4

The Dry and the Drier

Cooperation and Conflict in Moroccan Irrigation

John R. Welch

Successful reconstructions of human social evolution and plans for the future of an overpopulated globe depend, at least in part, on understanding stress and the patterns of conflict or cooperation it provokes. In this chapter I examine a stress familiar to agrarian populations in arid regions—water scarcity—as it is dealt with in four irrigation systems in the geographically unified, but ecologically and culturally diverse region surrounding the central Moroccan town of Sefrou (figure 4.1). The region's ethnographic records document irrigation strategies ranging from traditional, communally owned systems in the relatively wet, but infertile mountains, to larger, market-oriented systems fraught with competition over water. Responses to water deficits in the four systems appear to vary with the frequency and intensity of the stress, and cooperation is as common a response as conflict. These findings support a critique of Geertz's (1972) classic comparison of irrigation in Bali and Morocco, "The Wet and the Dry," wherein the author asserts that "agonistic individualism" is a Moroccan "cultural presupposition," an invariant aspect of the nation's human interaction that derives from water scarcity (this claim is expanded in subsequent work by Geertz, Geertz, and Rosen 1979 and Rosen 1984).

Beyond criticizing Geertz, I examine the structure of the Sefrou drought response. In the descent from the smaller, wetter upland systems to the larger, drier lowland fields, increasing water scarcity causes greater competition until, in the lowest and driest system, cooperation reemerges as a dominant theme in stress mitigation and water use. Beyond the descriptive level, these patterns of unselfish cooperation and entrepreneurial competition appear to be structured hierarchically. Increasingly severe stresses provoke riskier and more costly responses; higher order attempts at stress mitigation tend to limit the effectiveness of lower-order responses. Each step up the hierarchy of response options carries exposure to new risk along with the promise of stress reduction. The concept of hierarchical response to living system perturbations developed in Slobodkin's (e.g., 1968) work provokes consideration of the temporal stability of

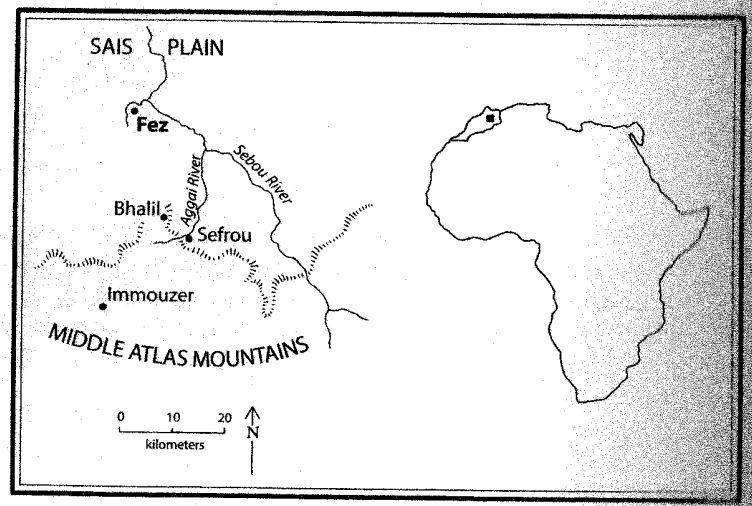

Figure 4.1 Location of the Sefrou region, Morocco.

agrarian adaptations to arid regions. The severe decline in Moroccan food production that accompanied the recent drought (1981–1984) increases the study's "real world" relevance. Ethnographic and archaeological research into the range and effectiveness of drought-coping mechanisms in arid lands' irrigation systems is needed.

The ecological and evolutionary framework adopted in this study differs from valuable work by Pascon (1977), Bouderbala et al. (1984), Hammoudi (1985), and Mahdi (1986). These analyses of the allocation of critical resources in irrigation systems point to economic and political histories as the primary determinants of behavior patterns. Data for a comparable analysis of the Sefrou region have not been obtained.

Sefrou Agrarian Ecology

The Sefrou region's environment is "characterized by a highly irregular and uncertain set of climatic conditions and a wide variety of microenvironments" (Geertz et al. 1979:8; see table 4.1). There are about 200 frost-free days at 1500 meters above sea level. Annual precipitation ranges from 300 to 1100 millimeters and occurs mostly from November through April.

Table 4.1 Environmental characteristics of the Sefrou region, Morocco.

	Mountains	Piedmont	Lowland plains
Elevation	1100–2500 meters	500–1100 meters	100–500 meters
Hydrology	Abundant surface water in springs, streams, lakes	Numerous, irregularly spaced springs	Surface water confined to numerous wadis, a few perennial streams
Settlement	Hamlets and camps near water, pasture	Villages and camps around oases and shrines	Towns and villages along water courses
Land Use/Users	Transhumant Berber pastoralists supplement economy with dry and irrigated cereal farming	Settled Berber pastoralists and irrigated agriculturalists with limited dry farming; some Arab population	Irrigated horticulture, some dry farming; urban markets; ethnic diversity
Limitations	Less than 1/5 of land arable; stony soils	Variable stream and spring flow; soils stony in places	Variable stream flows; socio-political factors
System	Ait Sidi Musa	Ain Sultan	Sefrou and Lower Aggai

midsummer is sometimes totally dry. The marked spatial, seasonal, and interannual variation in rainfall that Geertz identifies as the source of the confrontational nature of Moroccan socioeconomic intercourse is apparent (see also Kacemi 1992).

Social Patterns

The town of Sefrou occupies an escarpment that separates the lower piedmont from the wetter, upland plains and the zone of Berber domination

from that of government control (Vinogradov 1974:38). Berber farmer-pastoralist economies dominate the piedmont and mountains. Some Berbers, along with Arabs, Jews, and Europeans, mingle in the more populous, fertile, economically specialized, and arid lowlands. Most of this discussion focuses on Berber ecology, but Arabs and others also participate in lowland irrigation. The two Berber subtribes examined here, the Ait Yusi (population 60,000 in 130 villages) and the Ait Mguild (population 74,000), are territorial groups with segmentary, patrilineal-patrilocal organization (see Chiapuris 1979; also Vinogradov 1974; Miller 1984).

Chiapuris (1977, 1979:58, 63) sees a Middle Atlas Berber unity derived from linguistic, cultural, and environmental commonalities and a previous concern with territorial defense.[1] Changing boundaries between groups serve to adjust populations to local resources, especially farmland and pasture (Chiapuris 1979:37). Kinship remains important in determining group affiliation, but membership today is more open. Territorial borders, once closely monitored and hotly contested, now change constantly with governmental decrees and private land transactions (Rosen 1979:24).

Agricultural Patterns

The people of Sefrou make a living through a combination of goat and sheep pastoralism, market and subsistence farming, and some manufacturing and trading. Agriculture has expanded in the last century as pastoral transhumance has been constrained by governmental policies and environmental degradation (Chiapuris 1979). The Ait Mguild cultivated 7,300 hectares in 1936; by 1950, this figure had grown to 33,500 hectares (Raynal 1960:305).

Four classes of agricultural land are found in the area: irrigated fields, dry plowlands, pastures, and less productive "no man's lands" separating Berber territories (Chiapuris 1979:68). Wheat is the staple crop, but a wide range of grains and vegetables is cultivated. Lowland plots are typically worth more than highland fields of the same size because of their easier access to markets, deeper soils, and longer growing seasons. Similarly, because irrigated fields can be planted more frequently and produce good harvests more reliably than dry upland farms, the former are typically worth at least twice as much. Shorter fallow cycles are possible on irrigated land due to nutrients brought by irrigation, fertilizers introduced using movable corrals, and to more common intercropping. The impossibility

Table 4.2 Estimated seed inputs and yields (kg/ha) in the Sefrou region, Morocco.

		Lowlands				Highlands			
		Irrigated fields		Dry fields		Irrigated fields		Dry fields	
Crop	Seed input	Yield	Ratio	Yield	Ratio	Yield	Ratio	Yield	Ratio
Hard wheat	90	540	1:6	360	1:4	630	1:7	450	1:5
Soft wheat	90	540	1:6	540	1:6	630	1:7	450	1:5
Barley	92	525	1:5	735	1:7	525	1:5	420	1:4
Maize	44	315	1:7			270	1:6		
Average		400	1:6	545	1:5.7	514	1:6.25	440	1:4.7

Source: Data from Boyle 1977:121–127; see also Chiapuris 1979:75.

of dry field double cropping means that—holding field size constant—wet fields commonly produce at least twice as much per year.

Boyle's (1977) study of the Ait Mguild illustrates patterns in Berber land tenure and transhumant cultivation. Table 4.2 describes the two cultivated territories of the Aït Sīdī Musa clan. Only six of the thirty households that Boyle studied had irrigated land at the clan's lowland farms; twenty-seven had irrigated fields in the highlands. Poorer households had less total land and, proportionally, even less irrigated land. Furthermore, smaller landholders used shorter fallow cycles.

Even discounting irrigation system construction costs, labor input for irrigated fields is far greater in comparison to labor required in dry land farming. Dry fields need few water management inputs, receive less fertilizer, and are tilled less. Wheat, fava bean, and lentil seed are broadcast on dry fields prior to a second plowing. Dry barley fields are plowed only after broadcasting. Irrigated fields destined for maize, chickpeas, or wheat are preplowed. On lowland farms, where vegetation invades fallow lands more quickly than in the highlands, additional labor is required for plowing and weeding. The last notable difference in labor inputs is that farmers must descend periodically from summer herding camps to weed, water, and harvest lowland irrigated fields.

For a given harvest, the yields from wet and dry fields may be comparable. The critical difference is that the irrigated farms can be planted soon after harvest and be expected to produce equally consistently without fal-

low. Yields from dry fields drop precipitously when the soil is not rested. Interestingly, Berber farmers' reliance on irrigated lowland farms seems to have occurred in the absence of absolute land shortages. Instead, this form of labor intensification may buffer circumscribed pastoralists against social and climatic uncertainty.

Irrigation Patterns

Two distinct types of water distribution are used in the Sefrou region (see Geertz 1972:34). In the *mubīh* or "queue" distribution system, water and land are inseparable (see Glick's Syrian type; 1970:230). A landholder's water right is derived from kinship, and cannot be transferred independently of land. Nor can the right holder's place in the queue be used to irrigate another plot. This inflexibility permits no commerce in land and water as separate commodities, thus encouraging continuous, intensive plot cultivation.

The second approach, *l-māa' bi-sāà* (water by the hour) is comparable to Glick's (1970) Yemenite type of irrigation and appears more attuned to market forces. Rights to the water source for a specified period are held separately from land and may be transferred (through purchase or loan) for use on any plot. The volume delivered is a function of water flow over the time owned, and farmers engage in entrepreneurial maneuvering to obtain sufficient water, especially during droughts. Field condition (i.e., degree of desiccation) is only considered in l-māa' bi-sāà distribution when water is abundant. In contrast, in queue systems, the length of time a landholder has access to water is dependent on the flow volume and the size and condition of the plot. Right holders at the head of the queue are, especially in dry years, in an enviable position to monopolize the irrigation flow.

Four Sefrou Irrigation Systems

With this information as background, each system's organizational and technical means for capturing and allocating water and for coping with shortages can now be examined. Table 4.3 summarizes the four systems, arranging them from dry to driest, from highest in elevation to lowest, and from relative socioeconomic homogeneity to heterogeneity.[2]

Table 4.3 Characteristics of four irrigation systems of the Sefrou Region, Morocco.

	Ait Sidi Musa	Ait Sidi Lahcen	Sefrou Oasis	Lower Aggai
Precipitation	dry (1100 mm)	—	—	driest (200 mm)
Elevation	high (1300 m)	—	—	lowest (500 m)
System size	smallest (147 ha)	large	largest (625 ha)	large
Source	stream	springs	Aggai River	Aggai River
Distribution	queue	timed	combination	combination
Market role	minimal	olives only	primarily cash	vegetables
Cash crop	crops (vegetables)	olive trees		
Population	low	medium	highest	high
Settlement	camps	village around springs and shrine	Sefrou (30,000)	villages outside of Sefrou
Land and water	inalienable: kinship-based	alienable: based on fictive kinship	alienable: bought and sold	alienable: bought, sold, and shared
Authority	1 part-time jārí	1 full-time jārí	5 full-time jārí	2 full-time jārí
Social diversity	lowest	—	—	highest
Disputes	rare	occasional	constant	common

Upland Irrigation Systems of the Ait Sidi Musa Clan

About half of the Sidi Musa clan's highland farms are irrigated with simple ditches leading from permanent streams. Irrigation is preferred, but most families also dry farm. Water distribution involves breaching one of the shallow ditches to allow water to run down cultivated slopes. Boyle (1977: 122) estimates that 30 to 40 percent of the flow is wasted through inefficient distribution, but notes that there is enough water to meet most needs in most years.

Informal associations of farmers using particular ditches administer the Ait Sidi Musa system. The size of the associations ranges from four to twelve farmers, depending on ditch length. The group selects an irrigation chief (*jārí*) from the membership. The jārí should reside near the ditch and be respected, energetic, and judicious. In addition to his own farming, the jārí delegates maintenance tasks, supervises water distribution, and mediates disputes. If jārí mediation is unsuccessful, lineage elders, the tribal council, and—if the conflict remains unresolved—Morocco's civil authorities and regional and appellate courts may be called upon in turn. This is the first example of hierarchical response to stress. The means for dispute resolution can be seen as a series of increasingly costly and risky responses to persisting problems.

Sultan's Spring (Ain Sultan) Irrigation System

The second system is lower and slightly drier. The Ain Sultan spring is the water source for the approximately 400 households that make up the village of Sidi Lahcen. Each household relies on an average of 2 hectares of dry and 1 hectare of irrigated land. Rosen (1979:31) observes that "most of the villagers attempt to keep three or four separate plots. . . . This distributes the risk of crop failure over several microecological niches." The size and quality of the plots are, in general, evenly distributed among the households.

Irrigation is the foundation for the Sidi Lahcen economy. Most subsistence crops are dry-farmed, but the 20,000 olive trees—the primary source for cash—depend on irrigation: "Practically all the trees and land at Sidi Lahcen are private property. . . the olive crop is essential for the purchase of goods from outside the valley" (Rosen 1979:31). The Sultan's spring is led to fields by a 6-kilometer ditch. The l-māa' bi-sāà distribution cycles through ten sixteen-hour days and twelve eight-hour nights. Turns in the cycle may be as short as fifteen minutes, and water must be available for the next user when the turn ends. That the allocations are timed in a fixed cycle suggests the evolution of "water by the hour" distribution from a queue type of system.

Negotiations to minimize water movement between plots and to assure prompt delivery are continuous. The haggling employs a vocabulary based on farmers' putative genealogical links to the village founders—the developers of the irrigation system. Four of the ten named days are

reserved for alleged founder descendants in upper villages, two days for descendants living in lower villages, and four for lineages lacking ties to founders. Each of these days is further partitioned by clan and family membership. Rosen (1979:33) notes that this "conceptual system projects an overarching level of relatedness . . . that serves to order the basic structure of the irrigation system at the same time it allows maximal adjustment to ecological, political, and personal necessity."

When there is consensus to begin the summer's irrigation, the water holders meet, elect a jārí, and establish a starting point for the delivery sequence by lottery. Each water right holder is responsible for maintaining a stretch of the primary ditch proportional to his water rights. Land holders lacking irrigation rights have no maintenance duties. Because unirrigated land produces little in most years, water assets are, figuratively as well as literally, perceived as more liquid—and thus more valuable. The dispute resolution hierarchy is similar to that described for the Sidi Musa system.

Town of Sefrou Irrigation System

Lower and drier still is the Sefrou Oasis system. The five primary canals leading from the Aggai River in 1955 irrigated 1260 plots (Rosen 1979:115, 118). Each canal feeds a discrete set of fields and is administered separately. Both land and water are privately, rather than communally, held. The five irrigation chiefs are appointed by the Sefrou pasha and are occupied full-time from March through October managing ditch maintenance, the blend of timed and queue distribution, and frequent disputes over flow allocation. Unlike jārí for the two upland systems, these men have legal authority to settle disputes, delegate maintenance tasks, and impose penalties for deviations from established procedures. For these reasons, and because they are responsible to the pasha, these jārí are accorded greater deference than in the uplands, and often use this status to their advantage in other social and economic domains.

Individual plots receive what their owners (and whoever feels like contributing an opinion) consider a thorough watering in a mubīh cycle, but the river is allocated to each primary canal by the hour, using a l-māa' bi-sāà variant. Water shortages prompt greater interest in allocation by the individual farmers and subject jārí decisions to increasingly thorough scrutiny. Perhaps because of social heterogeneity and market penetration, the Sefrou irrigation system contains few kinship-based sources of organi-

zational variability. This feature of the Sefrou system accounts for the observation that, despite a reliable water supply, "disputes are common and quite heated" (Rosen 1979:61): "An overall moral and legal code serves as the context in which individuals contract and contend with one another, adjusting their personal needs more through direct confrontation—a kind of agonistic individualism—than through elaborately constructed group relations."

Unresolved disputes may be brought up at plot owners' meetings. If the dispute persists or escalates, an honored elder may mediate. Continuing dissension may then be taken, in turn, before the Sefrou pasha, the local civil governor, and the regional and national courts. Each step up this hierarchy brings greater public attention and increased potential losses of local autonomy and individual status.

The Lower Aggai Irrigation System

Below Sefrou the dwindling and increasingly saline Aggai River is virtually consumed by three more canals. Because of flow unreliability, all water is directed to the largest of the three canals (Al-glet) one year and divided between the two smaller canals (Beni Mansour, Dar Attar) in alternating years. Cash-economy forces are apparent: Olive trees must be irrigated at least enough to sustain them through years when their owners lack irrigation rights. Plots on the canal with rights in a given year are typically planted in maize and vegetables; hardy cereals are planted in plots slated to be dry. Farmers with irrigation rights during drought years can realize large profits on scarce, and, therefore, lucrative garden crops. These factors encourage efficient use of the meager flow by farmers with rights for the year.

Mubīh distribution is the rule, but important exceptions occur. During wet years, when the two smaller canals share the flow, Dar Attar receives two-thirds of each day's water, Beni Mansour the remaining third. Similar partitioning occurs on the Al-glet canal, with secondary ditches receiving proportionally smaller allocations. Compared to the other three systems, the more prevalent water scarcity in the Lower Aggai system means less reliable harvests. Farmers cope with this by constantly adjusting the timing of irrigation, relaxing the alternating legal prerogative to the river, regularly sharing scarce water, and stooping to elaborate forms of deceit and theft (Rosen 1979:121–122).

Cooperation, Conflict, or Combination?

Geertz's comparison of Balinese and Moroccan irrigation ecology concludes that, "As a chameleon tunes himself to his setting . . . a society tunes itself to its landscape. . . To connect the restless irregularity of much of Moroccan life, the tense expectancy and the aggressive opportunism of it, to the uncertain, capricious climate is not, therefore to yield to vulgar materialism, for it is in part that climate that projects the aura of irregularity and tension" (Geertz 1972:38). Reminiscent of "national character" studies by Mead and Benedict, Geertz's poetic notion that "agonistic individualism" derives from Morocco's aridity glosses over the links among social and environmental variables. In so doing, Geertz (1972:37) disregards his own good advice (1972:37): "environment is but one variable among many. . . . And it is one whose actual force must be empirically determined, not a priori declaimed." With interpretation as both the point of departure and the destination for Geertz's study, there is no appeal to epistemological principles (see also Netting 1982; Foster 1986). Furthermore, the assertion that an entire culture is basally eristic could be construed as racist.

Cooperation in Sefrou Irrigation

"The necessity for an ordered, predictable system of water allocation has divisive as well as cohesive potentialities" (Millon, Hall, and Diaz 1962: 513). Water scarcity can and does foster both cooperation and conflict in irrigation systems (see Maass and Anderson 1978; Bolin 1990), and the four systems discussed here are exemplary in this regard. Geertz and Rosen, however, focus on the discordant effect of insufficient water and imply that conflict should increase as water grows scarce.

Long-term studies of individual systems are required to fully assess this idea, but the comparisons drawn here offer some insights. Water scarcity and conflict increase concomitantly through the first three systems. But competitive behavior peaks (in the Sefrou oasis) before the low point of water scarcity (Lower Aggai) is reached. It is in the most drought-prone system that cooperation resurfaces. Competition remains fierce in some Lower Aggai arenas, but it cannot escalate without the loss of valuable olive trees. Because the Lower Aggai olive trees require summer irrigation merely to survive, farmers from the division slated to be dry for a particular summer rely on the year's wet division to relax their rights to

the entire flow. If one division asserted their prerogative, they could expect the same treatment during the next drought. The olive trees would go thirsty; some would die, and no one would be richer or wiser for having exercised their rights.

Also central to the Geertz and Rosen arguments is the assumption that water is treated as a commodity throughout Morocco. Geertz (1972:36) asserts, "private ownership of water is the organizing principle, a principle developed to levels of legal complexity which stand in marked contrast to the technical simplicity of the actual system." Because Geertz provides few historical or political data to support this argument (cf., Geertz 1963), the attribution of agonistic individualism to privatization is unconvincing. Another problem in this regard is that neither Geertz nor Rosen consider the implications of mubīh distribution, in which individual's irrigation rights are usufruct and water and land are inalienable. Mubīh is the rule in the highest system, where self-promoting maneuvers are discouraged through collective water ownership. The land is owned by individuals, but is virtually worthless without water. Irrigation rights are unavailable to farmers who fail to fulfill obligations to the collective. The Lower Aggai system indicates that queue-type allocation can serve diverse individual and collective goals even in a large system.

Cooperation rather than individualism prevails in all successful irrigation systems (Lees 1989; Bolin 1990), and a consideration of the many forms of cooperation central to Moroccan irrigation further challenges Geertz's lax methods and interpretive conclusions. In Sefrou, communal crop harvesting and transport, irrigation facility maintenance, and religious brotherhoods create multidimensional ties between individuals (for another Moroccan example, see Herzenni 1994). These ties supplement kinship links in systems that might be considered more traditional; they replace or coopt blood relationships in social contexts less structured by kinship.

Even as farmers retreat from kinship-based cooperation, economic relations (even those between members of unrelated clans) continue to be processed through a kinship idiom (see Boyle 1977). Lineage, religious, and tribal affiliations persist as significant determinants of patterns of economic interaction and land ownership in the Sefrou region, especially in circumscribed oases and pastures. Furthermore, economic gains invariably radiate along ties based on such affiliations. There are noncontractual, status-based aspects of all of these interpersonal ties, and these relationships help to define cooperative and competitive responses to water scarcity and other stresses. Competition is but one side of Sefrou irrigation, one perspective on a complex situation. Agonistic individualism may be only the most striking aspect (to an outsider) of the region's socioeconomic process. Geertz rightly considers water scarcity as a powerful determinant of patterns in behavior and world view, but his failure to examine cooperation and other possible determinants invites criticism.

Ecology, Evolution, and Adaptive Response

Regardless of their focus on material conditions, symbol systems, or other factors influencing behavior, anthropologists' conclusions should be well grounded in empirical data. Geertz's interpretive approach *assumes* adaptation in its search for webs of meaning. In contrast, ecological and evolutionary approaches generally avoid submerging empirical observations in the murk of semantic coherence. Such positivist studies grapple with the complex present—often in pursuit of information useful in inferring aspects of past behavior or discerning future needs (see Raikes 1967). People do not live by the integration of their symbolic structures alone, and it seems reasonable to request that understanding and promoting adaptation be given priority over elegant interpretive excursions (see Netting 1982).

The concept of adaptation is common ground for ecological and evolutionary anthropology. Slobodkin's (1968:202) definition of adaptation—a living system is adapted to the extent that it maintains homeostasis in response to stresses (selective pressures) without sacrificing the capacity to respond to subsequent stresses—brings static ecosystems into the evolutionary realm of selective pressures and differential survival. Slobodkin's predictive theory of adaptation holds that organisms faced with growing (or undiminishing) stress will employ more costly responses. This framework provides both theory and method for analyzing stress response (see Minnis 1985).

The Sefrou data constitute an appropriate case for applying Slobodkin's framework for at least three reasons. First, water availability is a significant problem. Precipitation shortfalls result in poor harvests for that year and can seriously deplete the groundwater reserves upon which subsequent harvests depend (Kacemi 1992). Second, irrigation is central to Morocco's food supply and to the long-term success of individuals, households, and communities. Farmers surveyed by Boyle (1977:149) "claimed

a twofold to threefold difference in yields on irrigable land between good and bad years, a fivefold to sixfold difference on dry land." Although groundwater-based irrigation systems (e.g., Ain Sultan) are preferred due to greater resistance to drought, most systems rely on the less predictable surface flows. Third, each of the four Sefrou systems includes hierarchical structures for response to water scarcity. Drought-resistant cultigens are planted. Smaller amounts of land are plowed and seeded. Water may be stored "in the soil" by avoiding tillage. Water capture and delivery efficiency are enhanced by cleaning canals and springs, building higher and sturdier banks to curb losses to evaporation and infiltration, or irrigating through the night. The length of turns can be more closely monitored or decreased across the board. Rosen (1984:63–65) even describes a hierarchy of prayers employed to deal with water scarcity. The sequence runs from everyday preemptive requests, through stronger cycles to interrupt dry spells, and into religious petitions so forceful that the people recognize the risk that destructive floods, rather than healing rains, may answer their appeals.

When these responses to water scarcity fail, elaborate forms of theft and deceit may emerge; increasingly formal and institutionalized means of conflict resolution may be called upon. Such a cycle of escalating responses to stress may eventually entail radical and irreversible social alteration. Each of the Sefrou systems includes means for mediating disputes over land and water, first by individuals, then by jārí, then by local notables and authorities, and finally by regional and national courts. These variations on the hierarchical response theme underscore the wide range of options available to farmers concerned with water scarcity. From this perspective, the Sefrou systems seem generally well adapted in terms of their stress-coping capacity.

Hierarchical Response and Differential Survival

Prolonged drought is clearly among the many challenges separating sustainable strategies from those less well-adapted. Documenting the variable effectiveness and resilience of subsistence strategies where water scarcity is a primary limiting factor contributes insight into the development of human economic strategies and our ability to feed growing populations in arid lands. Anthropologists need better techniques for understanding

the evolutionary bottlenecks that Weins (1977) calls "crunch periods," and Slobodkin's (1968) concept is one promising avenue.

The Moroccan data indicate the utility of hierarchical response for organizing and comparing information on irrigation systems and suggest the potential benefits of expanding the analysis through ethnographic and archaeological studies. As analytic units, irrigation systems are superior to villages because of the clear connections to soil, climate, hydrology, technology, and social groups (Brunhes 1902; Kelly 1983). Ties to conflict and risk management structures are also apparent, particularly in arid lands (see Steward 1955; Lees 1974; Hunt and Hunt 1976).

A detailed study of irrigation system responses to water scarcity might profitably employ a Slobodkin framework for data collection and analysis. The results of long-term fieldwork could be integrated with information on variations in climatic, hydrological, and technological factors. Collecting detailed data on the magnitude, duration, and frequency of water scarcity, along with the costliness, effectiveness, and implications of responses would refine and quantify definitions for variables central to Slobodkin's theory.

Such an analysis of irrigation ecology would be valuable for several reasons. First, if Slobodkin's approach proves useful, anthropology would benefit from a definition of adaptation that integrates ecological and evolutionary approaches appropriate for analyses on a human scale. Second, because irrigation systems are material representations of social institutions and behavior patterns, archaeologists involved in their study could expand and strengthen inferences about ancient institutions and behaviors. Even acknowledging the importance of historical depth in analyses of irrigation systems, a vast gap remains between the pressing need to study the differential success of agrarian strategies and the scattered scraps of crockery, cutlery, and architecture that make up the archaeological record. We know little about the demographic, economic and organizational information encoded in irrigation system layout and technology. Bridging this gap will entail carefully focused fieldwork with living, functioning irrigation systems—irrigation ethnoarchaeology: "There is a great need for mapping present day systems . . . and relating to them the social systems concerned. . . . Having done that, it should be possible to determine whether a social organization receives its essential structure from factors outside irrigation needs" (Downing and Gibson 1974:x–xi).

Archaeology could, through this type of research, contribute to the study of sustainable adaptation, thus distancing the discipline from an earlier, more academic and antiquarian preoccupation with the splendors of ancient civilizations. Long-abandoned systems could provide cautionary tales as well as innovative strategies for dealing with nagging problems of fluctuating food and water supplies. In light of the severe drought that crippled North African agriculture in the early 1980s, research into extant irrigation systems should be tailored to complement development programmers' repertoire of technological and organizational strategies (Stockton 1988).

Concluding Thoughts

Irrigation agriculturalists have long attracted social scientists equipped with diverse methods, theories, and goals. This chapter has argued for the potential and need for research focused on the ecology and evolution of arid land agricultural systems. This focus, unlike the interpretive approach critiqued here, promises to help us to improve life where drought constitutes a prominent hazard. Too seldom are ecosystemic intricacies studied in conjunction with information on selective factors and adaptive responses in tightly defined behavior systems. This comparison has demonstrated the complexity—abstracted to the point of oversimplification by Geertz—of Sefrou irrigation. Slobodkin's theory of hierarchical response to stress has been useful in examining the Sefrou systems and merits further operationalization. The collection of quantified data on water scarcity and irrigation system coping mechanisms are appropriate directions for irrigation research in Morocco and elsewhere. The causes and consequences of variability in stresses and responses in living systems must be studied as a baseline for tracking the course of human socioeconomic evolution. Even if the data collected are inconsistent with Slobodkin's theory, the resulting technical and analytical methods will help to integrate ecological and evolutionary approaches.

Acknowledgments

This chapter is the result of research initiated in a 1986 cultural ecology seminar at the University of Arizona. The author is deeply indebted to the seminar leader, Bob Netting, and dedicates this work to the memory of this superb scholar and human being. Carol Kramer, Tad Park, and Jonathan Mabry also provided useful comments on earlier versions of the chapter.

Notes

1. The antiquity of communal land tenure and its ties to "traditional" as opposed to market-oriented economies are mentioned several times in this chapter, but these issues are too complex to address adequately here (for historical background see Gellner and Micaud 1972).

2. The uneven quality of the data employed will not support quantitative comparison of the four systems' productivity and sensitivity to climatic variation.

References Cited

Bolin, Inge
1990 Upsetting the Power Balance: Cooperation, Competition and Conflict along an Andean Irrigation System. *Human Organization* 49:140–48.

Bouderbala, N., J. Chiche, A. Herzenni, and Paul Pascon
1984 *La Question Hydraulique.* Rabat: Institut Agronomique et Veterinaire Hassan II.

Boyle, Walden P.
1977 *Contract and Kinship: The Economic Organization of the Beni Mguild Berbers of Morocco.* Ph.D. dissertation, University of California, Los Angeles. Ann Arbor: University Microfilms International.

Brunhes, Jean
1902 *L'Irrigation: Ses Conditions Geographiques, ses Modes et son Organisation.* Paris.

Chiapuris, John Paul
1977 *The Ait Ayash of the Central Atlas: a Study of Social Organization in Morocco.* Ph.D. dissertation, University of Michigan. Ann Arbor: University Microfilms International.
1979 *The Ait Ayash of the High Moulauya Plain: Rural Social Organization in Morocco.* Anthropological Papers of the Museum of Anthropology No. 69. Ann Arbor: University of Michigan.

Downing, Theodore E., and McGuire Gibson
1974 Preface. In *Irrigation's Impact on Society,* ed. T. E. Downing and McG. Gibson, ix–xi. Anthropological Papers No. 25. Tucson: University of Arizona Press.

Foster, S. W.
1986 Review of *Bargaining for Reality. American Anthropologist* 88: 206–8.

Geertz, Clifford
1963 *Agricultural Involution: The Processes of Ecological Change in Indonesia.* Berkeley: University of California Press.
1972 The Wet and the Dry: Traditional Irrigation in Bali and Morocco. *Human Ecology* 1:23–39.

Geertz, Clifford, Hildred Geertz, and Lawrence Rosen
1979 *Meaning and Order in Moroccan Society.* New York: Cambridge University Press.

Gellner, Ernest, and Charles Micaud (eds.)
1972 *Arabs and Berbers: From Tribe to Nation in North Africa.* Lexington, Mass.: Lexington Press.
Glick, Thomas F.
1970 *Irrigation and Society in Medieval Valencia.* Cambridge: Harvard University Press.
Hammoudi, Abdellah
1985 Subsistence and Relation: Water Rights and Water Distribution in the Dra'a Valley. In *Property, Social Structure and Law in the Modern Middle East,* ed. A. Mayer, 27–57. Albany: State University of New York Press.
Herzenni, Ahmed
1994 *The Cultural Economy of Technical Innovation in Semi-Arid Rural Morocco.* Ph.D., University of Kentucky, Lexington. Ann Arbor: University Microfilms International.
Hunt, Eva, and Robert C. Hunt
1976 Canal Irrigation and Local Social Organization. *Current Anthropology* 17:389–411.
Kacemi, Mouloud
1992 *Water Conservation, Crop Rotations, and Tillage Systems in Semiarid Morocco.* Ph.D. dissertation, Colorado State University, Fort Collins. Ann Arbor: University Microfilms International.
Kelly, William
1983 Concepts in the Anthropological Study of Irrigation. *American Anthropologist* 85:880–86.
Lees, Susan H.
1974 Hydraulic Development as a Process of Response. *Human Ecology* 2:159–75.
1989 On Irrigation and the Conflict Myth. *Current Anthropology* 30:343–44.
Maass, Arthur, and Raymond L. Anderson (editors)
1978 *. . . and the Desert Shall Rejoice: Conflict, Growth, and Justice in Arid Environments.* Cambridge, Mass.: MIT Press.
Mahdi, Mohamed
1986 Private Rights and Collective Management of Water in a High Atlas Berber Tribe. In *Proceedings of the Conference on Common Property Resource Management, 1985,* 181–97. Washington, D.C.: National Academy Press.
Miller, James A.
1984 *Imlil: A Moroccan Mountain Community in Change.* Boulder, Colo.: Westview Press.
Millon, René, Clara Hall, and May Diaz
1962 Conflict in the Modern Teotihuacan Irrigation System. *Comparative Studies in Society and History* 4:394–521.
Minnis, Paul E.
1985 *Social Adaptation to Food Stress.* Chicago: University of Chicago Press.
Netting, Robert McC.
1982 The Ecological Perspective: Holism and Scholasticism in Anthropology. In

Crisis in Anthropology, eds. E. Adamson Hoebel, R. Currier, and S. Kaiser, 271–92. New York: Garland Press.
Pascon, Paul
1977 *Le Haouz de Marrakech,* 2 vols. Rabat: CURS; Paris: CNRS.
Raikes, Robert
1967 *Water, Weather, and Prehistory.* London: John Baker.
Raynal, Rene
1960 La Terre et l'Homme en Haute Moulouya. *Bulletin Economique et Social du Maroc* 24(86–87):281–346.
Rosen, Lawrence
1979 Social Identity and Points of Attachment: Approaches to Social Organization. In *Meaning and Order in Moroccan Society,* ed. C. Geertz, H. Geertz, and L. Rosen, 19–22. New York: Cambridge University Press.
1984 *Bargaining for Reality, the Construction of Social Relations in a Muslim Community.* Chicago: University of Chicago Press.
Slobodkin, Lawrence R.
1968 Toward a Predictive Theory of Evolution. In *Population Biology and Evolution,* ed. R. L. Lewontin, 187–205. Syracuse: Syracuse University Press.
Steward, Julian H.
1955 *Irrigation Civilization: A Comparative Study.* Social Science Monograph No. 1. Washington, D.C.: Pan American Union.
Stockton, Charles W. (ed.)
1988 *Drought, Water Management and Food Production.* Mohammedia: Kingdom of Morocco.
Vinogradov, Amal Rassam
1974 *The Ait Ndhir of Morocco: A Study of the Social Transformation of a Berber Tribe.* Anthropological Papers of the Museum of Anthropology No. 55. Ann Arbor: University of Michigan.
Weins, John A.
1977 On Competition in Variable Environments. *American Scientist* 65:590–97.