Mark Moritz

CAREER: Pastoral Management of Open Access: The Emergence of a Complex Adaptive System

This Faculty Early Career Development (CAREER) award will fund research that will advance our understanding of pastoral management of social-ecological systems. Specifically, the project examines how mobile pastoralists in the Logone floodplain in the Far North Province of Cameroon coordinate their movements to avoid conflict and overgrazing in a land tenure system that is commonly described as open access, a situation generally regarded as leading to a tragedy of the commons. The hypothesis is that this management system is best understood as a case of emerging complexity, in which individual decision-making, coordination of movements among pastoralists, and participation in an information sharing network result in the emergence of a complex adaptive system in which access to and use of grazing resources is managed. The hypothesis will be tested in a multidisciplinary study of pastoral mobility that integrates spatial and ethnographic analyses as well as multi-agent simulations and analytical modeling. Understanding how these emergent systems work is critical for the management of rangelands across West Africa, most of which have some form of open access.

Intellectual Merit. This project will make three interrelated theoretical contributions to the study of social-ecological systems. Central to these contributions is complexity theory, which enables the PI to examine long-standing questions of property rights and social order in new and innovative ways. First, the project will use complexity theory to develop theories and concepts of property rights by studying property regimes as emergent structures. Second, it will use complexity theory to study the process of structuration of a mobile society through the lens of management of open access. Third, it will contribute to complexity theory by describing general principles that lead to the emergence of complexity in situations of open access and by studying how emerging structures shape individual action.

Broader Impacts. The educational goal of this multidisciplinary project is to train undergraduate and graduate students to become the new generation of scientists and policy makers who have the interdisciplinary skill set and perspective needed to analyze complex environmental problems and contribute to their solution. A special effort will be made to recruit minority students from groups that have traditionally been underrepresented in the sciences. Students from multiple disciplines will be trained and mentored through participation in all aspects of this research project, including design, grant writing, IRB review, fieldwork, data analysis, writing, presenting at professional meetings, and communicating with policy makers. A portion of the funding will support the development of lab facilities for use by undergraduate and graduate students conducting ethnographic, statistical, and spatial analysis, multi-agent simulations, and analytical modeling of complex social-ecological systems. In addition to training the next generation of scholars, this project has two other broader impacts. First, it will educate policy makers and practitioners in pastoral development about the existence and workings of emergent management systems through policy briefs and training workshops. Second, it will build local capacity of the *Centre d'Appui à la Recherche et au Pastoralisme* (CARPA), a non-governmental organization in Cameroon whose aim is to support and conduct research and sustainable development of pastoral systems in the Chad Basin.

Project Description (no more than 15 pages)

CAREER: PASTORAL MANAGEMENT OF OPEN ACCESS: THE EMERGENCE OF A COMPLEX ADAPTIVE SYSTEM

This Faculty Early Career Development (CAREER) award will fund research that will advance our understanding of pastoral management of social-ecological systems. Specifically, the project examines how mobile pastoralists in the Logone floodplain in the Far North Province of Cameroon coordinate their movements to avoid conflict and overgrazing in a land tenure system that is commonly described as open access, a situation generally regarded as leading to a tragedy of the commons. I hypothesize that this management system is best understood as a case of emerging complexity, in which individual decision-making, coordination of movements among pastoralists, and participation in an information sharing network result in the emergence of a complex adaptive system in which access to and use of grazing resources is managed. Understanding how these emergent systems work is critical for the management of rangelands across West Africa, most of which have some form of open access. I will test my hypothesis in a multi-disciplinary study that comprises three integrated and overlapping phases. First, I will use spatial analysis to describe how pastoralists adjust their grazing pressure to the available resources in the floodplain. Second, I will use ethnographic analyses to examine how pastoralists coordinate their movements. Third, I will test how coordination between agents at the micro level produces an emerging management system at the macro level using multi-agent simulations and analytical modeling.

This project will make three interrelated theoretical contributions to the study of social-ecological systems. Central to these contributions is complexity theory, which enables me to examine long-standing questions of property rights and social order in new and innovative ways. First, I will use complexity theory to develop theories and concepts of property rights by studying property regimes as emergent structures. Second, I will use complexity theory to study the process of structuration of a mobile society through the lens of management of open access. Third, I will contribute to complexity theory by describing general principles that lead to the emergence of complexity in situations of open access and by studying how emergent structures shape individual action.

SUMMARY OF RESULTS FROM PRIOR NSF SUPPORT

My research focuses on the transformation of African pastoral systems. In research projects in 1993, 1994, 1996, 1999, and 2000-1, I investigated how FulBe pastoralists in the Far North Province of Cameroon have adapted to changing ecological, political and institutional contexts that affect their lives and livelihoods. My current interest in pastoral mobility developed out of research funded in part by a Dissertation Improvement Grant from the NSF (*The market and the moral economy of Fulani pastoralists in northern Cameroon*, 1999, BCS-9910557). In this work I focused on the household economy of FulBe pastoralists and how it is shaped by processes of increasing pressures on rangelands, market incorporation, and the global religious movement of Wahhabi Islam (Moritz 2003). I found that in response to pressures on rangelands, peri-urban pastoralists have intensified their production system by supplementing natural forage with costly cottonseed cakes (Moritz under review-b). My findings showed that intensification is sustainable only for individuals who simultaneously pursue an extensive strategy of transhumance to the Logone floodplain, which underscores the continuing importance of mobility for sustainable development of pastoral systems in West Africa (Moritz under review-a).

RESEARCH PROBLEM: THE PARADOX OF MANAGING OPEN ACCESS

How do mobile pastoralists coordinate their movements to avoid conflict and avoid overgrazing in a land tenure system that is commonly described as open access? Every year, after the water recedes, thousands of Arab and FulBe pastoralists from Cameroon, Nigeria and Niger move with more than 200,000 cattle into the Logone floodplain in the Far North Province of Cameroon (Beauvilain 1981; Seignobos and Iyébi-Mandjek 2000; Zborowski 1996). Not only do they distribute themselves in the floodplain without major conflict, mobile pastoralists also adjust their grazing pressure effectively to the available natural forage without overgrazing the floodplain (Scholte, et al. 2006). Moreover, they achieve all this without any apparent formal institutions that regulate pastoral use of and access to the floodplain, as neither the state nor traditional authorities have effective control over grazing resources (Moritz, et al. 2002).

Management of open access may not be as paradoxical as the literature on common property regimes suggests (Bromley 1992; Feeny, et al. 1990; Lane 1998; McCay and Acheson 1987; Ostrom 1990; Peters 1994). Open access is contrasted with common property regimes, which are managed by an identifiable community of interdependent users who exclude outsiders and regulate use by members (Ciriacy-Wantrup and Bishop 1975; McCay and Acheson 1987; Ostrom 1990). However, a study that we conducted of mobile pastoralists in the Logone floodplain suggest that in this case open access is managed (Scholte, et al. 2006). In this study of pastoral mobility in five different years between 1993 and 1999, we found evidence of an ideal free distribution in which grazing pressure matches the available biomass in the floodplain, no indication of overgrazing, and an absence of conflicts between pastoralists, including newcomers. Thus, our findings suggest that there is pastoral management of open access in the Logone floodplain.

In their challenges to Hardin's tragedy of the commons (1968), which argued that rational actors are unable to manage common resources without over-exploiting them, scholars have repeatedly pointed out that what Hardin referred to as commons was actually a situation of open access (e.g., McCay and Acheson 1987; Ostrom 1990). In doing so they have drawn clear conceptual boundaries between open access and the commons, making the commons more formal and bounded, while downplaying any regulation of open access (see also, Turner 1999:2-3). To support the conceptual distinction between commons and open access, scholars frequently discuss case studies of common property regimes of African grazing lands that fit the commons paradigm, e.g., the *diina* code of the Maasina inner Niger Delta (Gallais 1984; Legrosse 1999; Moorehead 1998) and the South Turkana territorial sections (McCabe 2004). Some have gone as far as arguing that there are no pastoral systems that operated according to the open access paradigm (Lane 1998; McCabe 1990:83). The problem of this argument and conceptual framework is that it ignores those pastoral systems that fit neither the commons nor the open access paradigm, i.e., most pastoral systems in West Africa (Niamir 1995).

Invisible Institutions

Recent reviews of research on pastoral mobility have shown that most grazing lands in West Africa do not have a formal tenure systems like the *diina* code of the Maasina inner Niger Delta (Fernández-Giménez and Le Febre 2006; Niamir-Fuller and Turner 1999). Instead, access to and use of these grazing lands is regulated through a number of informal institutions, social networks, and norms of reciprocity that are characterized by flexibility, porosity, and malleability (Bassett and Turner 2007; Breusers 2001; Casimir 1992; Fernández-Giménez 2002; Fernández-Giménez and Le Febre 2006; Galaty 1994; Niamir 1995; Niamir 1990; Niamir-Fuller 1999a; Niamir-Fuller and Turner 1999; Turner 1999). The problem with descriptions of pastoral tenure systems as "partial, intermittent, flexible, opportunistic, ad hoc, and often invisible" (Cleaver 2000; Fernández-Giménez and Le Febre

2006:352) is that they do not explain how these "invisible institutions" lead to effective management of grazing systems. This is also noted by Fernández-Giménez and Le Febre, who argue in their review that "despite the reams of literature on pastoral societies and production systems, we still have relatively little understanding of how these institutions work" (2006:357).

I believe that our understanding is limited because we have not used an appropriate analytical framework to study how these invisible institutions lead to management systems. I argue that these pastoral systems should be studied as complex adaptive systems (Holland 1995; Lansing 2003).

An Emerging Management System

The theory of complex adaptive systems explains systems that are non-linear, dynamic and self-organizing like cities, immune systems, central nervous systems, and ecosystems (Holland 1995). Central to complex adaptive systems is the concept of emergence, or "the idea that complex global patterns with new properties can emerge from local interactions" (Lansing 2003:183). The study of complex adaptive systems has focused on discovering general mechanisms and properties that contribute to the emergence of complex systems (Holland 1995). The theory had been used in ecosystem research (e.g., Jannsen 2002; Levin 1998), social sciences (e.g., Axelrod 1997; Epstein 2007; Miller and Page 2007), geography (e.g., Brown, et al. 2007; Lambin , et al. 2003; Manson and O'Sullivan 2006), archaeology and anthropology (e.g., Kohler and Gumerman 2000; Lansing 2006; Tainter and Tainter 1996).

The primary method to study complex adaptive system is through multi-agent simulations, although scholars have also innovatively and effectively integrated spatial and/or ethnographic analyses in the study of the emergence of complexity (Dean, et al. 2000; Gimblett 2002; Kohler, et al. 2000; Lansing 1991, 2006). Lansing and his colleagues, for example, have studied emergent complexity in the rice irrigation system in Bali (1991; 2006). They found that, without central management, Balinese farmers coordinate irrigation and rice planting in (and between) water temple communities, resulting in optimal management in terms of rice production and pest control of entire watersheds. The management system emerges from the bottom up through coordination among individuals. The Bali case shows that the emergence of cooperation can also prevent a tragedy of the commons (see also, Axelrod 1984, 1997).

Lansing (2000:219-21) has suggested that pastoral systems can also be understood as complex adaptive systems, citing evidence from longitudinal, interdisciplinary studies of natural experiments in Inner Asia, which show that when pastoralists are allowed freedom of movement, rangeland degradation is minimal or negligible in contrast to areas when governments interfered with management of the range (Humphrey and Sneath 1999; Sneath 1998). What is not clear yet is how individual decision-making and coordination between individual pastoralists produce a complex adaptive system. My research seeks to make visible the "invisible institutions" through which mobile pastoralists coordinate their movements, and to show how these institutions produce an emerging management system.

Modeling Pastoral Systems

Although modeling of pastoral systems has become more common (Bousquet, et al. 1999; Coppolillo 2001; Coppolillo 2000; Janssen, et al. 2000; Kiker 1998; MacOpiyo 2005; Milner-Gulland, et al. 2006; Rouchier, et al. 2001; Swallow and Bromley 1994; Thornton, et al. 2003; Turner 2002), it has been slow to integrate all the lessons from the new rangeland ecology (Behnke Jr., et al. 1993; Ellis and Swift 1988; Westoby, et al. 1989). Most models focus on stocking rates, which are adjusted in response to environmental changes (Janssen, et al.

2000; Swallow and Bromley 1994), rather than on mobility, which has been shown to be much more important in management of rangeland ecosystems (Behnke Jr. and Scoones 1993; Ellis and Swift 1988; Sandford 1982). A few studies of pastoral mobility have used agent-based modeling (Bousquet, et al. 1999; MacOpiyo 2005; Milner-Gulland, et al. 2006), which is considered one of the key methods to study complex social-ecological systems (Bousquet and Le Page 2004; Janssen and Ostrom 2006), especially those of open access resources (Milner-Gulland, et al. 2006). The strength of my research project is the integrative approach, in which spatial and ethnographic data sets are used to design and validate the simulation.

Structuration of a Mobile Society

The pastoral population in the Logone floodplain has always been in flux. The pastoral groups that currently use the floodplain came in the last twenty to fifty years. Previous users have left and moved elsewhere (Moritz 1994). But despite the constant changes of its constituency, the social-ecological system remains remarkably stable and resilient. This suggests that the social organization of mobile pastoralists in the Logone floodplain is well adapted to the management of open access.

Swallow and Bromley (1995) have argued that the sociopolitical organization of a pastoral society shapes its property regimes. Pastoral societies with diffused government have common property regimes (e.g. the Nuer segmentary lineage system, Evans-Pritchard 1940), whereas societies with minimal or non-existent government have open access (e.g., the fragmentary lineage system of the FulBe, Dupire 1970). The instability and flexibility of the FulBe fragmentary lineage system may be well suited to situations of open access with emergent management systems that are common in West Africa. But it may also well be that the property regimes shape the sociopolitical organization of pastoral societies.

Viewed from this perspective, not only a management system emerges in the Logone floodplain, but also a mobile society (see also, Park 1992). Each year, when the water recedes and thousands of pastoralists from multiple sub-ethnic groups from different countries (including new comers) enter the floodplain, a society with a common set of norms and institutions is reproduced. The study of management of open access in the Logone floodplain thus offers an excellent case study of structuration – the process in which structures (norms and institutions) through action (social practices) reproduce the system (management system) (Giddens 1979, 1984).

The Political Ecology of Pastoral Mobility

I will examine pastoral management of open access using a political ecology approach, because one cannot understand pastoral mobility in the Logone floodplain if one does not consider the sociocultural, economic, political and historical context of the Chad Basin (Issa 2004; Roitman 2004; 2005). Political ecology, which broadly refers to the study of social-ecological systems using a political economy perspective, has become a dominant paradigm in the study of social-ecological systems in anthropology and geography (Biersack and Greenberg 2006; Blaikie and Brookfield 1987; Bryant and Bailey 1997; Peet and Watts 1996; Peluso and Watts 2001; Ribot and Peluso 2003; Robbins 2004; Stott and Sullivan 2000; Walker 2005). The political ecology of pastoral societies has focused on access to grazing resources (Bassett 1988; Little 2003). Two issues that affect access to and management of grazing resources in Africa are insecurity (e.g., Fleisher 2000; McCabe 2004) and absentee ownership of livestock (e.g., Bassett 1994; Little 1985).

Insecurity in the greater Chad Basin directly affects pastoralists' lives and constrains their mobility (Issa 2004; Moritz 1995, 2005; Moritz and Kari 2001; Scholte, et al. 1996). For

example, pastoralists in northern Cameroon are recently feeling the effects of a failed coup in the Central African Republic as insurgents are kidnapping their children for ransom (Issa 2007). In response, pastoralists are avoiding certain areas due to insecurity. Herder-farmer conflicts over natural resources have a similar effect (Moritz 2006a, b).

The shift in livestock ownership from subsistence pastoralists to absentee herd owners and the associated increase in political and economic inequalities among pastoralists will likely affect the management of open access in the Logone floodplain (see, Bassett 1994; Lane and Moorehead 1995; Raynaut 2001:17). But how social, economic, and political heterogeneity affects the management of natural resources remains unclear (Agrawal 1998; Baland and Platteau 2000; Ruttan 2006; Ruttan and Mulder 1999). For example, we do not know to what extent absentee owners from Nigeria and Cameroon (and their hired herders) share the norms that guide the management of open access and whether and how they use their economic and political power to gain access to grazing lands. Anecdotal evidence from earlier fieldwork in the floodplain suggests that absentee owners claimed exclusive rights over grazing areas. But it remains unclear how this affects the emerging management system of open access. This project will examine how insecurity and absentee herd owners affect the resilience of the social-ecological system in the Logone floodplain.

INTELLECTUAL MERIT

This project will make three interrelated theoretical contributions to the study of social-ecological systems. Central to these contributions is complexity theory, which enables me to examine long-standing questions of property relations and social order in new ways.

Emerging Complexity

The first theoretical contribution is to explain pastoral management of open access as a case of emergence of a complex adaptive system (Lansing 2003; Miller and Page 2007). I hypothesize that the pastoral management system of the Logone floodplain is best understood as a case of emerging complexity as individual decision-making and coordination between individual pastoralists at the microscopic level produces an ideal free distribution of pastoralists at the macroscopic level. This project will explore and theorize how individual agency at the lower level produces larger structures at the higher level in the pastoral management of rangelands. It also aims to expand the theory of emergent complexity by studying how emerging structures in turn shape action, a relationship that is not yet well developed in complexity theory. The overall goal is to contribute to the development of general principles that explain the emergence of complex systems in open access situations, be it grazing systems in West Africa or street parking in San Francisco.

Theorizing Property Regimes

The second contribution is to further develop theories and concepts in the study of property regimes (Agrawal 2001; Feeny, et al. 1990; Johnson 2004; Lane 1998; McCay and Acheson 1987; Ostrom 1990). Scholars working in common property regimes have drawn a sharp conceptual distinction between open access and common property and focused their research on successful common property regimes that fit the theoretical concepts (see also, Turner 1999). They have done this primarily to counter Hardin's tragedy of the commons (1968), the influence of which has been detrimental to the development of pastoral systems (Fratkin 1997). The problem is that in many pastoral systems there is no clear boundary between open access and common property. This project will theorize the "grey" area

between the two concepts. It may, for example be more appropriate to think of grazing lands as "open systems" rather than "open access" since there are institutions that regulate access (e.g., exclusive rights over wells), even though they do not fully control access and use (Igoe 2004). I will theorize property regimes as emergent structures in which coordination among users leads to a complex adaptive system.

Structure and Agency

The third theoretical contribution is to understand the structuration of society through the study of management of open access in the Logone floodplain. Giddens' theory of structuration aims to explain the "duality of structure" that people make society but are also constrained by it (1979; 1984). The Logone floodplain provides an ideal natural laboratory to study the process of structuration as the population of mobile pastoralists is in constant flux but the management system seems remarkably stable. Studying the management of open access as a case of emergent complexity enables me to study the structuration of a mobile society, in which the praxis of coordination of movement among agents (action) is organized by the "invisible institutions" (structures) which produce an adaptive pattern of mobility and distribution in the floodplain (system). The use of structuration theory (Giddens 1979, 1984) and practice theory (Bourdieu 1980) allows me also to examine how emergent structures shape action or practice, a relationship that is not well developed in complexity theory (which focuses on how actions lead to structures but not vice versa). Using and expanding the analytical framework of emergent complexity, this project thus aims to address a key theoretical problem in social science, that of social order (Bourdieu 1980; Durkheim 1893; Giddens 1984; Gluckman 1966; Parsons and Shills 1952).

RESEARCH DESIGN

Guyer et al. (2007:5) have argued that social-ecological systems are far too complex to be studied solely by ethnographers. They maintain that interdisciplinary collaborations are imperative (see also, Borgerhoff Mulder and Coppolillo 2005; Raynaut 2001). Following Little's approach to interdisciplinary study of the political ecology of pastoral systems (2003), I will collaborate with an ecologist (Paul Scholte), a geographer (Darla Munroe), and a theoretical biologist (Ian Hamilton) on the study of pastoral management of open access. In addition, I will collaborate with Cameroonian researchers from the *Centre d'Appui à la Recherche et au Pastoralisme* (CARPA) in the collection and analysis of vegetation and mobility data. Undergraduate and graduate students from multiple disciplines will be involved at all stages of the research.

Model and Objectives

I hypothesize that there are five mechanisms that lead to the emergence of a complex management system of open access in the Logone floodplain:

1. Herd movements are result of *individual decision-making* by herders who consider the needs and habits of their animals (Bassett and Koné 2006; Borgerhoff Mulder and Sellen 1994; Dyson-Hudson and Dyson-Hudson 1969; McCabe 1994; Niamir 1995:246; Schareika 2003a, b);
2. Ecological, epizootic, and political *constraints* shape the movements of pastoralists (Burnham 1979; Casimir and Rao 1992; Fernández-Giménez and Le Febre 2006; McCabe 2004; Niamir-Fuller 1999a; Stenning 1957);
3. Pastoralists share a number of informal *institutions* that guide their coordination of movements (Glatzer 1992; Niamir 1995:247-8; Niamir-Fuller and Turner 1999);

4. Pastoralists participate in *social networks* in which information about the constraints and movements of other pastoralists is shared (Bassett and Turner 2007; Fernández-Giménez 2002:60; Schareika 2003a, b); and
5. Participation in this network and access to the *information* is critical for optimal use of the floodplain by individual pastoralists (see also, McCabe 2004:146; 2003a:18).

In this model, individual decision-making, coordination of movements among pastoralists, and participation in the social network result in the *emergence of a complex management system* in which use of and access to grazing resources in the floodplain is managed. Simple rules may lead to the emergence of complex management systems (Lansing 2003), but it is unclear which rules or institutions are most critical for the management of open access in the Logone floodplain, and this remains to be tested.

In order to test my thesis that pastoral management of the Logone floodplain can best be understood as a case of emergent complexity, I have the following objectives:

1. Map pastoral mobility and monitor vegetation to ascertain whether there is an ideal free distribution (Farnsworth and Beecham 1999; Fretwell and Lucas 1970), in which the distribution of resources is matched by the distribution of animals (taking into account constraints on pastoral mobility like insecurity);
2. Study how pastoralists make decisions, participate in social networks, and coordinate their movements in order to further develop my model and formulate testable hypotheses;
3. Test the hypotheses using multi-agent simulations and analytical modeling; and,
4. Analyze whether and how economic and political inequality, resulting from shifts in livestock ownership from subsistence pastoralists to absentee herd owners, affects the management of open access.

Study Area, Population and Sample

The study will focus on a 400-km^2 section of the Logone floodplain with well-defined boundaries. The research site overlaps with the pilot zone of the Waza Logone Project (1990-2003), which started reflooding of the pilot zone by opening an old waterway in the dike along the Logone River in 1994 (Loth 2004; Scholte 2005). This led to changes in vegetation and transhumance patterns of mobile pastoralists, which we documented in earlier studies (Scholte, et al. 2006). The vegetation in the floodplain is relatively homogenous in terms of forage quantity and quality because of the extreme flatness of the area. The limited variation in forage quantity is due to the depth of the inundation; the lower the depressions, the higher the forage quantity (Scholte 2005; Scholte 2007). There is a weak coupling between herbivores and vegetation as the vegetation is controlled by flooding and "naturally protected" against overgrazing because much of the biomass is stored underground and the vegetation is inaccessible during six months of the year (Scholte and Brouwer Forthcoming).

The Logone floodplain is flooded by water from the Logone River and its branches in September. After the water recedes in December, thousands of Arab and FulBe pastoralists from Cameroon, Nigeria and Niger move with more than 200,000 cattle into the floodplain and remain there until the start of the rainy season in June. Pastoralists find nutritious regrowth and surface water in the floodplain far into the dry season, when surrounding pastures have dried up. Pastoralists move an average of ten times within the floodplain (seven transit camps and three sojourn camps) over the course of the dry season. The research population consists of all pastoralists that use the study area, either passing through (transit) or staying on (sojourn). From earlier studies we know that the area is used by approximately 550 households divided over 110 camps (Scholte, et al. 2006). The goal is

to collect mobility data from all the herds and households in the study area through a combination of surveys and satellite tracking for three consecutive years. Data will be collected for households, as the number and composition of the camps changes continually.

The Logone floodplain is an ideal site to examine the emergent management of open access for a number of reasons. It is a key resource area used by pastoralists from different Arab and FulBe sub-ethnic groups in the Chad Basin. State and traditional authorities have limited or no control over grazing lands. There are few villages and fields (but some conflicts with fishermen over fish canals). And the annual flooding sets the stage each year for a new round of coordination of movements. Ironically, the conditions that reduce the complexity of the social and ecological context facilitate the study of the emergence of complexity in the Logone floodplain.

Although the research focuses on the Logone floodplain, I will also document the mobility patterns of the research population outside the floodplain. It is critical to study pastoral mobility on larger spatio-temporal scales using the analytical frameworks of the mobility paradigm (Niamir-Fuller 1999b), new ecological thinking (Behnke Jr., et al. 1993; Scoones 1999), and the political and historical context of the Chad Basin (Roitman 2004).

RESEARCH PLAN

The research plan consists of three integrated and overlapping phases: a spatial phase, an ethnographic phase, and a modeling phase. For each I briefly describe the methods used in data collection and analysis.

The Spatial Phase

The objective of the spatial phase is to describe how pastoralists use the Logone floodplain, and in particular to find out whether there is an ideal free distribution of pastoralists.

Building a GIS database. I will build a GIS database by using SPOT satellite images of the study area and marking key features that affect pastoral mobility, e.g., ecological zones, rivers, depressions, villages, fields, fish canals, livestock markets, primary health care centers, and roads. I will also use the regional atlas of the province (Seignobos and Iyébi-Mandjek 2000). In addition to mobility data, the database will also contain vegetation data; demographic, social, and economic data from all the households; and "event" data in each of the years that mobility data is collected (e.g., insecurity, epizootics). I plan to collect vegetation and mobility data for three consecutive years.

Vegetation Monitoring. For each year that mobility data is collected, I will monitor vegetation to estimate primary productivity, working closely with Paul Scholte. It is important to study primary production in the different ecological zones in the study area to test whether there is an ideal free distribution that we have described (Scholte, et al. 2006). We will use a transect that is set up for long-term monitoring and we already have vegetation data from 1984-5, 1993-7, 1999, and 2002 (for detail on transect and methods see, Scholte 2005; Scholte 2007; Scholte, et al. 2006). I will also use remote sensing methods to estimate forage availability in the Logone floodplain, e.g., through Normalized Difference Vegetation Index (NDVI) data from the satellite images (Crabbe, et al. 2006; Diallo, et al. 1991; Turner 2002; Westra and Wulf 2004) and Normalized Difference Water Index (NDWI) to estimate flooding (Westra and De Wulf 2007) and biomass production (Scholte 2007).

Cattle Condition Scoring. An additional method to assess whether there is an ideal free distribution is to evaluate the condition of cattle in the study area (Coppolillo 2000). During

the mobility survey, CARPA researchers will score the condition of 25 randomly selected animals from all herds in each campsite using Nicholson's and Butterworth's guide to condition scoring of zebu cattle (Nicholson, et al. 1986). Condition scoring is an efficient and reliable way to assess (reproductive) health (van Niekerk 1982) and resource availability (Reed, et al. 1974).

Mapping Mobility. I will record mobility data for all the households in the study area for three consecutive years using a combination of surveys and GPS tracking. In previous studies we have successfully used surveys to record pastoralists' transhumance patterns – pastoralists could recall with ease how many days they had camped on each site in the preceding year – but we did not have GPS locations of the campsites, only approximate locations (Moritz 1994; Scholte, et al. 2006). In this project, I will use GPS devices to get the exact locations of the campsites and crosscheck the survey data. CARPA researchers will collect the data in two-week intervals throughout the dry season. Pastoralists will be asked about livestock losses (Scholte, et al. 2006) and their reasons for moving (McCabe 2004:161-2). In addition to mapping campsites, I will also track ten herds to document daily grazing patterns and to establish the radius of campsites (Turner and Hiernaux 2002). I will use a combination of handheld GPS devices (Adriansen and Nielsen 2005; Bassett and Koné 2006; Coppolillo 2000) and personal tracking devices that can be worn by herders (Elgethun, et al. 2003; Seto, et al. 2007) or cattle (Clark, et al. 2006).

Participatory Mapping Exercises. To study pastoralists' understandings of their social and physical environment I will use participatory mapping exercises (see, Craig, et al. 2002; McCabe 2004:65-70; Mohamed and Ventura 2000). For example, I will ask what constitutes a campsite and what are its boundaries? What are the different ecological zones? I will analyze how pastoralists' conceptions of the landscape shape their distribution.

Consensus Analysis. I will use freelists, rankings, pile sorts to collect data about the cultural domains of landscape in general and campsites in particular (e.g., locations, preferences, and associated users) (Borgatti 1999; Weller and Romney 1988). I will examine the data using multi-dimensional scaling (Weller 1998). In particular, I will use consensus analysis to determine to what extent conceptions are shared and to what extent there is agreement on desirability of campsites (Weller and Romney 1990). I will use ANTHROPAC software to analyze the data (Borgatti 1996).

Spatial Analysis. Working closely with Darla Munroe I will use GIS software to look for spatio-temporal patterns in pastoral mobility (Munroe, et al. 2004). The goal is to describe pastoral mobility patterns and determine whether there is an ideal free distribution. We will examine distributions of grazing resources and grazing pressure, using data from vegetation monitoring, remote sensing data from satellite images, cattle condition scoring and mobility data.

The Ethnographic Phase

The objective of the ethnographic phase is to explain how pastoralists coordinate their use of the floodplain, including how shifts in livestock ownership affect this system. Using random samples, I will conduct an ethnographic study of pastoralists' decision-making, coordination, and social networks to build a model and formulate hypotheses about how these lead to the emergence of a complex management system of open access.
Ethnographic Interviews. I will study pastoralists decision-making using ethnographic interviews (Spradley 1979) as well as observations and audio recordings of the process by

which decisions about movements are made in the different camps (see also, Barth 1961; Lansing 2006). Research assistants will transcribe recordings of the meetings. I will use semi-structured interviews to collect data on the "invisible institutions", i.e., the rules and principles that guide the coordination of movements and use of campsites among pastoralists. I will pay close attentions to conflicts in which "norms" are violated, and in particular to those conflicts that involve hired herdsmen, absentee owners, and independent subsistence herders to understand how political and economic inequality affects the coordination of movements. I will interview all parties involved (whenever possible) and study the processes of negotiation. I will also use semi-structured interviews with key informants to estimate the percentage of animals and herds owned by absentee owners in other people's herds, as this is a sensitive topic (Moritz 2003).

Hypotheticals. I will use interview data to design hypotheticals to systematically examine the institutions that guide the coordination of movements and use of campsites among pastoralists (Edwards 1997). For example, I will ask informants to choose between endings or finish a scenario (e.g., one in which a herd owner finds his customary campsite occupied by a newcomer; one in which a newcomer comes to the floodplain for the first time and has decide where to camp; or one in which hired herder working for an absentee owner has to decide where to set up camp).

Social Network Surveys and Analysis. I will use surveys to collect social network data on structural variables between pairs of camp leaders (e.g., kinship relations, friendships, and frequency of meetings) (Degenne and Forsė 1999; Freeman, et al. 1989; Johnson 1994; Wasserman and Faust 1994). I will use a combination of free list and fixed choice questions to measure reliability and knowledge of other herd owners (e.g., who do you turn to for information on movements of others, pasture conditions, insecurity?). Actor attribute data will be collected in the other surveys (e.g., the mobility survey). I will conduct both micro analyses of ego-centered networks (e.g., how well are individuals connected?) and macro analyses of the whole network (e.g., what are the subgroups in the network?). I will pay particular close attention to place of old timers and newcomers in the networks (e.g., the correlation between connectivity or centrality in information sharing networks and the number of years that pastoralists have been in the floodplain. Social networks will also be compared with spatial analysis of the population (e.g., what is the correlation between place in the network and the location in the floodplain?). The study of social networks is key in examining the emergence of complexity (White and Johansen 2005). I will use UCINET to analyze the social network data (Borgatti, et al. 1996).

Ethnographic Data Analysis. I will use qualitative data analyses to study pastoralists' decision-making, coordination, and social networks. I will build a database with information for all the herd owners and their households. The database will include demographic data, social data, cattle condition data, and livestock ownership. I will use qualitative data analysis software (e.g., NVivo) to code and analyze interview data, hypotheticals data, and transcripts of recordings in order to study the cultural models that guide individual decision-making and the institutions that guide the coordination of movements (Bernard and Ryan 1998). A grounded theory approach will be used to develop hypotheses (e.g., the rules that contribute to the emergence of complexity)(Glaser and Strauss 1967; Strauss and Corbin 1990), which will be tested in multi-agent simulations.

The Modeling Phase

In the modeling phase, I will be working closely with Ian Hamilton using multi-agent simulations and analytical modeling to test the hypotheses to see how coordination among agents leads to an emerging management system of open access (Bousquet and Le Page 2004; Grimm, et al. 2005). I will use role games with pastoralists to validate the hypotheses and design the computer simulations (Bousquet, et al. 2002). I will use analytical modeling to capture what is happening in multi-agent simulations.

Role Games. I will use participatory modeling methods to examine pastoralists' decision-making and coordination in an experimental setting, to validate the hypotheses, and to design the multi-agent simulation (Barreteau, et al. 2003; Bousquet, et al. 2002). The role game will be played on a board that represents the floodplain. Players draw "household cards" and then propose moves and strategies. One round consists of multiple moves and represents one dry season in the floodplain. In the game, a situation is presented to the players but no rules, which are set by the players themselves. Facilitators take notes and debrief the game with the players. This method has been used successfully to study the emerging management of natural resources (Bousquet, et al. 2002).

Multi-Agent Simulations. I will use multi-agent simulations to test hypotheses about the emergence of complexity using REPAST software (North, et al. 2006; Samuelson and Macal 2006; reviewed in, Tobias and Hofmann 2004) or MABEL (Multi Agent-based Behavioral Economic Landscape), which integrates agent-based modeling and spatial analysis in ArcGIS (Alexandridisô and Pijanowski 2007). Using a parsimonious approach, I will start with simple rules for individual decision-making and coordination among pastoralists (e.g., move to desirable patch, keep minimum distance from others, first come first served) as my assumption is that despite the complexity of decision-making (Drent 2005; McCabe 2004), the emerging pattern is the result of relatively simple rules. I will make the simulations progressively more complex by adding additional rules, to find the best fit with the empirical data (Evans, et al. 2005). The outcomes of the simulation will be compared with observed patterns of pastoralists' distribution in the floodplain and the simulations will be evaluated in terms of fit to the data (Manson 2002). When simulations successfully match observed pattern, analytical modeling will be used to formulate a universal theorem that can be applied to other cases of emergent management systems of open access.

EDUCATIONAL ACTIVITIES

The study of social-ecological systems is beyond the scope of any one discipline and requires an interdisciplinary approach (Lambin and Geist 2006; Little and Leslie 1999; Moran and Ostrom 2005). In the future, these kinds of interdisciplinary studies will become ever more important as global warming has far-reaching effects on environments and the human populations that depend on them. It is critical that undergraduate and graduate students be not only thoroughly trained and educated in the theories and methods of their own discipline, but also that they acquire the skill set and perspectives of interdisciplinary research of complex social-ecological systems, and learn its potentials and challenges (e.g., Guyer and Lambin 1993; Taylor 2005; Turner 2002). For they are the future scientists that will be studying these environmental problems and contribute to their solution (Borgerhoff Mulder and Coppolillo 2005).

The educational activities are informed by Lave and Wenger's concept of community of practice (1991), in that I will create an interdisciplinary community of practice with a shared focus on the study of complex social-ecological systems. Undergraduates, graduate students, and faculty will learn from each other. As students move from peripheral to full participation in research activities they will increase their skills

and develop their identities as interdisciplinary scholars. This model of learning guides activities in the classroom, lab, the field and the working group.

Training Future Scientists

The primary educational goal of this project is to train and educate undergraduate and graduate students to work innovatively, collaboratively, and productively in interdisciplinary research projects that examine complex social-ecological systems. A special effort will be made to broaden the participation of minority students who have traditionally been underrepresented in the sciences. I will actively recruit undergraduates through the Ohio State University Young Scholars Program, which supports minority students from the nine largest urban school districts in the state from 7th grade through their undergraduate years at OSU. Graduate students will be recruited in collaboration with Patrice Dickerson, the Director of Diversity at the College of Social and Behavioral Sciences.

To achieve my educational goal I will actively involve undergraduate and graduate students from multiple disciplines in the study of management of open access in the Logone floodplain of Cameroon. Students from the Departments of Anthropology; Geography; Evolution, Ecology & Organismal Biology; and Agricultural, Environmental & Development Economics will be encouraged to participate. I will train and mentor students in all aspects of scientific research, including design, grant writing, IRB review, fieldwork, data analysis, writing, presenting at professional meetings, and communicating with policy makers. This intensive mentoring of graduate students is critical for their professional development and successful completion of the degree, in particular for minority students (Nettles and Millett 2006). The educational impact will be evaluated in terms of time to degree, publications, and placement of students participating in the project, and whether they pursue a career in the study and solution of complex environmental problems.

Apprenticeship will take place in courses, a weekly lab, and in the field. There are three sets of courses that I plan to teach. The first is aimed at training students how to conduct scientific research within interdisciplinary projects of social-ecological systems (e.g., *Research Design and Ethnographic Methods, Issues in Interdisciplinary Research of Social-Ecological Systems*). The second focuses on the theory of social-ecological systems (e.g., *Complex Adaptive Systems, The Ecology of Pastoral Societies*). The third is aimed at training students to communicate their research findings, including to the general public and policy makers (e.g., *Ethnographic Writing*, *Communicating Anthropology*). Some of these courses I have already taught successfully at other institutions; others I will develop during the tenure of the grant, like *Complex Adaptive Systems*, *Issues in Interdisciplinary Research of Social-Ecological Systems*, and *Communicating Anthropology*. Students interested in pursuing the interdisciplinary study of social-ecological systems will be encouraged to take modeling courses in the Department of Evolution, Ecology and Organismal Biology and Geographical Information Systems courses in the Department of Geography.

I will organize a weekly lab for students and faculty working on social-ecological systems, in particular the undergraduate and graduate students who participate in the research project. The goal of the lab is to create a community of practice in which students learn to think innovatively and rigorously as scientists. We will discuss epistemological, theoretical, methodological, ethical, and practical issues in ethnographic and interdisciplinary research. The lab will be a place where we discuss student work, e.g., grant proposals, research reports, posters, and where "expert" students learn to mentor "novice" students (Lave and Wenger 1991).

The courses and the lab will prepare students for successful participation in the research project. Undergraduates will participate in some of the research activities outlined in the research plan above (e.g., the study of social networks). Graduate students will

design their own independent research within the larger study of management of open access in the Logone floodplain. For example, a human biology student might study the relation between human disease patterns and pastoral mobility. All students will write research proposals, submit their research for IRB review, and write up the results in a report. In addition, I expect my graduate students to submit grant proposals to NSF and other funding agencies, to submit their report for publication to a peer-reviewed journal (e.g., in the Reports section of Current Anthropology), and to write a policy brief. I will work closely with all students at all stages of the research cycle, from design to writing, at OSU and in the field. In addition, CARPA researchers will provide assistance in the field and opportunities to learn how to collaborate with host-country experts.

I have first-hand experience of the excitement of training in interdisciplinary research and teaching, having been trained at the Institute of Environmental Sciences (CML) at Leiden University, where research and teaching are integrated to provide students with the knowledge and skills required to analyze environmental problems and to contribute to their solution in interdisciplinary efforts. I hope to give my students at OSU the same thorough training and excitement.

Developing an Institutional Infrastructure

A portion of the funding will support the development of a laboratory at OSU with computers, software and reference works to conduct ethnographic data analysis, statistical analysis, spatial analysis, multi-agent simulations, and analytical modeling. The laboratory will be used for hands-on training in my *Research Design and Ethnographic Methods* course, for data analysis by undergraduates, graduate students, and faculty, and as a meeting space for the lab. The shared space is essential for creating an interdisciplinary community of scholars working on social-ecological systems.

I will also organize a working group to foster interdisciplinary interaction and collaboration among researchers at OSU who are working on social-ecological systems. I envision the group to have regular meetings with presentations of research, discussions of new publications, and visits from exemplary scholars like Dr. Stephen Lansing, Dr. Emilio Moran, and Dr. Matthew Turner, who have participated in interdisciplinary projects of social-ecological systems. There is a strong faculty interest in such a group (which does not yet exist on the OSU campus), which is important for the education of students in the potentials and challenges of interdisciplinary research of social-ecological systems

BROADER IMPACT

In addition to training the next generation of interdisciplinary scholars of social-ecological systems, this project has two other broader impact goals: 1) to educate development professionals about emerging pastoral management systems of natural resources; and 2) to build local capacity in research and development of pastoral systems.

Implications for Pastoral Development

Sustainable development of African pastoral systems is critical not only for the millions of pastoralists whose livelihoods directly depend on it, but also for rural and urban populations for whom it provides the main source of protein (Galaty and Johnson 1990; Sandford 1983; Swallow and Bromley 1995:99). Understanding how pastoralists manage natural resources is key for sustainable development of pastoral systems in the Logone floodplain and elsewhere in West Africa (Fernández-Giménez and Le Febre 2006:341; McCabe 2003:92; Niamir 1995:248; Swift and Toulmin 1992:11).

Development professionals and policy makers do not always recognize management systems when they see them, and this is particularly true for emerging systems (Lansing 1991). "Western trained range managers often viewed traditional management systems as inefficient, destructive, and sometimes 'irrational', if they recognized them at all" (McCabe 2004:35; see also, Sandford 1983). An important objective is therefore to educate development professionals and policy makers about the workings of emergent management systems. For example, urging them not to formalize the institutions that produce complex adaptive systems, as similar interventions had disastrous effects in the past (Ayantunde, et al. 2000; Campbell, et al. 2001; Cleaver 2002; Fernández-Giménez 2002; Lane and Moorehead 1995; Niamir-Fuller 1998). Therefore I plan to disseminate the research results broadly in training workshops (e.g., at the World Bank), through dedicated clearinghouses of pastoral development networks (e.g., the World Initiative on Sustainable Pastoralism of the IUCN and the ELDIS pastoralism web site of the Institute of Development Studies), and direct communications with policy makers and development practitioners in Washington D.C., New York, London, Brussels, Nairobi, Yaoundé, and Maroua.

International Collaboration and Local Capacity Building

In this research project I will be working closely with Cameroonian researchers from the *Centre d'Appui à la Recherche et au Pastoralisme* (CARPA). CARPA is a non-governmental organization founded by FulBe from pastoral families, and its aim is to support research and sustainable development of pastoral systems in the Far North of Cameroon. CARPA members have great knowledge of the issues that concern mobile pastoralists and from their work for other research and development projects they have the training, experience, and expertise to collaborate in the collection and analysis of spatial and ethnographic data for this project. In the fourth year of the project, CARPA members and I will organize a conference in Maroua on *Pastoral Mobility in the Chad Basin*. Inviting scholars from universities, research institutions, and development organizations, we will build an international network of researchers working on pastoral systems in the Chad Basin and educate policy makers about emerging management systems.

One goal of this research project is to further build CARPA's capacity to independently research and develop pastoral systems by developing its logistical and scientific infrastructure. All field equipment will be donated to CARPA at the end of the project, and I will support and supervise further training of its members at the University of Ngaoundére (Cameroon). Because sustainable development of pastoral systems is an ongoing and ever changing challenge, it is vital to build the capacity of local researchers, who have a deep understanding of and a long-term commitment to pastoral systems.

SCHEDULE OF MAJOR ACTIVITIES

Fieldwork will be conducted primarily during winter quarter when pastoralists are in the Logone floodplain. In the first year I will collect spatial data, and in the subsequent three years I will collect mobility and vegetation data as well as ethnographic data. Data will be analyzed throughout the project, with an emphasis on spatial analysis in the early stages, ethnographic analysis and social network analysis in the middle stages, and multi-agent simulations and analytical modeling in the later stages of the project.

During the first four years of the project I will use the summer to pursue training in GIS, social network analysis, multi-agent simulations, and analytical modeling (e.g., training in social network analysis through the NSF Short Courses on Research Methods in Cultural Anthropology). Training in these methods is not only essential for successful

completion of this project, but also for my future research and teaching of complex social-ecological systems (Janssen, et al. 2007).

During the academic year I will teach two courses in the autumn quarter and two in the spring quarter. All courses are integrated in the research project, either by preparing students for research of social-ecological systems (e.g., *Research Design and Ethnographic Methods*) and/or by using my training to develop new courses (e.g., *Complex Adaptive Systems*). Lab meetings will be held throughout the academic year, but less frequently when I am in the field and students meet on their own.

Academic year	**Main Activities**
2008-9	Fieldwork in Winter Quarter (collection of spatial data, household survey, testing GPS tracking); Summer training in Geographical Information Systems.
2009-10	Fieldwork in Winter Quarter (mobility survey, vegetation monitoring, ethnographic research); Summer training in Social Network Analysis.
2010-11	Fieldwork in Winter Quarter (mobility survey, vegetation monitoring, study of social networks); Summer training in multi-agent simulations.
2011-12	Fieldwork in Winter Quarter (mobility survey, vegetation monitoring, role games); conference on *Pastoral Mobility in the Chad Basin* in Maroua; Summer training in analytical modeling.
2012-13	Multi-agent simulations and analytical modeling; publication of conference proceedings; writing research articles, a book manuscript, and policy briefs; workshops at development agencies; presentations at national conferences with students.

CAREER GOALS

The Faculty Early Career Development (CAREER) award will provide me with an excellent opportunity to undertake a long-term project that integrates innovative research and education of social-ecological systems in the institutional setting of the Ohio State University. As a faculty member of the Department of Anthropology, I am expected to teach four courses each year, to have an active research program, to publish in highly ranked journals, and to perform institutional and professional service. The Ohio State University and the Department of Anthropology are the perfect setting for me to pursue this multidisciplinary project that integrates research and education. In addition to promoting its core values – pursue knowledge for its own sake, ignite in students a lifelong love of learning, produce discoveries that make the world a better place, celebrate and learn from our diversity, open the world to its students – the Ohio State University aims to develop new multidisciplinary activities in the near future (The Ohio State University 2000). Teaching and research in the Department of Anthropology focuses on bio-cultural aspects of health, evolution, and ecology under a single, unified intellectual umbrella that integrates the different sub-disciplines. The department has a high involvement in interdisciplinary research programs and seeks to develop new and cutting-edge interdisciplinary research and teaching (Larsen 2007:3). My career goals for the next five years outlined here align perfectly with the missions of the university and the department. The CAREER award will give me the time and financial support to pursue these goals and will lay important building blocks for my future scientific career.

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