.85**	–6.91	–0.26	–3.88	–0.13
1986–1993 (Terroir approach)	23.35	1.27	33.20	1.68*	98.59	3.81**	98.93	3.76**
1993–2001 (NRM approach)	29.77	0.89	36.05	0.97	80.45	1.67*	81.55	1.66**
Distance to regional capital	–0.03	–2.16**	–0.04	–2.46**	–0.03	–0.99	–0.03	–0.94
External pressure								
Number of villages sharing pastures	5.16	0.14	–14.50	–0.36	–65.89	–0.94	–64.79	–0.90
Transhumants using pastures	–29.23	–0.54	–0.28	0.00	179.08	1.48	176.32	1.41
Market and agro-ecological								
Relative livestock:grain price	–50.49	–0.12	128.36	0.29	474.88	0.84	427.52	0.70
Distance to livestock market	–6.49	–0.30	10.03	0.43	20.06	0.82	17.64	0.63
Coefficient of variation, rainfall	524.14	1.73*	403.17	1.19	–734.04	–1.89*	–729.31	–1.90*
Constant	1141.13	2.18**	741.38	1.38	–1277.14	–1.83*	–1197.32	–1.64
Number of observations		48		48		48		48
R^2		0.59		0.59		0.57		0.55

Notes: *, Significant at 10% level; **, significant at 5% level; ***, significant at 1% level.

appears that in populous, heterogeneous communities located in the variable and low rainfall areas relatively close to the regional capital, there is a greater density of networks in both NRM and non-NRM organizations and thus, high network capacity. Collaboration between the institution of the chief and household members, and the number of programs that began in the earliest period (before 1986) also lead to higher network capacity.

At this point, it is worth comparing the estimation results for the network capacity index to previous research on social capital, which focused on the ability of individuals to rely on social relationships to accrue *private* benefits—that is, to increase a households' access to insurance, credit, and labor-sharing arrangements. The network capacity index constructed here may indeed reflect the capacity of individuals to exploit social relationships to improve individual or household well-being, and in that sense, could be considered to proxy "social capital," as the term has been previously employed.

Significant variables for the implementation capacity index are rather different from those in the first equation. Here, coefficients on heterogeneity in livestock holdings and migration for wage work have negative impacts on implementation capacity. The number of projects undertaken during the latter two periods lead to greater implementation capacity, indicating that the change in project focus may favor community-level implementation over individual household adoption of specific techniques. Collaborative rule-making, rules made without the chief, and whether the chief plays a dominant role have no statistically significant impact on implementation capacity. Finally, we note that the coefficient of variation in rainfall has a negative impact on implementation capacity. This indicates that collective action may be less valuable in such areas, perhaps because returns to various collective activities themselves are riskier in those areas. This is an interesting contrast with the network capacity variable, which is higher precisely in these areas.

Overall, the estimated equations provide evidence that these indices capture different aspects of cooperative capacity. In the next section, we examine how these capacity indices impact land use and allocation patterns observed at the community level.

Empirical Model Development

We write the equations for stock densities, land allocated to crops and mobility as:

$$SD = f(Coop, Rain, CoV_{Rain}, LandQual, InMig - N, InMig - T, PopDen, EthPas, CInf, Educ, TotalHa, P_l/P_g, MktDist) \quad (5.1)$$

$$PL_{crops} = f(Coop, Rain, CoV_{Rain}, LandQual, InMig - N, InMig - T, PopDen, EthPas, CInf, Educ, TotalHa, P_l/P_g, MktDist) \quad (5.2)$$

$$Mob = f(Coop, Rain, CoV_{Rain}, LandQual, RainDev99, InMig - N, InMig - T, PopDen, EthPas, CInf, Educ, TotalHa, P_l/P_g, MktDist) \quad (5.3)$$

As before, we include variables for cooperation (*Coop*), rainfall (*Rain*), and the coefficient of variation of rainfall (CoV_{Rain}). We also include land quality (*LandQual*), neighbors' use of community pastures (*InMig – N*), transhumance use of community pastures (*InMig – T*), population density (*PopDen*), a dummy variable capturing whether the majority of community members are from a traditional pastoralist tribe (*EthPas*), community infrastructure (*CInf*), an index of educational attainment in the community (*Educ*), the total land endowment (*TotalHa*), relative livestock to grain prices (P_l/P_g), distances to market (*MktDist*), and, in the mobility equation, the deviation between current rainfall and long-term means or between current rainfall and a spatial average (*RainDev*99). As with the Ethiopia case, we present two specifications for cooperative capacity, one using the indices for network and implementation capacity constructed in the previous section, and one using the exogenous explanatory variables. Because there are quite a few explanatory variables, we did not include explanatory variables that were not significant in either the network or implementation capacity equations, which is just two variables, the number of ethnic groups in the community and the index capturing the dominance of the chief in local organizations.

For the agro-ecological variables, in this case, we use just the coefficient of variation in rainfall, CoV_{Rain}, to proxy both mean and variability in rainfall, because the two measures are highly correlated, given the secondary dataset on which we are relying. For the mobility equations, we constructed an index of the proportionate difference between current and long-term rainfall, and of spatial deviations similar to that used in the Niger case, which serve as measures of *RainDev*99. The spatial difference and difference from the long-term mean measures are again highly correlated—with a simple correlation coefficient of .82—and again, we cannot include both in the same equation. Unlike the case for Niger, however, the spatial measure is not significant (although it is negative, as hypothesized), so we only present model results using the difference from the long-term means measure.

In addition, we did not collect the same information on rangeland quality as was the case for Ethiopia and Niger. Instead, we use three proxies for the land quality variable, *LandQual.* We have information on the distribution of three types of soils in the communities: *bolaare* soils, which are clayey but relatively rich in nutrients; *seeno* soils, which are sandy soils that are less rich in nutrients than *bolaare* soils; and *kollade* soils, which are the degraded lateritic soils poor in nutrients. The first two soils, although of different types, are considered to favor crop production relative to *kollade* soils. Thus, we use two dummy variables indicating whether the predominant soils are either *bolaare* or *seeno* soils, with *kollade* being the omitted categorical variable. We also use a dummy variable for whether there is a permanent surface-water source in the community.

For community characteristics, we include population density, a dummy variable

Figure 5.1 Proportional deviation from average annual rainfall, Burkina Faso

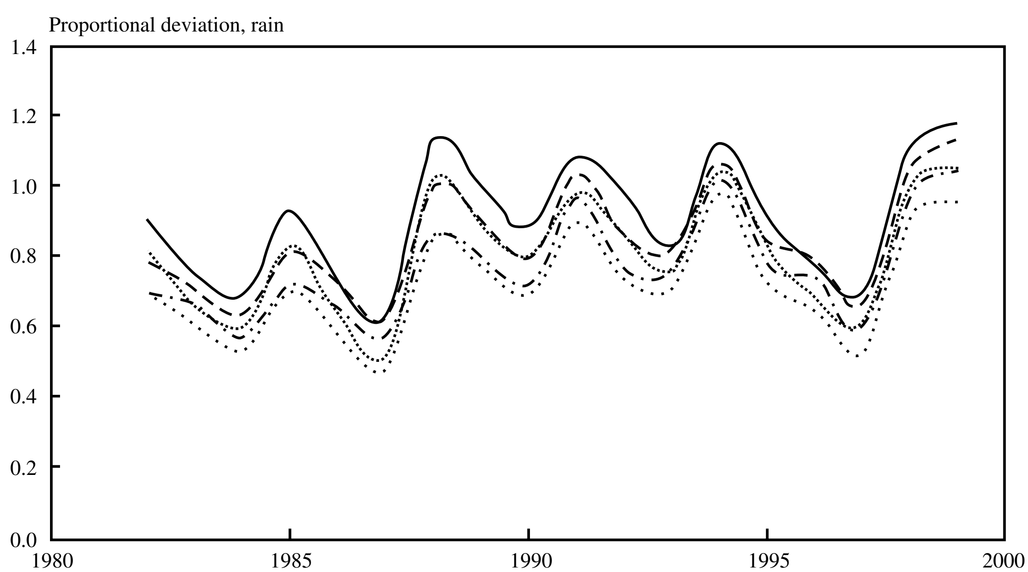
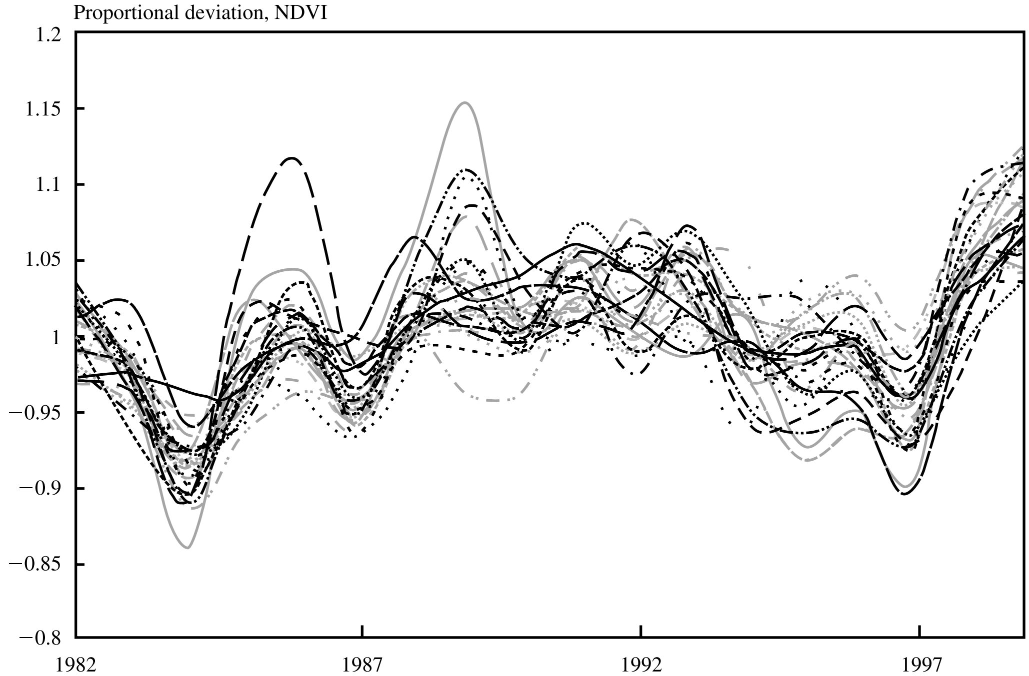


Figure 5.2 Proportional deviation from average NDVI, Burkina Faso



for whether the major ethnic group is traditionally pastoralist, and the total land constraint. We also have additional information on the number of households where at least one adult has had some schooling, *Educ*. The impact of education on land use and allocation is, in general, ambiguous, although anecdotal evidence supports the notion that adopting new crop practices and incorporating information from extension agents (who are largely crop-focused) may increase relative returns to education in cropping vs. livestock activities, thereby increasing land allocated to crops. As with the Niger case study, for community infrastructure, we summed up the number of motorcycles, transport carts, plows, and shops. We also include dummy variables for whether transhumants use community pastures, *InMig – T,* and the number of neighbors that access community pastures, *InMig – N.*

As before, the predicted impacts of relative livestock:grain price ratios and distance to markets are ambiguous, and depend on the relative value of crop production for grain relative to the value of crop residues in livestock production (McCarthy et al. 1998), and similarly, on the relative value of livestock outputs directly consumed or sold vs. those that are used as inputs into agriculture (manure, draft power). Observations by team members and conversations with those with experience in the relevant regions of Niger and Burkina Faso suggest that crops and livestock production are more integrated in Burkina Faso than in Niger, and certainly more so than in Ethiopia. Thus, we hypothesize that higher relative prices and shorter distances to market increase stock densities and also increase land allocated to crops.

Finally, we consider when the data were collected in terms of the drought cycle; as shown here, rainfall and normalized division vegetative index (NDVI) patterns are similar to Niger, although the low rainfall years of 1994 and 1997 are much less pronounced in the case of Burkina Faso (Figures 5.1 and 5.2). Thus, unlike Niger, where

Table 5.8 Impact of cooperative capacity on land allocation, stock densities, and herd mobility

	Stock density			
	Model 1		Model 2	
Parameter	**Coefficient**	***t*-statistic**	**Coefficient**	***t*-statistic**
Cooperation indices/determinants				
Index of network capacity	0.47	0.89		
Index of implementation capacity	–0.79	–1.87*		
Total households			0.04	1.44
Total households squared			-1.02×10^{-4}	–1.68
Number of quarters in community			–0.04	–0.52
Heterogeneity in livestock holdings			7.99×10^{-6}	1.91*
Percentage of households migrate for wage work			0.51	0.29
Index of collective rule-making, chief + others			–0.40	–0.81
Number of projects in community, before 1987			0.24	2.36**
Number of projects in community, 1988–1993			0.14	0.83
Number of projects in community, 1994–2000			0.19	1.26
Distance to regional capital			–0.17	–0.83
Agro-ecological characteristics				
Seeno soil, dominant	0.44	1.47	0.06	0.22
Bolaare soil, dominant	–0.45	–1.24	–0.56	–1.76*
Pond	–0.25	–1.02	–0.30	–1.32
Rainfall coefficient variation	–22.56	–2.67***	–21.78	–2.92***
Proportion, 1999: mean rainfall	–4.51	–1.74*	–3.87	–1.45
Community characteristics				
Population density^	0.66	2.64***	–0.81	–0.73
Dominant ethnic group, traditionally pastoralist	0.90	2.94***	0.73	2.76***
Percentage of households with public schooling	–0.64	–0.48	–1.11	–0.81
Assets and infrastructure	0.51	2.28**	0.23	0.67
Size of community landholdings^	0.05	0.14	–1.36	–1.31
Number of villages sharing pasture	–0.06	–0.29	0.06	0.3
Transhumants	1.26	3.55***	0.96	2.51**
Market				
Livestock:grain price^	2.47	1.06	1.36	0.71
Distance to cattle market (ln)^	0.14	1.62	0.12	0.85
Constant	1.47	0.48	6.17	1.28
ln(Sigma)				
Number of observations			48	
R^2		0.65	0.77	
Probability > χ^2				

Notes: ^ Indicates variables in natural logs. *, Significant at 10% level; **, significant at 5% level; ***, significant at 1% level.

rainfall at quite a few rainfall stations (and in communities as proxied by the NDVI values) was two standard deviations below the mean, this was true of only two communities in Burkina Faso in 1997.[33] As in the Niger and Ethiopia case studies, we ran a

[33] We stress here that we did not collect actual data at rainfall stations, and are relying only on secondary sources. Practically, this means that many of the communities are estimated to have experienced the same rainfall (e.g., there are five different observations for rainfall covering the 48 communities).

Percentage land cropped				Percentage herds migrating			
Model 1		Model 2		Model 1		Model 2	
Coefficient	z	Coefficient	z	Coefficient	z	Coefficient	z
0.13	1.03			–0.39	–0.82		
–0.34	–3.01***			0.46	1.75*		
		2.95×10^{-3}	0.36			0.02	1.55
		-5.04×10^{-6}	–0.29			-3.85×10^{-5}	–1.70
		-2.17×10^{-3}	–0.14			–0.01	–0.37
		1.81×10^{-6}	1.93*			0.00	–1.89*
		0.20	0.47			–0.67	–0.87
		0.09	0.73			–0.32	–1.88*
		0.04	1.53			0.03	0.93
		0.02	0.59			-3.88×10^{-3}	–0.06
		0.02	0.32			–0.05	–0.74
		-4.96×10^{-3}	–0.12			–0.07	–0.81
0.19	3.10***	0.12	1.46	–0.05	–0.47	–0.07	–0.77
–0.02	–0.26	–0.01	–0.18	0.12	0.92	0.03	0.26
0.03	0.53	-4.56×10^{-3}	–0.06	–0.14	–1.25	–0.12	–1.18
–2.52	–1.56	–0.06	–0.03	–1.05	–0.33	–6.92	–2.40**
0.08	1.71*	–0.08	–0.23	0.12	1.21	–0.49	–1.07
0.01	0.08	–0.04	–0.33	0.12	0.83	0.15	1.10
–0.36	–2.13**	–0.20	–0.72	0.82	1.97**	0.47	1.23
0.06	1.65	–0.03	–0.6	–0.02	–0.2	-7.15×10^{-4}	–0.01
2.87×10^{-3}	0.05	–0.17	–0.49	0.06	0.44	–0.43	–1.04
0.02	1	0.03	0.89	–0.17	–2.27**	–0.15	–2.34**
0.15	1.87*	0.02	0.16	0.21	1.29	0.28	1.64*
0.79	1.77*	0.57	1.23	–1.35	–1.59	–1.48	–1.50
0.04	1.73*	0.04	1.38	0.03	0.87	0.02	0.42
0.29	0.48	0.48	0.38	6.49	2.22**	8.34	2.37**
				–1.52	–10.48***	–1.68	–11.54***
48		48		48		48	
0.60		0.58					
				0.0002		0.0000	

number of specifications with a lagged rainfall deviation variable; again, coefficients on lagged effects were not significant, so we do not include them in the regression results reported in Table 5.8.

Looking first at the cooperation indices, we see that network capacity is not statistically significant in any of the equations. Implementation capacity, however, has a negative and significant impact on stock densities and land allocated to crops, indicating that such capacity enables community members to manage externalities. Implementation capacity also has a positive impact on herd mobility, indicating that it also reflects coordination capacity in the community. In the second set of regressions, we used the determinants of capacity indices directly in the stock density, cropland, and herd mobility equations. This adds an additional 10 variables to the equation, and, as can be seen, fewer coefficients are statistically significant in the stock density equation, although the qualitative results are very similar to the first set of regressions. None of the coefficients are significant in the land allocated to crops. In the stock density and cropland equations, only the heterogeneity in livestock holding variable is significant, and positive, as we expect. Herd mobility is lower when heterogeneity in livestock holdings is greater as well, and is also lower in communities in which the chief and community members more often collectively engage in rule-making. Because, in many communities, regulating herd movements was one of the strongest roles that chiefs played, this variable may be picking up the diminished authority of the chief, and at the same time, indicating that the new institutional structure has not been capable of replacing this role in regulating and coordinating herd movements.

Returning to the equations using the cooperation indices, of the agro-ecological variables, the dominance of *seeno* soil in a community, which is sandy but of relatively better quality than the *kollade* soils (the omitted soil category), leads to more land allocated to crops. The coefficient on the *bolaare* soil dummy variable, however, is not significant in any of the equations; nor is the coefficient on the dummy variable for whether the community has a permanent pond. Areas with high coefficients of variation of rainfall have lower stock densities and lower herd mobility in the second specification. The variable capturing the proportion of current rainfall to long-term mean is statistically significant and negative in the first specification for herd mobility, indicating that greater relative rainfall induces less mobility, as expected.

With respect to community characteristics, higher population densities leads to higher stock densities, and to more land allocated to crops. Unlike the case of communities in Niger, in Burkina Faso, ethnic majority matters for stock densities—communities with a traditionally pastoralist majority have higher stock densities—but there is no further impact on land allocated to crops or herd mobility. An increasing fraction of the population with some public schooling decreases land allocated to crops, indicating that greater schooling leads to improved opportunities for livestock vs. crop production in this area. This trend is also reflected in the greater herd mobility in communities with greater public education. A greater stock of agricultural assets and community infrastructure leads to higher stock densities; the coefficient is just shy of being significantly positive in the cropland equation. Total land endowment has no statistically significant impact on any of the variables, a result consistent with constant returns to scale in cropping and livestock production. In terms of external pressure on home resources, the number of villages with which the community shares pastures reduces herd mobility, indicating noncooperation between village members and those with whom they share pastures. Increasing the number of transhumants using community pastures leads to greater stock densities, and more land allocated to crops, indicating that members are appropriating land for the purpose of limiting access to transhumant herders. However, higher stock densities may be accommodated by greater herd mobility, as the coefficient on transhumants is positive and significant in the herd mobility equation. The issue of negotiating access and use by transhumants—who, in many cases, have historical claims to access various resources—can be a difficult and explosive issue; our results indicate that efforts at conflict negotiation and mediation are likely to remain very important issues in the region.

Concerning the market variables, the coefficient on relative livestock:grain price ratios is only significant in the cropland equation, indicating that greater relative livestock prices increases land allocated to crops; the coefficient on mobility is negative but not quite significant. Together, these results indicate that, as livestock activities become relatively more profitable, intensification may be occurring through a substitution of crop residues for external grazing resources, leaving the use of home pastures stable. Greater distances to cattle markets, however, lead to more cropped land, indicating that more land goes into cropping when markets are costly to access.

To summarize, the evidence suggests that increased cooperative capacity, as captured in the implementation index, indeed leads to lower stock densities, less land allocated to crops, and greater mobility. Network capacity has no statistically significant impact, and even the signs of the coefficients are opposite to what we would expect if this type of capacity were used to help manage the natural resource base. Recall that network capacity is higher in regions where one might expect individuals to participate in the networks to manage essentially household-level concerns (i.e., in populous, heterogeneous communities located in the variable and low rainfall areas but relatively close to the regional capital). Implementation capacity, however, is greater in higher and less variable rainfall regions, in more homogeneous communities with less migration for wage work, and in those that have more external projects begun after 1986, when the focus changed to community participation in natural resource management instead of a more narrow focus on individual household adoption of various technologies. All of these factors are more consistent with building capacity to manage community-level, as opposed to household-level, concerns. In addition, in Ethiopia, Niger, and Burkina Faso, there is evidence that heterogeneity in livestock holdings reduces the capacity of community members to agree, even informally, on land use and allocation patterns.

Higher population densities lead to greater stock densities—as is the case in both Ethiopia and Niger—and to more land allocated to crops. Greater public education leads to less land in crops, more mobility, and no increase in stock densities, indicating that greater human capital increases the capacity of community members to exploit the comparative advantage of livestock production relative to crop production in this marginal, semiarid region. Relative prices and distance to market have different impacts on land use and allocation variables than in Niger and Ethiopia. In Burkina Faso, higher relative prices but longer distances to market lead to more land allocated to crops, with no impact on stock densities or herd mobility. This contrasts with results from Ethiopia and Niger; in both of these countries, higher prices and shorter distances to market lead to greater stock densities, with no impact on land allocation or herd mobility. Also, stock densities and cropland are lower in areas of low rainfall and high rainfall variability, although we cannot test whether variability per se induces lower densities, as in the cases of Niger and Ethiopia.

CHAPTER 6

Cross-Country Comparison

Traditional, local-level, customary institutions prevail in all three countries that we studied: Ethiopia, Niger, and Burkina Faso. However, in Ethiopia the overwhelming majority of the people in the study area belongs to a single tribe, the Boran, who have developed a very complex system of rangeland management, characterized by layers of administration and delineation of various tribal tenurial arrangements, ranging from open access to private enclosures and croplands (Kamara 2001). Herd mobility is generally practiced within the boundaries of the Borana plateau; patterns of herd mobility are well established and revolve around the operation and maintenance of deep wells, whose customary administration is considered to be extremely efficient. Although interaction with the central government has generally been weak, government-initiated peasant associations do influence land allocated to crops within the study area (Kamara et al. 2004).

Alternatively, in southwestern Niger, many different ethnic groups are represented, both traditional pastoralists and traditional crop farmers, very often within the same community. The power and authority of traditional village and canton chiefs has waned and waxed through colonization and several postindependence governments, although the most recent legislative acts, the Act on Home Areas and the Act on Local Institutions, strongly support local customary authorities (Ngaido 1996). Nonetheless, there is a great deal more uncertainty about tenurial relationships and authority to enforce resource management than is the case in Ethiopia, and practical implementation of the rural code is largely stalled (Grell and Kirk 1999). Different groups also have different historical patterns of herd mobility; the patterns differ both within and between tribes, depending on settlement patterns (Turner 1999). Finally, like Niger, communities in Burkina Faso are composed of diverse ethnic groups, both pastoralist and agriculturalist. The power of local chiefs, however, has eroded more steadily; current plans for devolution of authority to manage local natural resources and the decentralization of public administration focus on the creation of democratically elected local management committees. As in Niger, historical patterns of herd mobility differ by ethnic groups, and options of mobility are decreasing, as transnational boundaries are more difficult to cross (e.g., into Mali) (Drabo et al. 2001).

In this chapter, we compare land use and allocation outcomes across countries. As might be expected, given the coefficients on explanatory variables in the country-specific land use and allocation equations found in Chapters 3–5, we reject a specification that pools observations across countries in favor of the country-specific regressions. We proceed by comparing descriptive statistics, presenting first the land use and allocation patterns, next presenting information on agro-ecological traits, market conditions, and community characteristics, followed by descriptive statistics on factors affecting cooperative capacity. We derive measures of overstocking and overallocation of land to either private pastures or cropland and compare the mean and distribution of outcomes across countries. We then return to a hypothesis stemming from the first model developed in Chapter 2, that overuse of pastures occurs less often in communities facing higher rainfall variability, because the difference between the social optimum and the noncooperative outcome—and thus the externalities that condition costs of cooperation—diminish as variability increases. Using the constructed estimates of overstocking, we present descriptive statistics on the relationship between overstocking and the coefficient of variation of rainfall.

Descriptive Statistics

As can be seen in the Table 6.1, mean stock densities calculated using the total land endowment are higher in Ethiopia than in either Burkina Faso or Niger, which are quite similar. Stock densities on pastureland in Ethiopia are similar to those in Niger, and both remain quite a bit higher than stock densities in Burkina Faso. However, herd migration to pastures outside community land is far more important in Ethiopia, as evidenced by the fact that 84 percent of herds were mobile during at least part of the year; as noted in Chapter 3, most communities are in fact surrounded by *forra* grazing areas open to all Boran, thus making direct comparison difficult. The proportion of the year during which livestock are mobile is quite low in both Niger and Burkina Faso. This result is intriguing, because in Niger, the year to which survey data referred was a poor rainfall year (although not nearly as poor as 1997), whereas rainfall was above average in nearly all areas in Burkina Faso in the year preceding the survey. Despite the rather low overall proportion of time most of the herds were migrating, in more than 40 percent and 50 percent of communities in Niger and Burkina Faso, respectively, at least some households engaged in mobility, if only for a relatively short time. Land in crops is much smaller—by half—in Ethiopia than in the West African countries; cultivated land per household being only one-third and less than one-quarter that figure in Niger and Burkina Faso, respectively. However, nearly 18 percent of community land in Ethiopia has been allocated to pastures with individualized rights of access and use. Thus, in terms of proportion of total land allocated to individual uses, all three countries have very similar proportions, .33, .33, and .39 for Ethiopia, Niger, and Burkina Faso, respectively.

To summarize, communities in Ethiopia rely more heavily on livestock production versus crops; tropical livestock units (TLU)

Table 6.1 Land use and allocation patterns

	Ethiopia	Niger	Burkina Faso
Stock densities (TLU/total ha), mean	.91[a,b]	.72	.71
Stock densities (TLU/total ha), median	.62[a,b]	.30[c]	.35
Stock densities (TLU/pasture ha), mean	1.03[b]	1.08[c]	.44
Stock densities (TLU/pasture ha), median	.79[a,b]	.48[c]	.25
Livestock holdings per household	19[a,b]	10	9
Communities with mobile herds, part of survey year, proportion	.84[a,b]	.41[c]	.52
Herd mobility, proportion of year	—	.14	.15
Land in crops, proportion	.15[a,b]	.34	.39
Cropland per household (ha)	3[a,b]	9[c]	13
Land in private pastures, proportion	.18	0	—

Note: —, Not available.
[a] Value for Ethiopia is significantly different from that for Niger.
[b] Value for Ethiopia is significantly different from that for Burkina Faso.
[c] Value for Niger is significantly different from that for Burkina Faso.

Table 6.2 Correlation coefficients—land allocation, use, and herd mobility

Ethiopia	Stock densities	Land in crops	Land in private pastures
Stock densities	1		
Land in crops, proportion	.15	1	
Land in private pastures, proportion	.08	–.13	1
Niger	**Stock densities**	**Land in crops**	**Herd mobility**
Stock densities	1		
Land in crops, proportion	–.13	1	
Herd mobility	.24	.04	1
Burkina Faso	**Stock densities**	**Land in crops**	**Herd mobility**
Stock densities	1		
Land in crops, proportion	.64	1	
Herd mobility	.19	–.15	1

per household are nearly double the figures in Burkina Faso and Niger, whereas the proportion of the land endowment allocated to crops in Ethiopia is less than half those in the West African countries. Unfortunately, because mobility is heavily relied on, and because the schedule of herd mobility is not nearly as tied to the cropping cycle as is the case in Niger and Burkina Faso, accurate information on the extent of mobility by all household herds throughout the year was very difficult to collect, and we were successful in doing so in less than half of the communities included in the sample. Nonetheless, the more crude measure of the proportion of communities in which herds were mobile during at least part of the previous year is 85 percent, far greater than in Niger and Burkina Faso. Overall, then, households in Ethiopia rely more heavily on livestock production and herd mobility. Comparing Niger and Burkina Faso, we note that stock densities are much greater in Niger, although they are similar to densities in Ethiopia. However, herd mobility appears to be much lower, indicating greater grazing pressure on home pastures than in either Ethiopia or Burkina Faso.

Although it is not possible to isolate the direct relationship between stockholding, allocation of land to individual use, and mobility, we can look at the correlation coefficients among these variables in each of the three countries (Table 6.2). In Ethiopia and Burkina Faso, there is a positive correlation between land allocated to individual use and stock densities, indicating that individual crop and pasture activities might be supporting greater stock densities in these countries. However, the relationship is negative in Niger, indicating that these two activities may be competing for scarce land resources. Herd mobility is positively correlated with stock densities in both Niger and Burkina Faso; this is expected, because greater mobility can allow a community to stock more livestock, and more livestock increases the value of mobility. The correlation between mobility and land allocated to crops is positive but quite low in Niger, but is negative in Burkina Faso, indicating that herd mobility and crop production may be competing activities in the latter country, perhaps in terms of family labor time.

Table 6.3 presents descriptive statistics for a subset of the agro-ecological, market, and community characteristics for the three countries. In general, the communities surveyed in Ethiopia have the highest mean, but most variable, rainfall; Ethiopia also has a bimodal rainfall distribution, whereas Niger and Burkina Faso have unimodal

Table 6.3 Agro-ecological and market conditions

	Ethiopia	Niger	Burkina Faso
Mean rainfall	599[a,b]	498	467
Coefficient of variation, rainfall	.38[a]	.23	.16
Distance to livestock markets (km)	41[a,b]	33[c]	13
Cattle price (U.S.$/kg)	.27[a,b]	.37	.41
Grain price (U.S.$/kg)	.33[b]	.29[c]	.18
Relative cattle:grain price ratio	.84[a,b]	1.31[c]	2.33

Note: We did not calculate whether the coefficient of variation of rainfall was significantly different between Ethiopia and Niger relative to Burkina Faso, as the data were from different sources.

[a] Figure is statistically different from corresponding figure for Niger.
[b] Figure is statistically different from corresponding figure for Burkina Faso.
[c] Figure is statistically different from corresponding figure for Burkina Faso.

Table 6.4 Community characteristics

	Ethiopia	Niger	Burkina Faso
Total landholdings	1105[a,b]	1777[c]	3070
Number of ethnic groups	—	1.62[c]	3.3
Proportion of population, dominant ethnic group	—	.95[c]	.71
Heterogeneity, cattle holdings	2.4[a]	1.3[c]	2.5
Migrating for wage work (%)	25[a,b]	48[c]	25
Communities with schools (%)	0	41	42
Total number of households	71[a,b]	100	91
Household density	.08[b]	.09[c]	.04

[a] Figure is statistically different from corresponding figure for Niger.
[b] Figure is statistically different from corresponding figure for Burkina Faso.
[c] Figure is statistically different from corresponding figure for Burkina Faso.

rainfall distributions. Households in Ethiopia and Niger are much farther from livestock markets on average than is the case with surveyed households in Burkina Faso. Probably the greatest difference among the countries is in terms of cattle prices, crop prices, and relative livestock:crop price ratios. In Burkina Faso, where many livestock traders in the Dori region themselves participate in markets and the end market is the capital (Ouagadougou) or even the market in Cote d'Ivoire, livestock prices are the highest. The major export markets for livestock in Ethiopia are in Kenya and, to a lesser extent, the Middle East; however, there are many middlemen and a long, treacherous distance between the Ethiopian cattle owner and the consumer in Nairobi. In Niger, cattle prices are lower than in Burkina Faso, but are still higher than in Ethiopia. Also interesting are the grain prices, which are very high relative to livestock prices in Ethiopia; as noted in Chapter 3, the Boran are a traditionally pastoralist tribe, continual crop farming is a relatively recent phenomenon for many people, this region has the lowest proportion of land allocated to crops, and the plateau is geographically isolated from the highland areas in Ethiopia, where most crop production is undertaken.

In Table 6.4, we note that total community landholdings are much larger in Burkina Faso than in Ethiopia and Niger, and households per hectare are correspondingly lower—nearly half those realized in Ethiopia and Niger. There is a great deal more ethnic diversity in Burkina Faso as well, and heterogeneity in cattle holdings is greater there than in Niger, although very similar to Ethiopia. Despite the diversity, the range of collective activities and rules over resource use and management is greater in Burkina Faso relative to either Ethiopia or Niger—although it must also be noted that the presence of large-scale externally funded projects is also greater in Burkina Faso. Still, lower relative household density, high relative livestock prices, and a rich and diverse set of institutions for collective action—perhaps even because of ethnic diversity—appear to be associated with a lower stock densities and greater mobility than is the case in Niger.

We can further compare communities by using the results from the empirical models given in Chapters 3–5 to estimate overstocking and overallocation of land to private uses.[34] Starting with Ethiopia, we calculate a "best cooperation" stock density, $SD^{BC}_{Estimated}$, using the coefficients from the estimated equations and setting the coefficient for the (normalized) cooperation index equal to 1 for each community. Note that this is not necessarily the social optimum that would arise if cooperation were costless; it is simply the stocking rate that would result if all communities achieved the same level of cooperative capacity as that achieved by the community with the highest cooperative capacity in the sample. We then calculate overstocking and overallocation of land to individuals:

$$\%Overstocking = 100\left(\frac{SD_{Estimated} - SD^{BC}_{Estimated}}{SD^{BC}_{Estimated}}\right)$$

$$\%OverAllocationLand = 100\left(\frac{LA_{Estimated} - LA^{BC}_{Estimated}}{LA^{BC}_{Estimated}}\right)$$

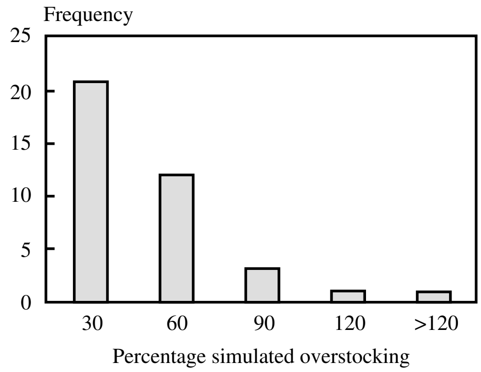
where $SD^{BC}_{Estimated}$ is the estimated socially optimal stock density, and $SD_{Estimated}$ is simply the predicted value. Similarly, $LA^{BC}_{Estimated}$ is the estimated socially optimal land allocation, and $LA_{Estimated}$ is the predicted value.

In Burkina Faso, we have two indices of cooperation, one reflecting network-based capacity and the other reflecting implementation capacity. As expected, lower implementation capacity leads to greater stock densities, more land allocated to crops, and lower mobility, but lower network capacity has no statistically significant impact. Because of this, we calculate best cooperative stock densities and cropland by setting only the coefficient on implementation capacity to 1.

In Niger, the situation is more complicated, because we do not have an index of cooperation per se, only exogenous characteristics thought to affect cooperation, some of which are hypothesized to affect stock densities directly, such as wage work. However, in the estimation results, only heterogeneity in cattle holding and ethnic heterogeneity were significant, so to derive a measure of cooperation stock densities, we set the coefficients on the heterogeneity in livestock holdings and the ethnic heterogeneity index equal to the lowest value observed in the sample. Because none of the cooperation variables were statistically significant in the mobility or land allocated to crop equations, we do not calculate similar figures for these variables. Simulated over-

[34]As noted previously, we did attempt to pool the observations across countries and run stock density, land in crops, and herd mobility equations (the latter using just Niger and Burkina Faso), but tests for the pooled regressions led us to reject this specification in all three cases.

Figure 6.1 Simulated overstocking, Ethiopia

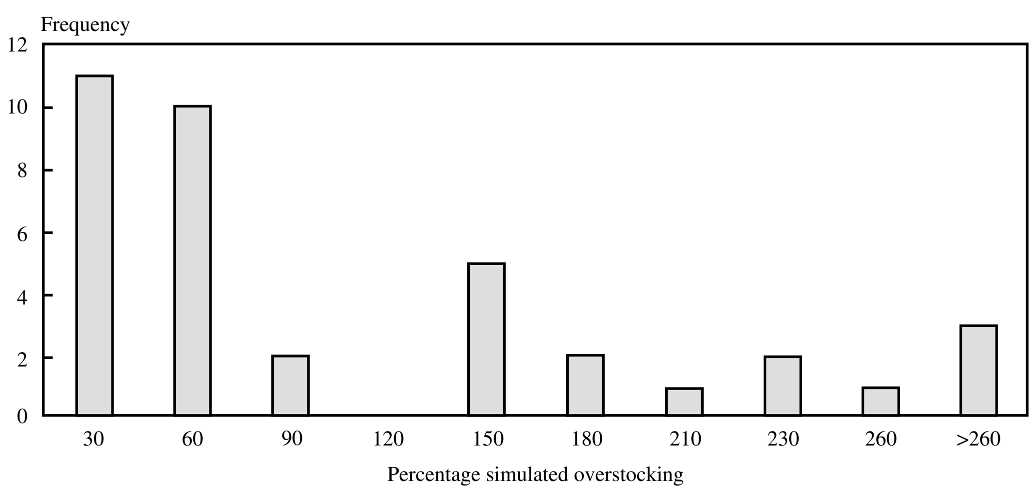


Note: Mean overstocking, 36 percent; median overstocking, 27 percent.

stocking is illustrated in Figures 6.1–6.3, which also give the mean and median simulated overstocking for each country. As highlighted in these histograms, there is evidence that communities are indeed overstocking, but the median, mean, and distribution of estimated overstocking differs substantially across countries. In Niger, recall that recent rainfall patterns have been the worst relative to long-term average rainfall, but median estimated overstocking is highest there, and there is a much wider distribution of overstocking across communities. In Ethiopia, median overstocking is 27 percent, and there are 11 communities with estimated overstocking at less than 20 percent, five of which are at less than 10 percent. Finally, Burkina Faso exhibits the lowest estimated overstocking, with a median of just 22 percent, and, like Ethiopia, a relatively small distribution, ranging from 0 to 120 percent.

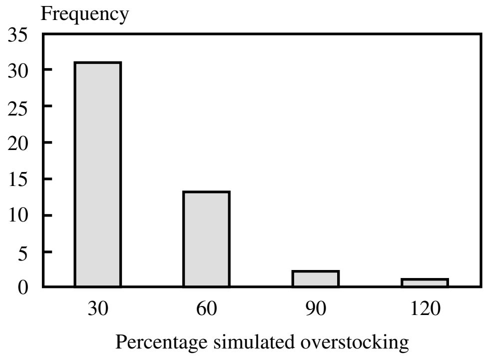
We now consider overallocation of land to individual use. In Ethiopia, there is no evidence that cropland is increasing due to noncooperation, but there is evidence that land is being allocated to private pasture enclosures. In Burkina Faso, there is evidence that when cooperative capacity is decreased, land is being allocated to cropland. Thus, we develop a measure of overallocation of land to private pasture enclosures in Ethiopia, and to cropland in Burkina Faso. Histograms, mean, and median figures are presented in Figures 6.4 and 6.5. For Ethiopia, only 32 observations are captured on the graph; there were four observations for which the calculated "optimal" allocation of land was negative, and one observation for which the calculated overallocation

Figure 6.2 Simulated overstocking, Niger



Note: Mean overstocking, 112 percent; median overstocking, 48 percent.

Figure 6.3 Simulated overstocking, Burkina Faso

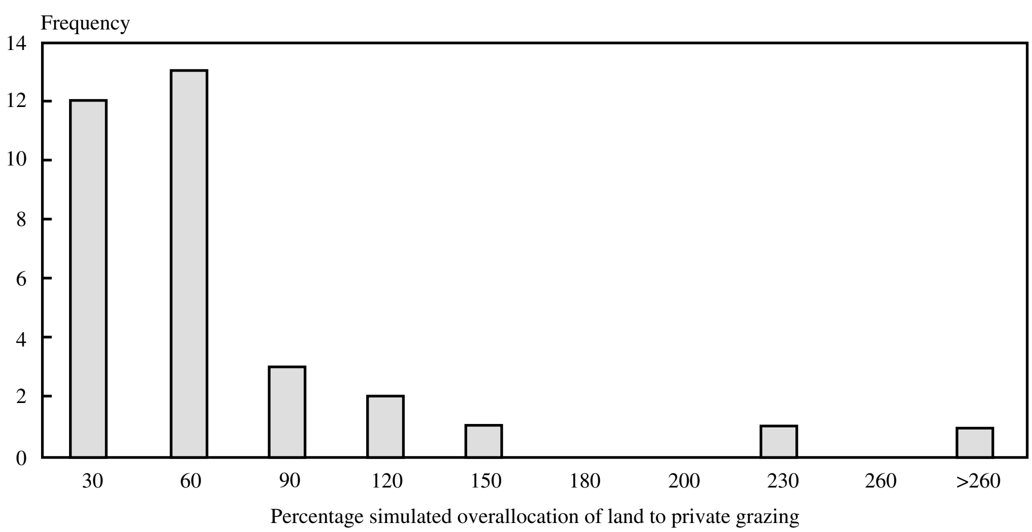


Note: Mean overstocking, 29 percent; median overstocking, 22 percent.

was approximately 1,000 percent. The latter result is because the predicted optimal land in pastures was very close to 0, driving the ratio to an extremely high level. For Burkina Faso, only 42 observations are used; calculated "optimal" allocation was negative in six of the communities.

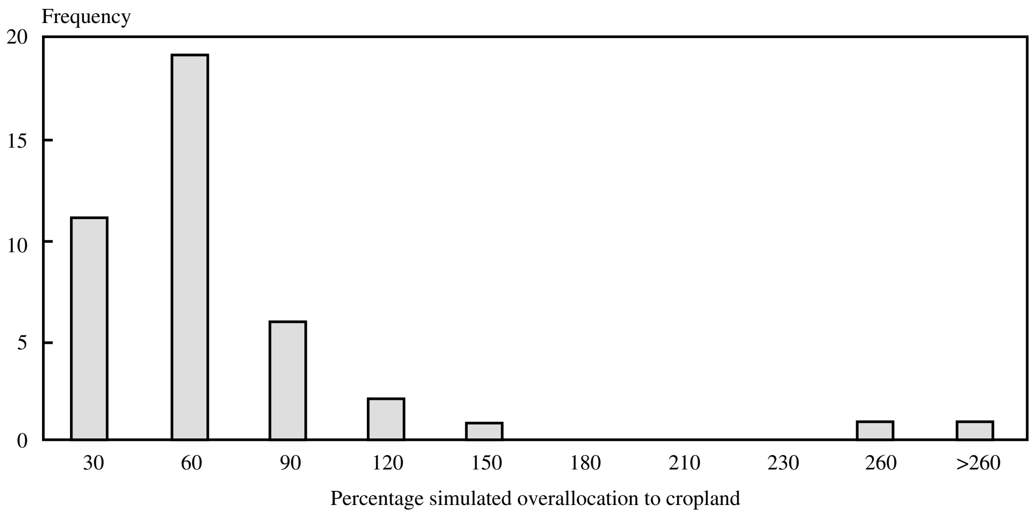
In general, the simulated percentage of overallocation of land to private uses is nearly the same, in terms of mean, median, and distribution, in both Ethiopia and Burkina Faso. As with the distribution of overstocking, overallocation of land to private grazing is concentrated between 0 and 60 percent. Estimated percentages of the overallocation of land to private pastures in Ethiopia are higher than for overstocking, with a mean of about 58 percent and a median of 44 percent. The mean allocation of land to private pastures in this subsample of 32 communities is approximately 18 percent for both actual and predicted values, whereas the mean allocation of land in private pastures is predicted to be 12 percent when the noncooperation variable takes a value of 0. In other words, if cooperative capacity across communities in Ethiopia were raised to the level achieved in that community with the highest capacity index, land allocated to private pastures would drop from 18 percent to 12 percent, on average. Also, evidence suggests that overallocation of land to cropland is a more important concern in both Ethiopia and Burkina Faso than is overstocking. Estimated percentages of overallocation of land to cropping are

Figure 6.4 Simulated overallocation of land to private pastures, Ethiopia



Note: Mean overallocation, 58 percent; median overallocation, 44 percent.

Figure 6.5 Simulated overallocation of land to crops, Burkina Faso



Note: Mean overallocation, 56 percent; median overallocation, 42 percent.

nearly double those for overstocking. In Burkina Faso, the mean allocation of land to cropland in the subsample of 42 is 41 percent for both actual and predicted values, whereas the mean simulated socially optimal allocation is just 30 percent.

Taken as a whole, the comparison across countries indicates that problems of overuse of pastureland may be of particular importance in Niger, and it appears that both high stock levels and limited herd mobility contribute to high overall grazing pressure. At the present time, there is less evidence to suggest that land is being privately appropriated for crops in Niger; the simple correlation coefficient between crops and stock densities is negative, and the indicators of cooperative capacity are not significant in the regressions. In comparison with communities with very similar agro-ecological conditions in Burkina Faso, communities in Niger have much smaller land endowments per household, and relative cattle:grain price ratios are much lower, distances to market much greater, and migration for wage work more prevalent. Also, greater ethnic and economic heterogeneity within communities in Burkina Faso do not appear to have large effects on cooperative capacity, although economic heterogeneity does lead to higher stock densities and less land allocated to common pastures. And although the power of traditional authorities may be considered greater in Niger than in Burkina Faso, there also remains a great deal of uncertainty regarding the future roles of the chief. Burkina Faso has also been going through the process of adopting agrarian reform laws and a complementary legal framework for implementation, a process that is still ongoing. Still, the process is continual if slow, and uncertainty of the role and authority of traditional chiefs has already been transformed, in contrast to the case of Niger.

Ethiopia is quite distinct, in that there is little ethnic heterogeneity, and customary institutions are still quite strong, although local government-created peasant associations do exert influence, particularly in land allocation patterns. Like Burkina Faso, however, the extent of uncertainty over who has rights over land use and allocation decisions is less well defined than is the case in

Niger.[35] Although land endowments at the community level are relatively low, the Boran are far more mobile and have access to large areas of both neighboring and distant pastures (*forra*). Still, pastoralists here face the worst cattle:grain terms of trade and are relatively isolated from markets. Evidence suggests that privatization of land for pasture is a greater problem on the Borana Plateau than is overstocking per se.

[35]Unlike the sedentary crop farmers located in the highlands of Ethiopia, because Borana lands have traditionally been under various forms of common access, they were substantially less affected by rules on agrarian reforms under the Derg and post-Derg regimes to limit landholding sizes and land redistribution programs (Kamara 2001); thus, the uncertainty in land tenure is quite different on the Borana Plateau compared to the highlands.

CHAPTER 7

Conclusion

There are two key sets of conclusions from the empirical research, the first related to cooperation in the management of local natural resources and the second related to the impact of climate variability. First, cooperative capacity does matter for such natural resource management issues as land allocation, exploitation of common pastures, and herd mobility—even though no formal rules and regulations were observed in the communities studied. Because these areas are subject to large fluctuations in rainfall both spatially and temporally, more flexible—and perhaps less formal—institutional arrangements may be best able to handle such variability in the external environment. But that does not mean that such arrangements will be equally successful across all communities at all times. Indeed, the capacity of communities to manage pastures and allocate land to its best use varies greatly both within and among countries. Factors that are generally associated with greater cooperative capacity include relatively small community size, more equal distribution of wealth, and fewer adults migrating for wage work, all of which should reduce negotiation and enforcement costs of undertaking collective action.

Formation of subgroups within communities may help to alleviate problems of group size and heterogeneity in wealth in larger, more diverse communities. From results presented in the Burkina Faso case study, we note that the number of quarters within a community increases network capacity, and at least does not have a negative impact on implementation capacity. Nevertheless, our research results do not provide direct evidence on whether subdivision would be the best way to manage group size and heterogeneity, as we did not observe the more formal division of resource management tasks in our country case studies, with the exception of water management in Burkina Faso. Evidence presented in McCarthy et al. (2004) suggests that subgroup management that occurs in large and heterogeneous communities performs similarly to community-level management committees in smaller communities; however, it is perhaps easier to assign roles and responsibilities to subgroups in the management of well-defined water resources than in the management of pasture resources. Details of optimal organizational structure will differ across regions and perhaps even communities; the point is that group size, wealth distribution, and opportunity costs of participation are likely to be key issues to be addressed by any organizational structure.

Other factors affecting cooperation differ across countries. For instance, external pressure to use community resources appears to have a much greater impact on cooperation in Ethiopia than in Burkina Faso or Niger. In Burkina Faso, sharing pastures with neighbors does tend to decrease herd mobility, but in Niger, it is associated with greater herd mobility. Higher productivity rangelands and higher effective livestock prices are associated with greater cooperative capacity in Ethiopia, but have no impact in Burkina Faso. Thus, the evidence suggests that more favorable livestock market conditions either increase cooperative capacity or have no impact; in either case, there is no evidence to suggest that better market conditions erode this capacity.

There is little evidence to suggest that livestock owners accumulate larger herds to mitigate vulnerability to rainfall shocks in high-variability environments. Our results instead suggest that herd sizes increase with rainfall variability at relatively low variability, but decrease in the higher-variability environments. In other words, we would expect that policies and programs that directly “insure” livestock owners—through feed subsidies in response to drought, for instance—would likely lead to larger herds in high-variability environments. We must emphasize that our results are consistent with this hypothesis, but, given the one-period nature of the survey, we did not test the hypothesis directly. This is still a contentious issue, as a wide range of researchers, policymakers, and indeed, herders themselves, believe that holding onto more livestock is a strategy to mitigate the impact of climate shocks, such as drought. Here, we note that the theoretical reasoning underpinning such a strategy is based on the very strong assumption that there are no externalities of any kind associated with grazing livestock, and thus, that individually rational strategies are also socially rational strategies. More specifically, this proposition is based on the assumption that there are no one-period externalities affecting animal productivity (including animal mortality), no dynamic externalities affecting future forage productivity, and no externalities affecting the riskiness of livestock production.

Thus, we can only say that our results imply that policymakers designing crises mitigation strategies—as many governments that are signatories to the UN Convention to Combat Desertification are doing—must carefully consider insurance and crises mitigation mechanisms that do not lead to dramatic increases in the national herd. On a precautionary note, Hazell et al. (2003) discuss the experiences of drought subsidy schemes in Jordan, Syria, Morocco, and Tunisia. Particularly in Jordan, stock numbers increased dramatically in response to a drought feed subsidy program instituted after 1990, so much so that feed subsidies were required to sustain the herd even in non-drought years and ultimately proved fiscally unsustainable (Hazell 1999). It is difficult, of course, to sort out the effects of increasing the mean returns to livestock implied by the subsidies and the effect due to reducing downside risk; but the fourfold increase witnessed in Jordan certainly seems to indicate that the response was due to both increase mean and reduced variance of livestock returns.

Mobility remains an important part of these systems. Given the rather complicated patterns of herd mobility into and out of community areas in Ethiopia, we were not able to gather good enough data to include this variable in the statistical analyses. Still, more than 84 percent of the communities relied on mobility for at least part of the previous year, and in the 12 communities for which data were quite good, herds were mobile for nearly 40 percent of the year. The number of communities in which at least some members engaged in herd mobility is lower in Niger and Burkina Faso, but mobility is still practiced in more than 40 percent in both these countries. And better cooperative capacity in communities supports greater herd mobility. Nonetheless, herders’ rights to access traditional grazing areas are generally eroding everywhere, perhaps particularly for livestock owners found in the southern part of our survey region in Niger (see Turner 1999). Results indicate that communities with more traditional pastoralists do tend to rely more heavily on herd mobility, but the impact is weak and not robust across specifications. Given the nature of our study, we did not collect data on exogenous changes that limit mobility, such as the establishment of state parks and reserves and encroachment of cropland; such an analyses would likely require historical or time-series data and coverage of a much wider geographical area. Nonetheless, our results indicate that pastoral land tenure and drought mitigation policies will need to take into account the continued reliance on herd mobility—even by those not considered to be traditionally pastoralist—as well as factors that either directly or indirectly limit mobility.

In addition, it is fitting to note that the equations quite poorly estimated land allocation decisions in both Niger and Ethiopia, although the econometric results are fairly good for Burkina Faso. These results suggest that the overlapping jurisdiction of chiefs and local representatives of the government is likely to play an important role in the decision to allocate cropland to individual households (Swallow and Kamara 1999; Meinzen-Dick and Pradhan 2002), and that the community-level, aggregated information used in the econometric analysis fails to capture key aspects of how these overlapping institutions interact and affect land allocation decisions, and particularly, how these relationships differ among communities in the same region (and thus technically subject to the same ambiguities).

This problem highlights one of the major constraints of this type of study; namely, that data on institutions—their goals and objectives, managerial structure, and mechanisms for implementing rules and undertaking collective action—have been aggregated to develop a community-level indicator of cooperative capacity. Such aggregation does not enable us to examine the multiple claims over resources and the institutional basis on which these claims are made. A more detailed understanding of overlapping claims of access, use, and management of the various resources and the legal and normative frameworks supporting these multiple claims is particularly relevant for considering the equity aspects of various land use and allocation outcomes (see Meinzen-Dick and Pradhan 2002). Similarly, linking community-level results with household outcomes is critically important. After all, it may be the case that lower stock densities, greater mobility, and more land allocated to common pastures do not have large impacts on household welfare. The team did not collect household data in Ethiopia or Niger, but household data were collected in Burkina Faso. As reported in Dutilly-Diane et al. (2003), greater implementation capacity at the community level—which leads to lower stock densities and greater mobility, although not necessarily more land in common pastures—does indeed lead to higher incomes from livestock and to higher overall income at the household level. Thus, future research should incorporate both household- and community-level studies, even though such research is quite data intensive.

APPENDIX 1

Proof That the Stocking Level Is Higher under Noncooperation Than under Joint Maximization

In the following, we let $R = \sigma_\theta^2 \phi_A$. The maximization problems and first-order conditions for the N-player game and joint maximization solutions are:

Joint-Maximization:

$$\max_{\mathrm{L}} \; EU(\pi^{JM}) = PNLf - cNL - \frac{N}{2} R_i (PLf)^2 \tag{A1}$$

$$PN\big[f + LNf' - PR_i Lf\,[(f + NLf')]\big] - Nc = 0 \tag{A2}$$

$$\big[f + LNf' - PR_i Lf\,[(f + NLf')]\big] = \frac{c}{P} \tag{A3}$$

Noncooperative Game:

$$\max_{\mathrm{L}_i} \; EU(\pi_i^{NC}) = P_L L_i f - cL_i - \tfrac{1}{2} R_i (P_L L_i f)^2 \tag{A4}$$

$$P_L\big[f + L_i f' - P_L R_i L_i f\,[(f + L_i f')]\big] - c = 0 \tag{A5}$$

$$\big[f + L_i f' - P_L R_i L_i f\,[(f + L_i f')]\big] = \frac{c}{P_L} \tag{A6}$$

In equilibrium, both first order conditions must equal c/P_L. By establishing the sign of equation (A3), we can determine under what conditions the stocking rate under noncooperation is greater than under joint maximization:

$$[f + Lf']\,[1 - P_L RLf] \gtreqless [f + Lf' + (N-1)Lf']\,[1 - P_L RLf] \tag{A7}$$

We immediately note that:

$$[f + Lf'] > [f + Lf' + (N-1)Lf'] \tag{A8}$$

The left-hand side of the equation (noncooperation) is greater than the right-hand side (joint maximization) at the same stocking rate; therefore, in equilibrium, the stock level must be greater under noncooperation than under joint maximization.

We also note that $[f + Lf'] > [f + Lf'][1 - P_L RLf]$, or alternatively, that the stocking rate when risk is greater than 0 is always greater than the stocking rate when the risk is less than 0. The risky, noncooperative stocking rate may be less than the riskless, joint-maximization solution:

$$[f + Lf' - P_L Rlf(f + Lf')] \lesseqgtr [f + NLf'] \quad \text{(A9)}$$

$$[f - P_L Rlf(f + Lf')] \lesseqgtr [f + (N-1)Lf'] \quad \text{(A10)}$$

So that:

$$[f - P_L Rlf(f + Lf')] > [f + (N-1)Lf'], \text{ when } P_L Rlf[f + Lf'] < |(N-1)Lf'|$$

$$[f - P_L Rlf(f + Lf')] = [f + (N-1)Lf'], \text{ when } P_L Rlf[f + Lf'] = |(N-1)Lf'|$$

$$[f - P_L Rlf(f + Lf')] < [f + (N-1)Lf'], \text{ when } P_L Rlf[f + Lf'] > |(N-1)Lf'|$$

APPENDIX 2

Change in the Total Externality for Increases in Risk

The externality is given by $Lf' - PRLfLf'$, which can be rewritten as $Lf'(1 - PRLf)$. Differentiating with respect to R gives:

$$(1 - PRLf)(f' + Lf'')\frac{dL}{dR} - Lf'\left[PLf + PR(f + Lf')\frac{dL}{dR}\right] \qquad \text{(A11)}$$

First, we note that $dL/dR < 0$. Thus, the first term is positive, although the second term is indeterminate. Rearranging the second term gives:

$$-PLf'\left[Lf + R\text{L}f'\frac{dL}{dR} + Rf\frac{dL}{dR}\right] \qquad \text{(A12)}$$

Re-arranging the terms inside the bracket yields:

$$Lf\left[1 + \frac{Rf'}{f}\frac{dL}{dR} + \frac{R}{L}\frac{dL}{dR}\right] \qquad \text{(A13)}$$

If this term is positive, then equation (A11) will also be positive. Let $\varepsilon_{LR} = (R/L)(dL/dR)$, the elasticity of input levels with respect to a change in risk. Then,

$$Lf\ \frac{Rf'}{f}\frac{dL}{dR} + Lf(1 + \varepsilon_{LR}) \qquad \text{(A14)}$$

The first term is positive; a sufficient condition for the second term to be positive is that the elasticity be less than one. In this case, the change in total externalities will decrease with increases in risk.

APPENDIX 3

Descriptive Statistics for Ethiopia, Niger, and Burkina Faso

Table A3.1 Descriptive statistics, Ethiopia

Variable	Mean	Standard deviation	Minimum	Maximum
Endogenous				
Stock density (TLU/total ha)	.91	.65	.10	2.92
Stock density (TLU/pasture ha)	1.03	1.24	.15	3.95
Land in private pastures, proportion	.09	.08	0	.46
Land in crops, proportion	.15	.15	0	.60
Climate				
Average rainfall	599	167	353	873
Coefficient of variation of rainfall	.38	.11	.21	.68
Rainfall in 1996	586	186	344	802
Cooperation: indicators				
Number of meetings per year	37	23.4	6	114
Proportion of households attending (average)	39	33	4	100
Sum of grazing rules	1.8	.97	0	4
Sum of water-related rules	2.1	.70	1	3
Sum of settlement and cultivation rules	1.2	.66	0	2
Violations: grazing rules	5.7	10.3	0	50
Violations: water rules	1.5	2.2	0	9
Violations: settlement and cultivation rules	7.0	14.5	0	70
Cooperation: determinants				
Total number of households	71	66	8	297
Coefficient of variation of livestock holdings	2.4	1.6	.83	9.0
Proportion of households with migrant worker	25	36	0	100
Use of community pastures by outsiders (dummy)	.61	.50	0	1
Herd mobility (dummy)	.82	.39	0	1
Production/profitability/demographic				
Range quality index	3.6	1.2	2.1	5.7
Relative livestock:grain price ratio index	.84	.19	.69	1.28
Distance to market (km)	41	29	5	120
Total land area (ha)	1,105	567	249	3,035
Population density (households/ha)	.08	.10	.01	.58
Years cultivating	12	13	0	60
Practice haymaking (dummy)	.29	.45	0	1

Table A3.2 Descriptive statistics, Niger

Variable	Mean	Standard deviation	Minimum	Maximum
Endogenous				
Mobility (proportion of year)	.14	.18	0	.53
Stock density (TLU/total ha)	.72	1.13	.01	4.02
Stock density (TLU/pasture ha)	1.08	1.61	.04	7.44
Proportion of land in crops	.33	.16	.09	.42
Climate				
Average rainfall	498.23	90.68	335.70	649.81
Coefficient of variation of rainfall	.23	.06	.08	.37
Rainfall in 1996	567.05	109.18	429.75	750.83
Cooperation				
Total number of households	99.51	70.40	20.00	307.00
Coefficient of variation of livestock holdings	1.18	.83	.25	4.50
Coefficient of variation of millet yields	.33	.36	.08	2.22
Number of ethnic groups	1.62	.89	1.00	4.00
Proportion of households not of ethnic majority	.05	.11	0	.42
Proportion of households with migrants	.48	.20	.06	.83
Use of community pastures by outsiders in rainy season (number of animals)	590.37	1,151.29	121.00	4,050.00
Use of community pastures by outsiders in dry season (number of animals)	128.32	350.58	0	1,800.00
Transhumant herd sizes	2,408.92	3,600.00	0	10,000.00
Production/profitability/demographic				
Range quality index	1.49	.69	0.01	2.73
Relative livestock:millet price ratio	1.31	.24	.87	1.60
Distance to market (km)	32.68	22.64	1.00	79.00
Total land area (ha)				
Population density				
Agricultural assets per household	.29	.28	0	1.42
Schools, shops, transportation infrastructure	.76	2.02	0	9

Table A3.3 Descriptive statistics, Burkina Faso

Variable	Mean	Standard deviation	Minimum	Maximum
Endogenous				
Stock density (TLU/total ha)	.71	.95	.05	4.00
Stock density (TLU/pasture ha)	.44	.67	.04	3.60
Proportion of land in crops	.39	.22	.06	.90
Herd mobility	.15	.19	0	.67
Climate				
Average rainfall	467	64	397	555
Coefficient of variation of rainfall	.16	.01	.14	.17
Rainfall in 1996	610	58	544	703
Cooperation: indicators				
Network NRM	4	2.1	1	11
Membership NRM	.76	.23	.34	1.13
Network others	3.2	2.2	0	9
Membership others	.28	.29	0	1
Number of meetings	6	4.3	2	25
Number of activities	2.7	1.8	0	7
Number of rules	3.6	.94	2	6
Participation in meetings	.53	.22	0	1
Participation in work	.52	.22	0	1
Cooperation: determinants				
Total number of households	91	56	14	280
Coefficient of variation of livestock holdings	2.5	1.5	.49	7.64
Proportion of households with migrant workers	.24	.16	0	.59
Transhumants (dummy)	.5	.5	0	1
Number of ethnic groups	3.3	1.7	1	8
Production/profitability/demographic				
"Richest" soil (*bolaare*) dominant (dummy)	.38	.5	0	1
Relative livestock:grain price ratio index	2.33	.15	2.1	2.6
Distance to market (km)	23	36	0	196
Total land area (ha)	3,070	2,181	586	9,058
Population density	.04	.04	.01	.20
Proportion of households with at least one member with public schooling	.07	.11	0	.54
Dominant ethnic group: agriculturalist	.48	.50	0	0

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