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Implications of Land Development on Nomadic Pastoralism: Ecological Relaxation and Biosocial Diversity in Human Populations

Hannah R. Bradley
Scripps College

Implications of land development on nomadic pastoralism:

Ecological relaxation and biosocial diversity in human populations

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Hannah Bradley

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Abstract

Nomadic pastoralism is an ancient subsistence strategy, historically balanced and in continuity with sedentary societies. Sedentarization of nomads occurs normally because of ecological disasters, economic opportunities, urbanization, and government policy. In this paper, I examine the effect of changing land use patterns on nomadic pastoral populations in Asia, Africa, and the Middle East, using biogeographic methodology to further explore the contemporary relationship between humans and their environments. Nomadic population information gleaned from diverse ethnographic studies, and GIS data on anthropogenic biome distributions, were used to calculate changes in nomadic population, area of developed land, and nomadic/sedentary population density over the last century in seven countries. There was a significant decrease in the proportion of national populations practicing nomadic pastoralism (paired t-test, $p=0.0038$, $n=7$), but no significant overall change in total nomadic populations (paired t-test, $p=0.41$, $n=7$); nomadic population decreased in all countries but Sudan and Somalia. There was also no significant change in undeveloped land available for nomadic pastoralism (mean change -12.5%, S.D. ±15.8, paired t-test $p=0.07$, $n=7$), though the area of land available for nomadic pastoralism decreased in most countries. There was a negative linear correlation between land development and nomadic population when Somalia and Sudan were omitted ($r^2=0.84$). Nomadic population density decreased in most countries, but increased in Somalia and Sudan. Some nomadic populations may be experiencing an extinction debt effect, where habitat loss combines with increased population density (Somalia, Sudan), but in most others where the population seemed to decrease more rapidly than would be expected due to habitat loss (Saudi Arabia, Mauritania, Iraq, and Afghanistan). The variable relationship between density and habitat loss implies that social factors often overshadow the ecological: though there is a correlation between habitat loss and nomadic population decline, causation is unclear. Despite the limitations of this study, nomadic populations do seem to have a natural balance with their cultural and biological environments that is disrupted by changes in social dynamics with sedentary populations and their subsequent environmental impacts. The loss of cultural diversity inherent in this disruption may decrease the flexibility and adaptability of the overall biosocial human ecosystem.

Introduction:

Nomadic Pastoralism

Nomadic pastoralists are populations who raise livestock and are somewhat mobile, although there is a broad continuum within these activities that varies from population to population (Salzman and Galaty 1990). Indeed, the flexibility and adaptability of the nomadic lifestyle is one of its most important attributes (Blench 2001). This paper deals with nomadic pastoralists in Asia, Africa, and the Middle East, excluding nomadic tradespeople such as the Roma or Travellers of Eurasia, as well as nomadic hunter-gatherers, and focusing on nomadic and semi-nomadic herding groups. The word "nomad" has often carried a connotation of aimless wandering: Humphrey and Sneath, in their 2005 survey of pastoralism in inner Asia, named their book *The End of Nomadism*, in protest of this very term. Often, researchers prefer the use of "mobile pastoralism" or simply "pastoralism" to refer to this particular lifestyle. Though each nomadic culture is different, all nomadic pastoralists share subsistence and cultural patterns, such as communal use of pasturelands and the managing of family livestock herds (Salzman and Galaty 1990).

Explanations of the origins of nomadic pastoralism range from ecological to political, but whatever the case may be, nomadic and sedentary societies have always been closely tied through trade and cultural influence. Nomads often inhabit lands that are incapable of supporting agriculture (Ikeya and Fratkin 2005, Homewood 2008), including savannas, dry highlands, and tundra. Because of this, some scholars, such as Stein (1981, in Salzman and Galaty 1990), describe agriculture and pastoralism as two complementary, variably interdependent activities that evolved to inhabit different ecological niches, possibly because of climatic drying in some areas (Smil 1991). Ikeya and Fratkin (2005) refer to the

relationship between nomadic and sedentary societies as an "ecological symbiosis": depending on the status of trade and land use/dispute, this relationship can be "competitive," "symbiotic," or "predator-prey." Khazanov and Wink (2001) reiterate the reality that nomadic pastoralism is almost never a "closed system," completely independent from other societies; nomads have always gained diverse foods, such as flour and vegetables, from sedentary groups. In his work on energy use in human systems, Smil (1991) describes pastoralism as "intermittent and extensive use of land," with population densities similar to some foraging or gatherer groups, estimated at 0.8-2.2 people/km^2 in East Africa. According to Smil (1991), the outside "energy input" from trading and other interactions with sedentary groups helps to sustain nomadism and prevent overgrazing by nomadic herds.

This interdependence functions in both directions, with sedentary societies in Asia, Africa, and the Middle East gaining technologies and even fashion trends from their nomadic counterparts, as well as a large proportion of their milk and meat products. Nomads have had an irrefutably large impact on regional politics for thousands of years: the Mongols, for example, shaped history in Asia and Europe for centuries (Khazanov and Wink 2001). Going beyond simply interdependence, the two identities—nomad and sedentary—are historically mutable and flexible: Salzman and Galaty (1990) refer to this as a "nomadic-sedentary continuum." Pastoralism is often placed on an intractable socio-evolutionary timeline on which movement from a mobile to a sedentary lifestyle is inevitable as societies optimize their subsistence and production; however, depending on the situation, nomads may practice some degree of sedentary agriculture, and sedentary groups may adopt mobile pastoralism. This has occurred even in recent years, as in Mongolia after the disintegration of the Soviet Union, and in Afghanistan in the 1980s and 1990s due to difficult economic situations in its

northwestern region (Blench 2001). There is both a historical and contemporary link between sedentary and nomadic lifestyles.

Sedentarization

Because of this long-standing relationship, understanding the current situation of nomads is part of understanding our modern world. Though nomadism has always been in a kind of dynamic equilibrium with the forces of sedentarization, with some portion of the population always shifting between sedentary and nomadic subsistence, these forces are today changing and increasing, further challenging the balance between nomadic pastoralists and their sedentary counterparts.

In *When Nomads Settle*, Salzman (1980) describes three models of the causation of sedentarization: "drought and decline," in which catastrophic droughts or other environmental disasters kill off pastoralists' herds, causing them to resort to life in sedentary villages; "defeat and degradation," in which pastoral lands are seized, either through tribal competition or force from national governments, forcing the inhabitants into settlement; and "failure and fall-away," in which, at a more micro-level, individuals may fail to support their families using nomadic pastoralism and resort to other sedentary pursuits for survival. Sedentarization, as a diversification of sources of income or subsistence, may often be a response to economic stress in an attempt to remain self-sufficient, or as a way to gain more diverse opportunities (Oba and Boku 2010). Nomadic pastoralism is a subsistence *strategy*, and as such, it is practiced because it is strategic and adaptive for people to do so. Research by McPeak and Little (in Fratkin and Roth 2005) in Kenya, and by Oba and Boku (2010) in Ethiopia showed that both very poor and rich pastoralists would increase their

implementation of sedentary farming, either as a last resort or as a way of gaining further wealth.

However, in the case study *Making a Market*, the Orma people of Kenya were increasingly forced to depend on trade, the cash market, and settlement into towns because of a long series of social and biological push-factors including war, disease, and drought, and were then stuck in the cash economy (Ensminger 1992). Political policies, the forces of the cash economy, trends towards urbanization, the globalization of the economy—including the market for pastoral products—and unequal social opportunities are all driving forces of sedentarization outside normal give and take of the "nomadic-sedentary continuum." In Humphrey and Sneath's (1999) examination of pastoralism in Russia and China, the authors show that urbanization and sedentarization are two distinct phenomena; the first draws rural inhabitants into urban and cultural centers, while the latter refers to a change from nomadic to sedentary economic pursuits. Increased urbanization does not necessarily equal a decline in mobility or pastoralism, but increased sedentarization is more closely linked to population-wide lifestyle changes (1999). Although movement back and forth between nomadism and sedentary agriculture has always occurred in response to ecological or economic catastrophes, and as part of a drive to diversify survival strategies, it can also be due to national or international social trends outside of historic parameters and not always easily reversible.

"Development" efforts by governments, including encouraging movement to crop production or ranching style livestock production, are often driven by views of nomadism as backward or inefficient. One of the most common arguments used against nomadism as a viable lifestyle is the "tragedy of the commons," first published in an essay of the same name

in 1968 by Garrett Hardin: the logic of this argument has led to the misrepresentation of nomadism as wasteful and unsustainable. Focus on improving livestock production to a Western ranching model, and creating civil society pastoral organizations may not be exactly what pastoralists need, since this helps drive "expropriation and wealth accumulation" (Homewood 2008) that still breaks down the cultural balance of this subsistence strategy. Ensminger noted in *Making a Market* (1992) that development of Kenyan property laws in Orma territory tended to favor sedentary stock-owners instead of the pastoralists, who had less access to the state: development policies may sometimes do more harm than good. Forced settlement has also occurred repeatedly throughout history, in colonial states to streamline control over native populations, in Iran and Turkey, and in the Soviet Union and China as part of agricultural collectivization: both forced sedentarization, as well as sedentarization trends that are pushed by outside social pressure, are viable human rights concerns for nomadic peoples.

Though it is a constantly oscillating trend, the general consensus is that the nature of nomadic pastoralism is changing worldwide, usually towards a more sedentary model, due to varied social and biological factors. Blench (2001) cites advancing agriculture, enclosure of land, and alternative economic opportunities as main causes for declines in pastoralism worldwide. Ikeya and Fratkin (2005) suggest that conflicts among nomads and between nomads and neighboring groups may increase as increasing populations and decreasing land and resources lead to intensifying competition. The nomadic-sedentary continuum, though historically reversible and adaptable, may become increasingly rigid as increased environmental and social pressures exerted by land privatization, land degradation, and

changing power structures make movement between nomadic pastoralism and sedentarism more difficult.

Nomadic Culture and Change

The study of the interconnectivity between cultures and their environments is an academic balancing act between the extremes of environmental and cultural determinism that has had many incarnations over the last few centuries. Is cultural activity determined by the culture's local environment (environmental determinism)? Are cultural situations completely incomparable, with the environment having no effect on their development (cultural determinism)? Is cultural change an adaptation to environmental factors (cultural ecology)? Are cultural practices simply a way of maintaining equilibrium with the environment (ecological functionalism)? The debate continues over the best approach to describing this relationship, with current fields such as ethnobiology and political ecology also trying to fill the gaps. Assuming a link between a culture and its ecological milieu is not necessarily fully reductionist: knowing the traditional language of describing natural surroundings and the profound cultural relationship to the land is important in understanding the self-perception and worldview of any indigenous people (Maffi 2005).

The culture of nomadic pastoralism in intrinsically linked to the land on which it is practiced and therefore the economic strategy utilized by its people. In *Stone Age Economics* (1972), one of the seminal works on economic anthropology, Sahlins argues that the economic strategies of a society are part of its culture, like religion, not simply a type of behavior or innate set of value judgments of individuals. Besides his well-known theory of the "original affluent society"—that because hunter-gatherers have all their basic needs met, with free time left over, they are in fact "wealthier" than some more complex societies—

Sahlins also attempts to explain the pressure exerted on cultures by their environments. For example, the necessity of mobility for survival may create a cultural preference for fewer belongings that must be transported (Sahlins 1972). Nomadic cultural identity is at least partially bound to their animals and to their lifestyle of mobility, as well as to their relations with sedentary societies.

Because of their shared subsistence strategy, nomadic pastoralist societies share some other cultural traits that would undergo change alongside subsistence patterns. Nomadic pastoralists' concepts of wealth are also based in their animals, a fact noted by many ethnographers in different settings. Oba and Boku (2010) report from their research with pastoralists in Ethiopia that Borana herders felt that "poor" families that had abandoned nomadic pastoralism had lost their very identities as Borana. Pastoralists often look down on sedentary life as difficult or poor although others, such as in Adano and Wisonberg's research in Kenya (in Fratkin and Roth 2005), see sedentary agriculture as possibly liberating, as it lends independence to poor nomads who would otherwise be dependent on their relatives. In either case, entrance into sedentary agriculture, or into a cash economy based in sedentary society, implies a fundamental change in the relationships of formerly nomadic individuals to their families and to each other.

The economic changes implied by sedentarization may mean a change in social organization and cultural practice for nomadic populations. Culture change is a natural process, and nomadism is not simply traditional and unchanging: nomadism is more or less defined by its adaptability and flexibility. However, the possibility of changing cultural practices and possible absorption into sedentary culture may be seen as a threat to nomadic pastoralists' identities and social structure.

The Human Biogeography Approach

Besides the overarching goal of examining the contemporary realities of nomadic groups, I used the biogeographical framework of this study to further examine the ways in which ecological anthropology can be quantified to study human societies. By even attempting to pursue quantifiable scientific data about diverse human populations, a study of this kind naturally privileges certain kinds of information, mainly population counts and habitat area data, that cover multiple cultures and continents, over qualitative information about specific cultural situations. It also implies that humans can be categorized into black and white, nomad/sedentary categories that can be statistically analyzed, when, as previously mentioned, the gray areas of human social interactions are usually extremely apparent. Despite this, searching for overall trends can be a valuable pursuit that informs decisions about future development and cultural policies—if the natural gray area of these situations is not ultimately ignored. Other studies have attempted to create detailed models of the social process by which nomadic groups become sedentary or are subsumed into national economies (Mace *et al.* 1993, Symanski *et al.* 1975), but I wanted to specifically examine the ecological relationship of nomadic pastoralists to their subsistence strategy and thus the way that land use change would affect their populations. Though ecological factors are difficult to extract from their social milieu, I adopted a quantitative approach to more deeply examine the contemporary complexities of human ecology, specifically the human ecosystem of the nomadic-sedentary continuum.

"Human biogeography" takes the methodology and theories of biogeography—the study of the distribution of species across geographic changes (Lomolino *et al.* 2010)—and applies them to our own species. Studying humans biogeographically combines many

disciplines, such as anthropology/ethnography, ecology, genetics, and sociology, to holistically study the effects of ecological factors on human dispersal, migration, and evolution (Terrell, 2006). Often, concepts of human biogeography are applied to prehistoric events, such as in the study of cultural variation across the Pacific Islands, or of how prehistoric human migrations across southwestern Asia were affected by sea level changes (Pope and Terrell, 2008). Dividing humans into discrete "populations" for analysis, especially in the modern era, is difficult because of the mobility and mutability between populations (Terrell, 2006). Scientists often overlook humans' natural interactions with their environment, and although biogeography is not typically applied to human beings, biogeographic principles can be used to look at long-term trends in human populations.

Even though humans have become extremely adept at creating their own favorable living environments through technology, it is expected that populations will still exhibit the effects of ecological change. For example, despite technology, human "range expansion" occurs much like any other species, with some newly arrived populations failing and others succeeding (Lomolino *et al.* 2010). Human habitation also continues to maintain very non-random distributions, falling generally in warmer areas near water, and human populations tend to obey laws of island biogeography: larger land masses tend to have higher linguistic and cultural diversity than smaller islands (Lomolino *et al.* 2010). If we remove our assumption that all human activities are "unnatural," destructive to nature, and disconnected from it, it can be useful to think of agriculture as another foraging technique, or the domestication of animals as a type of interspecies mutualism: nomadic pastoralism might be thought of as a human mutualism, a sort of niche exploitation that led to the biodiversification of human foraging strategies.

In his essay on the value of human biogeography, Terrell (2006) writes:

> "…adopting when appropriate an explicitly biogeographical perspective on our species can make it easier to model and investigate questions about the size and distribution of human communities, their haphazard or structured interactions with one another, and the conditions and events leading to our current biological and cultural diversity as a species.
> "Because biogeographical thinking is probabilistic rather than deterministic, and because biogeography stresses relationships between species and the evolving spatial complexities of their environments, a biogeographer's approach to ourselves can further studies of the events and circumstances that have contributed to the evolution of similarities and differences among people and their ways of life."

In this project, I wanted to use the vocabulary of biogeographic principles, mainly range collapse and ecological relaxation, to examine changes in contemporary nomadic groups, combining social and biological sources to analyze changes in this particular human "population".

Human biogeography explores the effects of environmental and geologic factors on the human organism, and vice versa: both how human population patterns are affected by geography, but also how humans affect natural biota (Ellis and Ramankutty 2010, 2008, Vitousek 1997). Anthropogenic biomes, or "anthromes"—biomes that have been significantly altered by humans, as opposed to "wildlands"—are estimated by Ellis and Ramankutty (2008) to cover about 75% of today's ice-free land area: these authors suggest that the world is now composed of natural systems embedded in human systems, instead of the inverse. The effects of this shift should be apparent in changes in range and movement of terrestrial organisms, of which human pastoralists are my focus.

Human habitation is necessarily dependent on the type of biome, or ecological community (Lomolino *et al.*, 2010), present, and the type of social lifestyle led by different groups affects the population density ceiling for the local environment. Basic historical forms of human–ecosystem interaction are associated with major differences in population density,

including foraging (< 1 person/km^2), shifting (> 10 persons/km^2), and continuous cultivation (> 100 persons/km^2); populations denser than 2500 persons/km^2 are believed to be unsupportable by traditional subsistence agriculture (Smil, 1991; Netting, 1993 in Ellis and Ramankutty, 2008). Logically, the amount of available land will inform whether sedentary or nomadic lifestyles are possible in a particular landscape, and land that is transformed into cities, cultivated for agriculture, or otherwise environmentally altered, may not allow for the mobile lifestyle of nomadic pastoral people.

In all species, habitat loss affects species richness, abundance, and distribution (Fahrig, 2003), an effect often referred to as ecological relaxation or faunal relaxation (Lomolino *et al.* 2010). Depending on the extinction rate, generation time, and recolonization rate of a species, there may be a "lag" period between the initial decrease in habitat size and the subsequent decrease in species diversity (Vellend *et al.* 2006); the rules of island biogeography have long proved able to predict diversity loss from habitat loss along predictable species-area curves. The decrease of ideal habitat should affect the abundance of different human populations, following patterns seen in other organisms.

Research Questions and Hypothesis

"Habitat loss" in this project was quantified by examining changes in the distribution of developed land using GIS software. By examining correlations between data on nomadic population and GIS data on changes in the area of anthropogenically altered biomes in countries with nomadic populations, I expected that I would be able to see a biogeographical trend in pastoralist populations linking the human population to ecological change. Overall, I expected that as anthropogenically altered biomes increase in their dominance, the nomadic population would decline because of decrease in viable "habitat."

Though I expected overall declines in both nomadic population and available habitat, I wanted to further delineate the nature of this decline: by examining changes in population density, I wanted to see the relative rates of loss of land and population. This would serve to categorize possible future trends in nomadic populations and lend further detail to their relationship with sedentary and urban populations. I expected changes in nomadic population density of each population to fall into one of 5 possible outcomes:

1. *Habitat shrinks + increase in nomad population density*

This could indicate that nomadic populations are experiencing a delay preceding a collapse/ecological relaxation of the population as the habitat shrinks. However, this could also be sign of increasing efficiency of pastoral husbandry techniques or an increase in birth rates with a corresponding decrease in mortality associated with better healthcare access and technologies, resulting in higher sustainable population density.

2. *Habitat shrinks + decrease in nomad population density*

This would indicate that the change in nomadic population is occurring faster that the change in habitat area, implying that social factors such as urbanization and sedentarization are having more of an effect on the population than the change in the actual environment.

3. *Habitat shrinks + constant nomad population density*

This would imply a direct linear correlation between habitat decrease and population decrease, as both are declining at the same rate.

4. *Habitat constant + change in nomad population density*

This might indicate that the effects of urbanization, cultural change, and the push of the market economy towards or away from a sedentary lifestyle outweigh the effects of actual habitat loss, or that habitat loss is not a viable indicator of nomad population changes. This

might also indicate that the metrics used for land use change in this study were not adequate to represent habitat degradation or other changes affecting nomadic populations.

5. *Habitat constant + constant nomad population density (stable)*

Stable population density, in the absence of large losses of open land, may indicate that pastoralism is still a viable economic lifestyle, or that there is little social or political pressure to sedentarize.

I expected most populations to fall into outcomes 1 or 3, implying a future decline in populations practicing nomadic pastoralism that is causally linked to increased land alteration and development. If most populations fell in outcomes 2 or 4, this might imply an overriding role of social factors over ecological factors. If the populations fell into a mix of all possible outcomes, this might prove the null hypothesis that there is no predictable trend in causation of nomadic population changes, implying that policy decisions on land use, social programs, etc. are very important for the outcomes of individual nations' nomadic populations.

Methods and Materials

For this study, I looked specifically at changes in nomadic populations and land use in Mongolia, Sudan, Iraq, Saudi Arabia, Somalia, Afghanistan, and Mauritania. These specific countries were chosen because of the historic and continuing presence of nomadic pastoralist populations within their borders, as well as availability of data about these populations.

Numerical data about nomadic populations were gleaned through a wide review of literature and online sources about nomadic groups: journal articles, ethnographic and geographic studies, and public information about national cultural practices and demographics were all searched for mention of current and historic nomadic population figures (see Bibliography, "Population Sources"). I attempted to find population data for a range of dates between 1900 and 2000 for each country. The data found were on irregular dates, with some countries ranging from 1956-1993, or 1900-1970, etc. (see Table 1).

I also located total populations of each country using a similar method, through government statistical data for current populations and through literature search for demographic data on historic populations (Lahmayer, 2002; USCB, 2011). When information about nomadic populations was reported as percentages of the total population, I extrapolated estimations of nomadic population based on total national population (Table 1). Changes in nomadic populations were graphed over time to visually represent overall patterns.

Table 1: Calculated estimates of nomadic population by year and country.

Country	Year	Total Population	Percent Nomadic (%)	Est. Nomadic Population
Sudan	1956	10,404,000	13	1,352,520
	1973	14,958,000	10	1,495,800
	1983	20,564,400	10	2,056,440
	1993	27,255,000	10	2,725,500
Mongolia	1900	604,000	90	543,600
	1925	684,000	86.6	592,344
	1956	845,500	74	625,670
	1990	2,190,000	18.7	409,530
Saudi Arabia	1950	3,916,000	50	1,958,000
	1970	6,198,000	11	681,780
	1974	7,012,600	25	1,753,150
	2000	22,023,500	5	1,101,175
Mauritania	1965	1,187,000	72.5	860,575
	1975	1,404,000	30	421,200
	1992	2,043,000	20	408,600
Afghanistan	1925	5,735,000	33	1,892,550
	1975	14,132,000	2.5	353,300
Somalia	1931	1,370,000	81	1,109,700
	1967	3,429,000	73	2,503,170
	1975	4,128,000	59	2,435,520
	1993	6,101,000	50	3,050,500
Iraq	1900	2,060,000	38	782,800
	1970	9,440,000	2.8	264,320

Data about anthropogenic biomes were taken from Ellis and Ramankutty (2010), which included public online GIS data showing global distribution of anthropogenic biomes ("anthromes") in 100-year timesteps between 1700 and 2000. In their study, "anthromes" were classified based on population density, land use (agriculture, etc), and land cover (bare earth vs. vegetation) into 18 categories and 3 "wild" biomes, distributed globally (Figure 1, see also Appendix 1; Ellis & Ramankutty, 2008, 2010). Using ArcGIS software, I calculated the relative distribution of anthrome categories within each of the target countries' political boundaries at the 1900 and 2000 timesteps. I then calculated the proportion of total national area having significant anthropogenic alteration using categories 11-35 ("Dense Urban" -

"Populated Croplands") to define "developed" land. I determined this range to be most representative of changing human impact because it excluded open rangelands and wildlands that would presumably be most suitable to the pastoralist lifestyle. The percent change in undeveloped land was calculated for each country to determine cross-national trends in land use over the past century (Table 2), and the distribution of "altered" lands between classes 11-35 was also charted for each country to show the nature of land development.

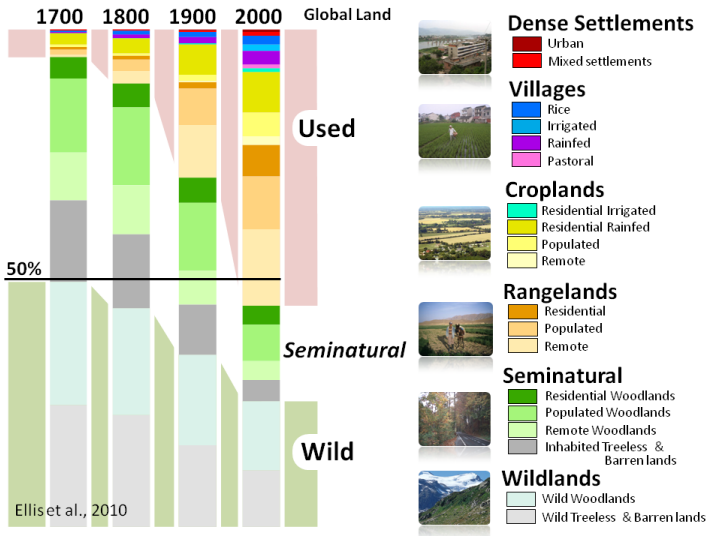

Figure 1. Anthrome classes (Ellis and Ramankutty 2010; see also Appendix 1).

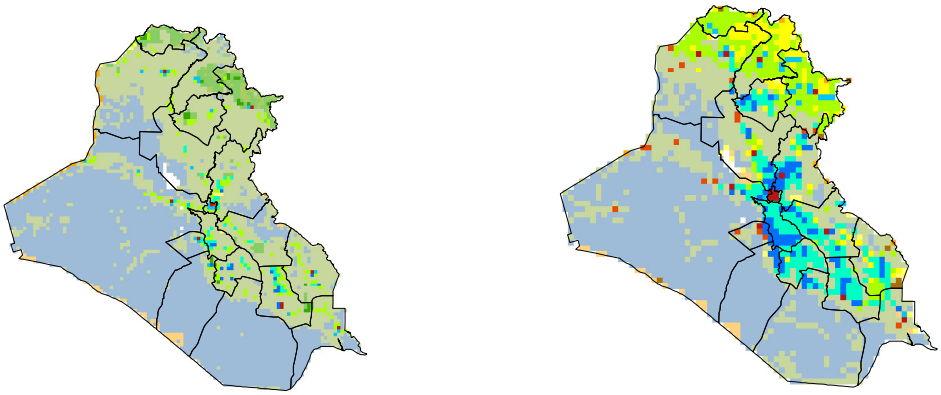

Figure 2. Example: GIS anthrome distribution in Iraq 1900 (left) and 2000 (right).

Changes in land use and changes in population density were evaluated by combining (1) the earliest and latest known population datapoints with (2) the 1900 and 2000 calculations of total available land, in order to calculate the estimated nomadic density (nomads/km^2) at these two general timesteps. I also repeated this using the inverse data for sedentary populations (total population – nomadic population) and developed lands to calculate changes in sedentary population densities. Significance of perceived trends over time was analyzed using paired t-tests, with significance set at $p<0.05$. Change in population and change in area of developed land were used to extrapolate possible correlations.

Table 2. Land use change 1900-2000.

		Altered land 1900		Altered land 2000	
Country	Total Area	Percentage (%)	km^2	Percentage (%)	km^2
Sudan	2,505,813	0.10	2531.2	14.12	353802.7
Saudi	2,149,690	0.29	6176.2	1.07	23085.4
Mongolia	1,564,116	1.90	29767.2	1.21	18935.2
Mauritania	1,030,700	0.24	2430.0	1.23	12709.9
Afghan	652,230	6.29	41005.8	37.54	244860.5
Somalia	627,337	0.02	101.2	3.76	23604.1
Iraq	438,317	6.95	30475.9	40.06	175604.4

Results:

Change in nomadic population in the examined countries was highly variable (Figure 3). The mean change in total nomadic population over reported dates between 1900 and 2000 was 113% (S.D. ±98%); there was no significant change in total nomadic population (paired t-test, p=0.41). Two of the countries studied (Sudan and Somalia, Figure 4) experienced an increase in total nomadic population over approximately the last century, while the other five decreased (Figure 4). However, there was a significant overall decrease in the proportion of the population practicing nomadic pastoralism (mean -34.3%, S.D. ± 22.8, paired t-test, p=0.0038, Figure 4).

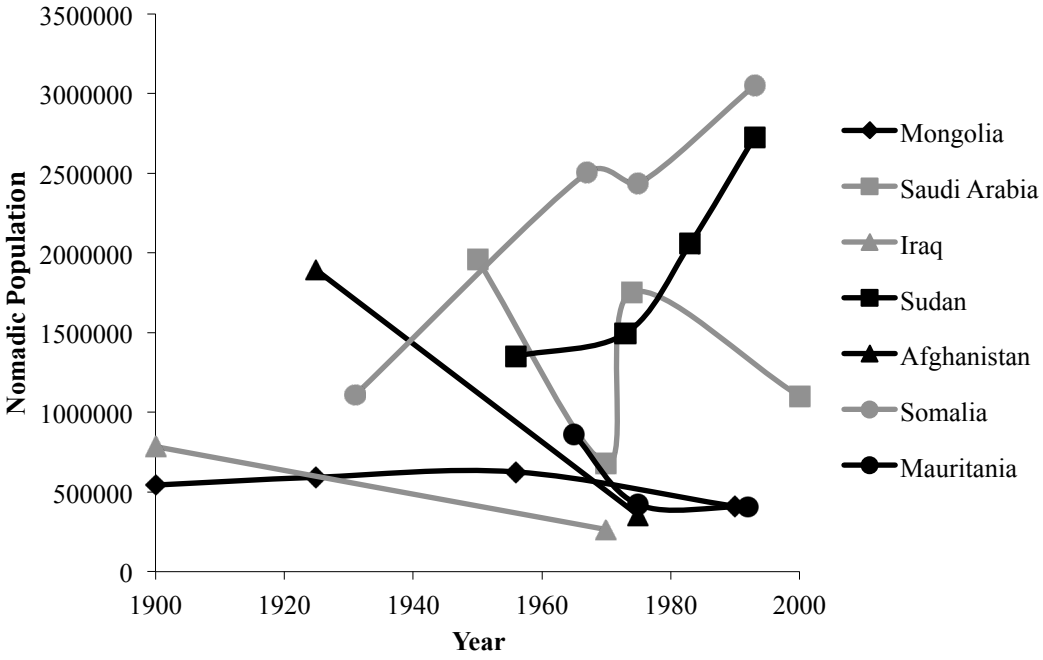

Figure 3. Total nomadic population between 1900 and 2000 (n=7).

In most cases, the amount of highly anthropogenically altered land—urban, village, and cropland—increased from 1900 to 2000, therefore resulting in a decrease in land available for pastoralism (mean change in available land -12.5%, S.D. ±15.8%, Figure 5).

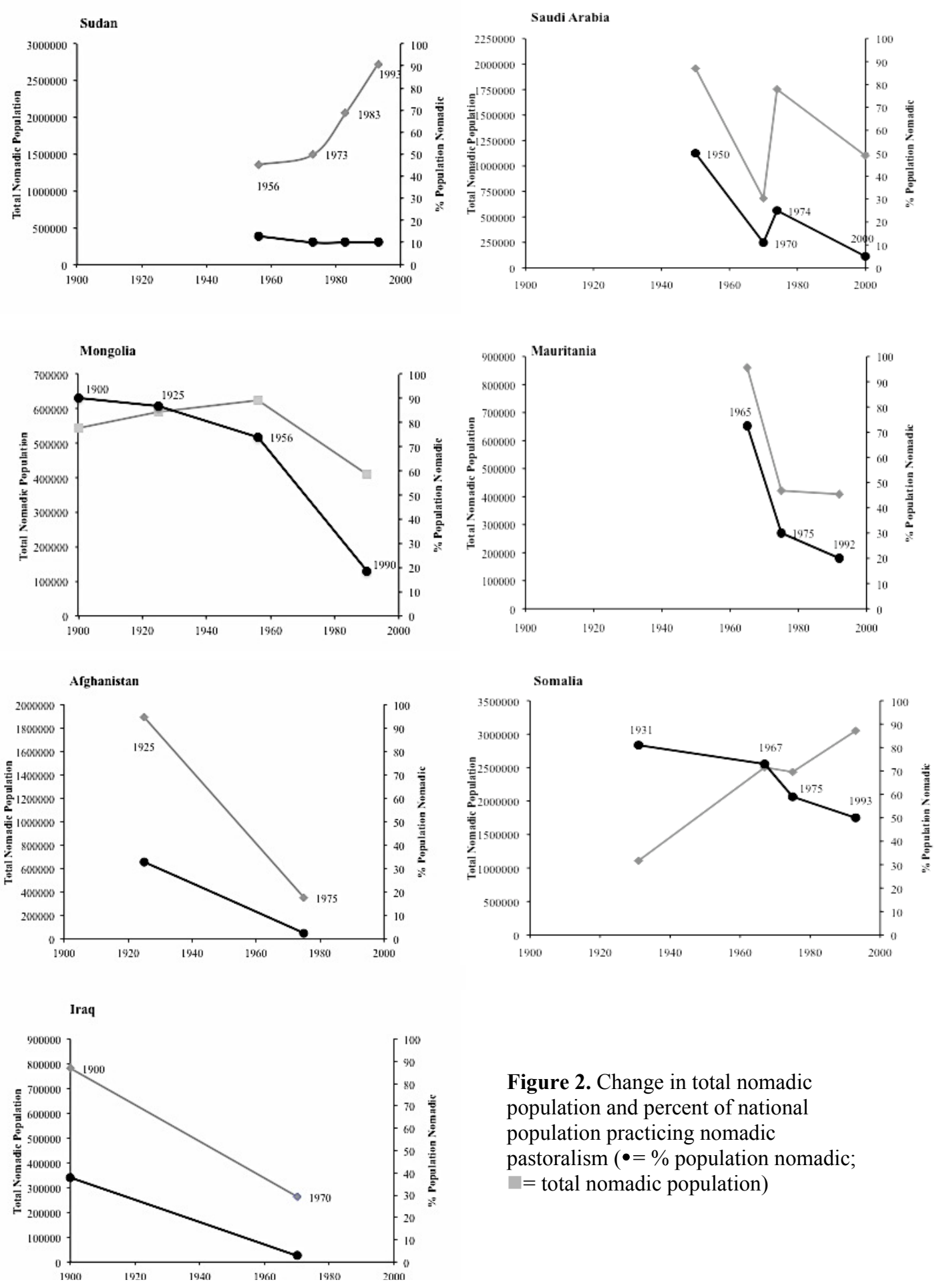

Figure 2. Change in total nomadic population and percent of national population practicing nomadic pastoralism (•= % population nomadic; ■= total nomadic population)

However, though this trend was visible, it was not statistically significant (paired t-test, p=0.07). In Mongolia, there was an estimated decrease in urban land, possibly because of a change in the categorization of land use in this country between the 1900 and 2000 mappings by Ellis and Ramankutty (2010). Iraq and Afghanistan had the largest relative losses of open land, followed by Somalia and Sudan.

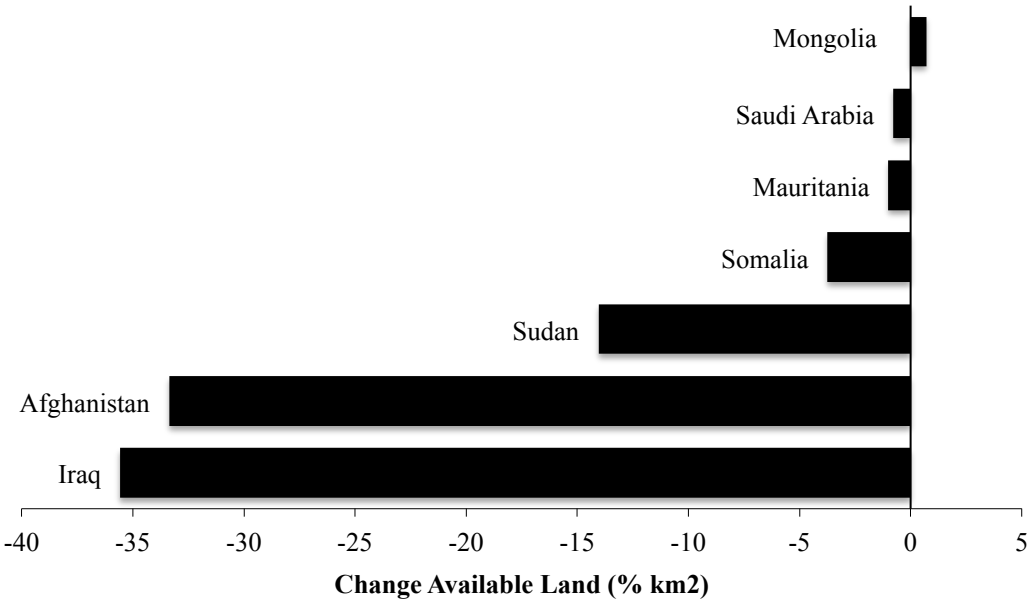

Figure 3. Percent change in land available for mobile pastoralism (% Δ km^2) (n=7).

When Somalia and Sudan were excluded, there was a negative correlation between the increase in developed land and decrease in total nomadic pastoralist population (Figure 6, r^2=0.84).

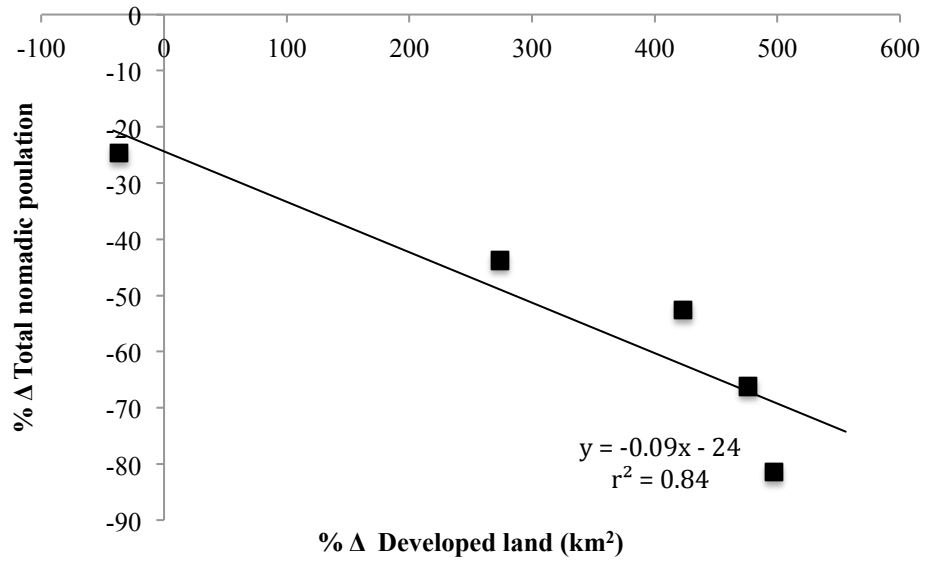

Figure 4: Relationship between change in developed land and change in nomadic population between high and low timesteps ($y=-0.09x - 24$, $r^2=0.84$, excluding Somalia and Sudan).

Most nations experienced a decrease in nomadic population density (Figure 7), with a mean change in density of -0.008 (S.D. ±1.58). The exceptions were again Somalia and Sudan, which each had an estimated increase in population density of at least 50%, from approximately 0.5 to 1.25 in Sudan and 1.75 to over 5.0 in Somalia.

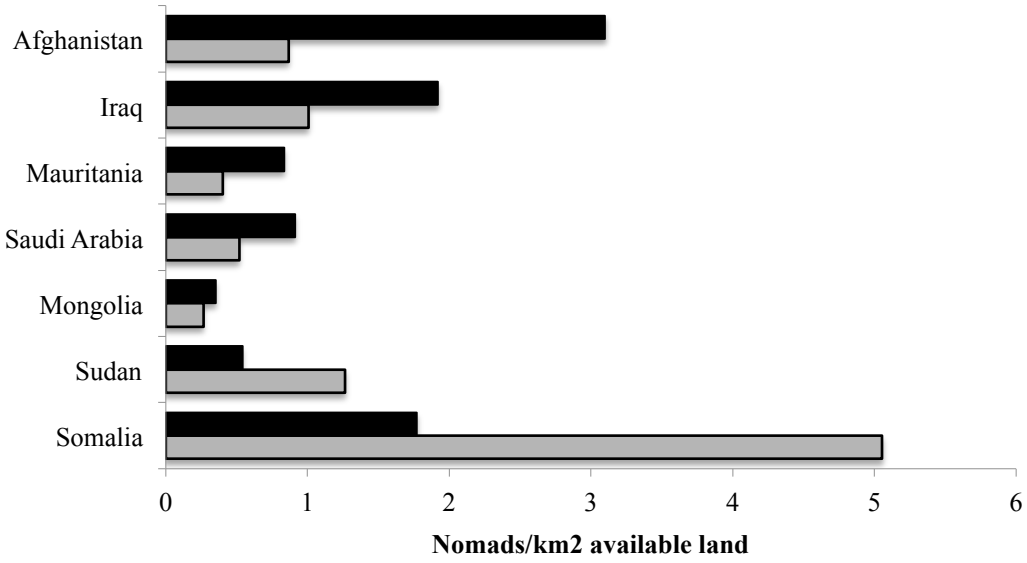

Figure 7. Nomadic population density (nomads/km^2) in 1900 and 2000 (■= 1900, n=7, ■ = 2000, n=7).

Several coinciding effects were especially notable: Afghanistan, Iraq, and Sudan experienced the largest decreases in open land, but only Sudan had an increase in nomadic population density, with Afghanistan and Iraq having some of the largest decreases in nomadic density. Somalia had a nominal decrease in open land but a large increase in nomadic population density. Mongolia remained relatively stable in both land and nomadic population density. Mauritania and Saudi Arabia both had small relative losses of about 1% of total undeveloped land, but both still showed decreases in nomadic population density of almost 50%.

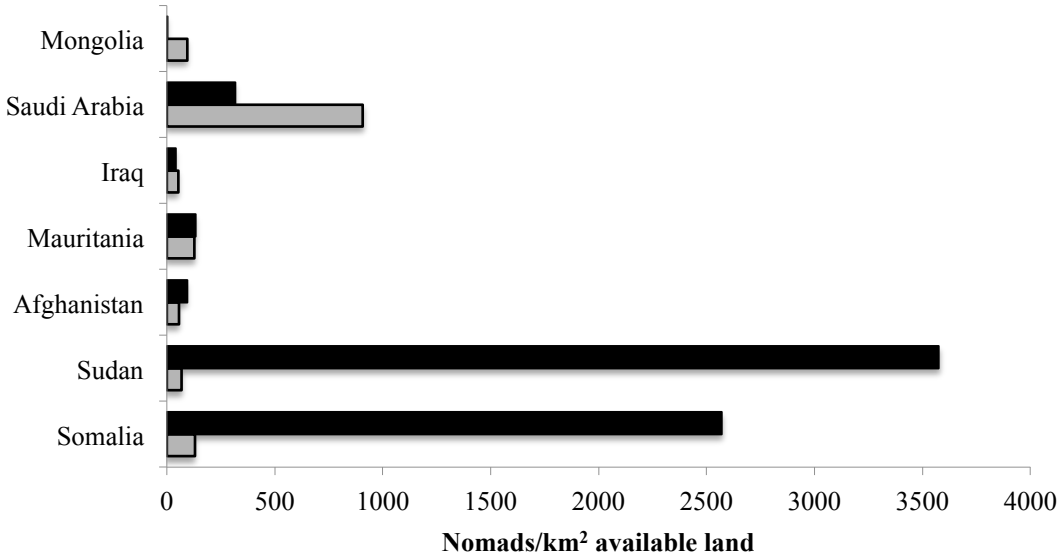

Figure 8. Sedentary population density (nomads/km^2) in 1900 and 2000 (■= 1900, n=7, ■ = 2000, n=7).

In Sudan and Somalia, the calculated sedentary population density decreased dramatically, while nomadic population density in those same countries had increased (Figure 9). Sedentary population also decreased in Afghanistan and Mauritania, but increased in the remaining three countries (Mongolia, Saudi, and Iraq, Figure 8). In Mauritania and Afghanistan, both nomadic and sedentary population densities dropped, while in Iraq and especially Saudi Arabia, sedentary population density increased while nomadic density decreased (Figure 9). The change in sedentary population density was not calculated for Mongolia, because of the previously mentioned data discrepancy.

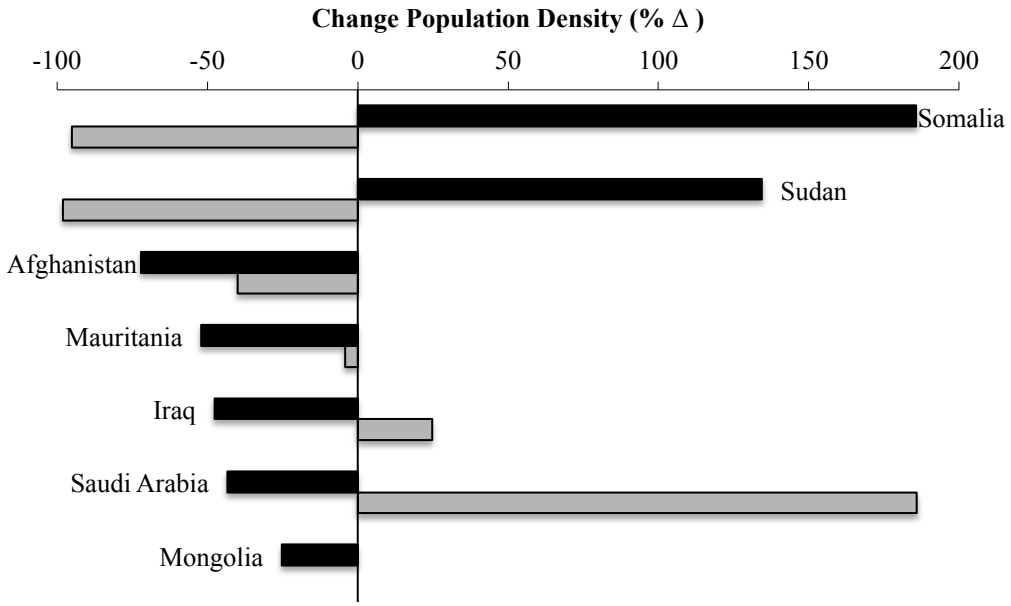

Figure 9. Percent change of population density (persons/km^2) between 1900 and 2000 (■= % Δ nomadic population density, n=7, ■= % Δ sedentary population density, n=6 [Mongolia excluded]).

Plotting the area of developed land falling in each of the anthrome classes 11-34 in 1900 and 2000 (Figure 10) also showed varied distribution of total gains in developed land between cropland, urban lands, and villages among the study countries. Saudi Arabia, Mauritania, and Iraq had larger relative increases in urban lands, while most of the other countries' increases in developed lands were mainly in croplands and, to a lesser extent, village lands.

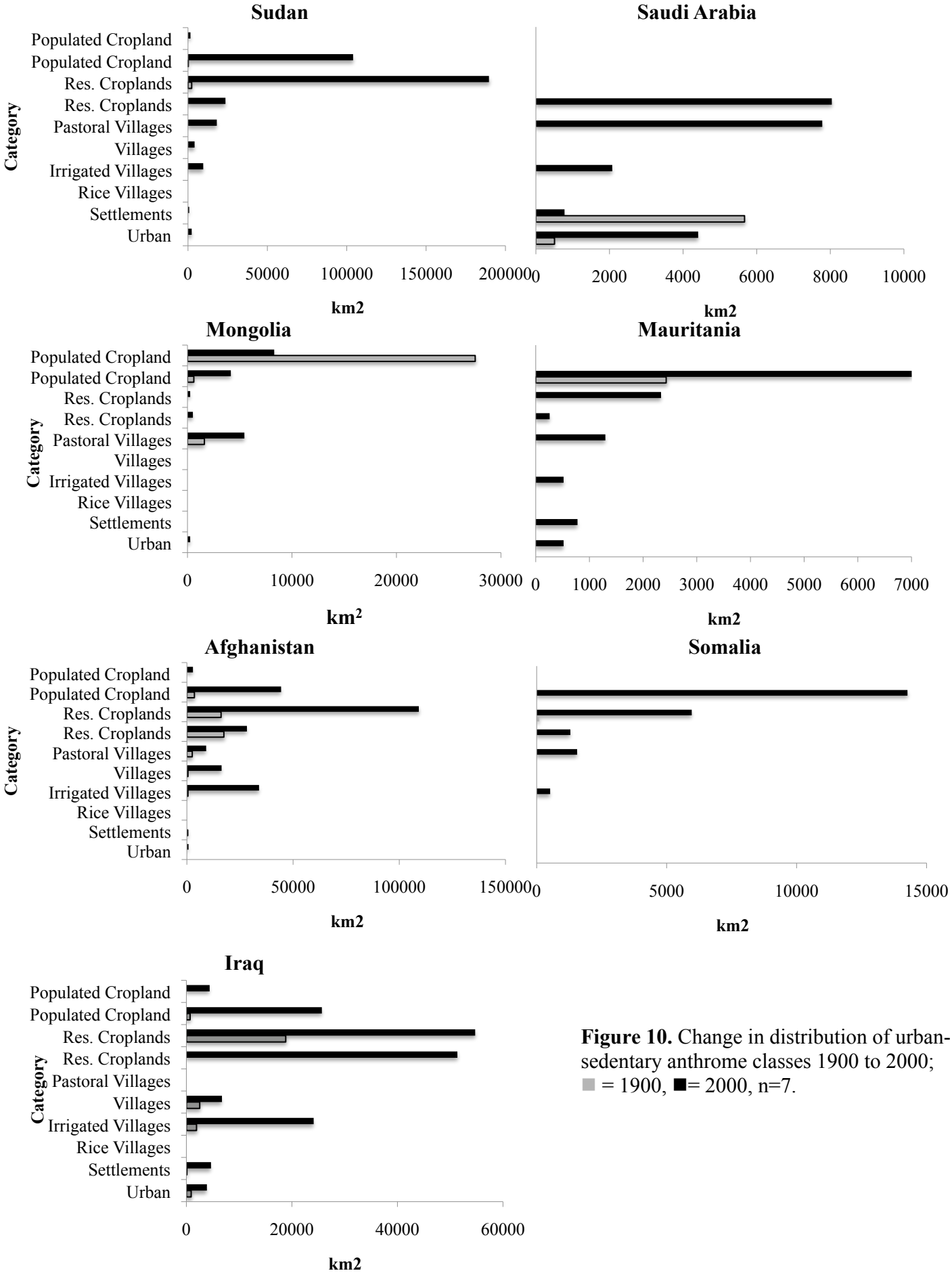

Figure 10. Change in distribution of urban-sedentary anthrome classes 1900 to 2000; ■ = 1900, ■= 2000, n=7.

Discussion:

I hypothesized that my analysis would delineate a cross-national trend linking decreases in available open land to decreases in nomadic populations. I also hoped to shed further light on the relationship between nomadic and sedentary societies, so I hypothesized five possible population density outcomes in each country, which would each depend on the amount of habitat lost and the rate of change in nomadic populations. I did find a possible correlation between increased anthropogenically altered land and declining nomadic populations, but causation remains unclear, and the high variability in population density outcomes among the study countries suggests that social factors often overshadow the absolute ecological impacts of habitat loss on nomadic pastoralist populations.

Though only loosely, the results of declining nomadic population and decrease in available pastoralist habitat do fit the hypothesis that both available, undeveloped land and nomadic populations would decline in tandem. There was a significant overall decline in the proportion of all countries' populations practicing mobile pastoralism, but no significant change in the total nomadic populations (Figure 3, Figure 4). There was a quantitative overall increase in anthropogenically altered land and reciprocal decrease in land available for pastoralism, but this trend was also not significant. Many factors may have decreased the clarity of this overall trend: in Somalia and Sudan, both developing countries with high birth rates, the high overall population growth rate may have outstripped nominal decreases in the ratio of nomads to their sedentary counterparts, equaling a calculated increase in the nomadic population, where population increases may have mainly been only in sedentary populations. Political and economic unrest may also encourage people in these nations to rely on more traditional economic strategies for survival. In Saudi Arabia, because total nomadic

population was calculated based on the total national population, the nomadic population may have been highly overestimated if "total" national population also included migrant laborers, who comprise a large proportion of the Saudi workforce. Saudi Arabia and Somalia also had several competing estimates of nomadic population during the 1960s and 1970s (see Figure 4, Saudi Arabia and Somalia). Only when Sudan and Somalia were removed as outliers for extenuating social situations does a significant trend emerge linking increases in developed land to decline in total nomadic population (Figure 6). This may imply that ecological factors such as habitat loss are only salient to nomadic population change when sedentary society is relatively stable.

In general, there was a relatively small percentage of available land lost: less than 10% in four of seven cases, though available habitat—mostly rangelands and wildlands—in Afghanistan and Iraq decreased by over 30%. The effect of land loss on nomadic pastoral subsistence may be nonlinear, with small losses in land equalling large losses in productivity, promoting increased sedentarization or declines in family size, etc. The area of land lost may also have been the most productive land; though pastoralism often takes advantage of land not suitable for other forms of production, the increasing relegation of pastoralists to poorer-quality land may also affect their adaptability and survival. It is also possible that more refined technology, improved animal husbandry, increased access to medical care and food relief, or help from sedentary neighbors may mediate the effects of actual habitat loss.

Even if the land lost was not the most productive, it may have still been important "corridor" land vital to maintaining mobility and access to seasonal pastures for nomadic pastoralists; land enclosure and changes in land tenure policies are often cited as obstacles to maintaining mobile pastoralist economies (Ikeya and Fratkin 2005, Humphrey and Sneath

2005). Perhaps one of the most interesting follow-up studies to my research would be to more closely examine the effects of habitat fragmentation on changes in nomadic populations: do nomadic populations decline more in countries where the remaining habitat is more fragmented? Habitat loss is often subsumed into discussions of the effects of fragmentation and vice versa (Fahrig 2003): habitat fragmentation per se does not necessarily have a negative effect, as many habitats are naturally fragmented, and factors such as patch quality, matrix quality between patches, and distance between patches also affect populations (Thomson, lecture, 2011). However, studies have shown the negative effects of both habitat loss and habitat fragmentation specifically, depending on the mobility and dispersal ability of the species (Thornton 2011). Decrease in area *and* increase of patchiness in an ideal habitat may affect abundance of human populations, as it does in nonhuman ecosystems. ArcGIS could be used to calculate the degree of fragmentation of undeveloped lands in each nation: once developed and undeveloped lands are lumped into two classes of polygons, the ratio of the area of undeveloped land to the length of borders with developed land could be calculated to give a metric of fragmentation in each country. This could lend further insight into how quantitative habitat loss is qualitatively different in each country.

The probable error margins on all the population statistics used in this research are also undoubtedly high. They were gleaned from the work of many different researchers with different research practices, and some researchers' estimates of nomadic populations may have been biased by political leanings: where nomadism is considered backward and undesirable, it may be advantageous to underestimate their populations. Precise estimations of nomadic populations are not easy (noted in Blench 2001); nomadism is not usually a byline on any census, and even ethnicity is not an exact metric for the subsistence practice of

individuals. Nomadic groups are also, by definition, mobile and often ignore all but the most guarded borders. Despite the weaknesses in the data—mainly the inconsistency of the datapoints for nomadic populations between countries, and the lack of detailed information on land use practices in each of the investigated countries—the analysis did predict 1900 nomadic population densities within the range expected by Smil's (1991) estimation of normal nomadic population densities (between 0.8 and 2.2, see Figure 7). Though it is very possible that the high levels of "noise" and variability of nomadic populations may still cloud any sound predictions based on my analysis, this lends some credence to my methodology.

Specific Outcomes

The general correlation of my two main datasets supports the hypothesis of a connection between ecological habitat loss and decline of nomadic populations, but causation remains unclear. Examining the nomadic and sedentary population density estimations in each of the study countries over time lends further insight into the role of social factors in the above trend. Each of my hypothesized possible outcomes could be identified in one or more of the seven study nations.

1. **Habitat decrease + increase in nomad population density: Sudan and Somalia**

Sudan and Somalia both experienced a loss in open land (Figure 5) and an increase in nomadic population density (Figure 7). This could imply an impending faunal relaxation and crash in the nomadic population, an effect that would be more obvious if these countries had also had a decreased or stable total nomadic population, though in actuality both Sudan and Somalia had large overall increases in nomadic population. However, both countries also experienced large decreases in sedentary population density (Figure 8), which seems counterintuitive, except that sedentary density was calculated across urban lands, village

lands, and croplands: in both Sudan and Somalia, there was very large increases in developed land mainly in croplands (Figure 10), and the rapid expansion of croplands and other occupied lands may have caused this large decrease in calculated sedentary density. It is possible that this expansion of croplands is contracting the nomadic population, increasing nomadic population density and possibly encouraging a future crash, though modern technology and access to healthcare—for both pastoralists and their herds—may be able to sustain these increased population densities.

2. Habitat decrease + decrease in nomad population density: Iraq and Afghanistan

In both Iraq and Afghanistan, nomad population seems to have decreased faster than land use, resulting in a decrease in nomad population density (Figure 7). This may indicate that social push factors for sedentarization and urbanization were more important that ecological factors for the decline of nomadic populations.

Estimations of changes in the sedentary population density in Iraq and Afghanistan indicated an increased sedentary density in Iraq and a decreased sedentary density in Afghanistan (Figure 8), though far less dramatically than Saudi Arabia, Sudan, or Somalia. Afghanistan and Iraq had large increases in cropland, but both countries also had larger increases in village and dense urban lands than in either Sudan or Somalia (Figure 10). Iraq, however, had much larger increases in dense urban lands than any of these four, possibly causing the estimated increase in sedentary density in Iraq. From this, we may guess that expansion of settled agriculture and movement of pastoralists into urban and sedentary society may have caused the decrease in nomadic population density, while the higher ratio of expanding sedentary lands to population increase in Afghanistan resulted in its decrease in sedentary density compared to Iraq. The variation between these two countries, though both

fall into the second outcome, supports the idea that the process of change in nomadic populations is subject to powerful social forces that vary between countries depending on societal trends such as urbanization.

3. **Habitat decrease + constant nomad population density**

Because nomadic population density—and sedentary population density—changed considerably in most countries (Figure 7), it seems unlikely that there is a clear linear relationship between habitat loss and nomadic population change, but that other supra-ecological factors are in fact playing a larger role in affecting these changes. Because the change in nomadic population density was not technically significant (mean -.008 S.D. ±1.58), it could be argued that all countries, by default, fall under this outcome. But by this logic, one would point out that the decrease in habitat was also not significant, so no change occurred at all—also unlikely.

4. **Habitat constant + change in nomad population density: Mauritania and Saudi Arabia**

In both Mauritania and Saudi Arabia, there was relatively little open land lost, but there was still a large decrease in the nomadic population density by about half (Figure 7). This indicates that either social push factors were more important than actual habitat loss, or that the small amount of habitat lost was vital to pastoralism—quite possible in countries like Saudi Arabia and Mauritania with large percentages of unproductive desert land.

5. **Habitat constant + constant nomad population density (stable): Mongolia**

Mongolia ostensibly lost very little of its large total area, though again, discrepancy in land classification caused the data to show an actual increase in available land, which is unlikely, making estimation of population density changes difficult. Mongolia may in reality

fall under outcome #3 or #4, but the distinction may be subtle because of Mongolia's very sparse population. Mongolia's total nomadic population did purportedly decrease by approximately 24% between 1900 and 1990, implying some change in nomadic lifestyle practices: Soviet collectivization in the early 20th century also adds another level of social complexity to the history of nomadism in Mongolia over the past century. Other studies suggest that the disintegration of formal and informal cultural institutions that had historically regulated the use of pasturelands have decreased nomadic mobility: changes in administrative land boundaries have limited the areas open to grazing and migration, decreasing the range of areas available to pastoralism, resulting in environmental degradation because of overgrazing (Fernandez-Gimenez 1999). The "tragedy of the commons" would seem to have more of an effect when traditional cultural checks and balances break down. Even if habitat area is statistically constant, fragmentation and changing land tenure practices may still be affecting nomadic populations.

Examination of these outcomes indicates that social factors, such as changes in national land use policy, urbanization, and economics may be more important and variable than I hypothesized, and seem to overshadow the direct effects of habitat loss, though changes in land use are still salient issues for nomadic pastoralist subsistence. Though these results imply the relative impossibility of generalizing the environmental relationship of nomadism to land development with the current data, perhaps if we cannot think about human cultural systems ecologically, it may still be possible to think about sociocultural interactions as cultural ecosystems.

Because all countries had a decrease in the percentage of the overall population practicing nomadic pastoralism, there is evidence that an inherent change in balance between sedentary and nomadic populations is occurring, and even small local disappearances of nomadic pastoralism may be worrisome for the cultural diversity of the human ecosystem. As in non-human ecosystems, where more biodiverse ecological communities have been shown to be more resistant to invasive species and to ecosystem collapse (Zavalata et al. 2004, Worm *et al.* 2006), it is possible a loss in cultural diversity may result in decreased overall societal adaptability. Nomadic pastoralism may be a minority social group in most countries, but as in other ecosystems, losses in the most rare species can result in decreased resistance to invasive species and disease (Lyons and Schwartz 2001). Studies of ecosystem function (the economic productivity of a given ecosystem) have also shown that loss of any diversity in an ecosystem can severely decrease functional production (Worm *et al.* 2006): decrease in mobile pastoralist populations may indicate a decrease in the resilience and overall function of the naturally diverse human ecological system.

Edge zones, whether they are edges between different ecological habitat types or between cultural groups, as in the historical interactions between nomads and sedentary groups, are usually the most diverse. The exchange between cultures that occurs at these edges can promote resistance to disaster and promotes long-term societal persistence, because of the sharing of technologies, economic strategies, and cultural ideas (Turner et al. 2003). The site of the nomadic-sedentary continuum, I believe, represents an edge zone within the human biosocial ecosystem, which includes urban cities, suburbs, as well as the sedentary farmers that nomadic pastoralists commonly associate with. Decline of this edge-zone may indicate future decline in the flexibility and productivity of the whole ecosystem,

and by losing the diversity of strategies and perspectives represented by a diversity of cultures and cultural practices, humanity as a whole loses some of its potential to adapt to future problems to which the globalized status-quo is not suited (Muhlhausler 1995**,** in Maffi 2005).

The general decrease in prevalence of nomadic pastoralism in this human-ecological system, along with the increase in anthropogenically altered land, implies that nomadic populations, as well as the biocultural diversity of these regions, are being altered by increased sedentary dominance over the landscape. Awareness about changes in nomadic pastoralist populations is important for understanding loss of overall biocultural diversity, as well as for awareness of the status of indigenous rights worldwide.

Cultural Implications for Nomadic Populations

Increased social influence of sedentary nations could imply long-term cultural changes for (former) nomadic pastoralists. Entrance into the cash economy, increased draw to cities due to urbanization, and the lifestyle changes inherent in sedentarization all may become more and more affective as the historic sedentary-nomadic relationship becomes more and more imbalanced in the contemporary biosocial ecosystem.

A change in economic practice implies a change in the normal social interaction in nomadic pastoralist culture. In *Making a Market* (1992), Ensminger examines the movement of the Orma pastoralists of Ethiopia to a cash economy: she notes how the ideology or "moral economy" of helping, sharing, etc. is put into opposition with the market forces of the new cash economy. The "real income" of the poorest individuals did increase once the switch was made, but I see this as still showing that the change in the market made a change in the practiced ideology of the culture, which implies certain psychological consequences. The

cash economy created a gradient of richer and poorer, making collective decisions, such as those involving public grazing, difficult because of the economic disparities between parties. In his heartfelt essay about the spiritual link between contemporary social problems—such as alcoholism and domestic abuse—in Native Alaskan communities and the trauma of the cultural loss associated with the Great Death epidemics in the early 20th century, Harold Napoleon (1996) links these problems specifically to the loss of the traditional way of thinking about and living in the environment, called *yuuyaraq*. Though cultural change is natural and expected over time, it can have lasting negative impacts on the psychology of individuals. For nomadic pastoralists, the decline in nomadism described in this study may imply a coming period of transition that may take time to reach a new equilibrium.

Future Studies:

The study of global trends in indigenous land use may benefit from further research on the interrelation of sedentary and nomadic cultural and biological systems. It is possible that a more refined and sensitive model could more exactly capture this human ecological system. However, pastoralists' "tropical arid" and "semi-arid" lands may be difficult to predict based on Western models, as they are more subject to boom-and-bust and dynamic disequilibrium patterns than more predictable temperate grasslands, upon which most of these models are based (Homewood 2008).

Improvements to the methodology used in this study could include:

- Inclusion of more countries into the study for broader comparison
- Addition of more population statistics in more regular timesteps
- Addition of information sedentary and nomadic demographic trends affecting both nomadic and sedentary populations

- Identification and exclusion of open lands unused by pastoralists in each specific country, such as desert lands or forest lands, depending on local pastoral practices
- Case-by-case qualification of land "loss" to cover physical loss, loss of access, fragmentation, environmental degradation, etc.
- Further analysis of Ellis and Ramankutty (2008) methodology for error and sources
- Further detail in land use patterns, adding more timesteps to give a clearer picture of the acceleration or deceleration of land use change over the last 100 years

Through this research, I hoped to investigate the human-ecological relationship by attempting to examine the biogeographic changes in nomadic pastoral populations across continents over the last century. Though a clear causality between habitat loss and declining nomadic populations was not identified, this research may imply a natural balance between human groups and their cultural and biological environments that is disrupted by changes in power dynamics and their subsequent environmental impacts. A parallel kind of research might be illustrated in the work by Harmon and Loh to create an "Index of Biocultural Diversity," to show the connectivity between cultural/linguistic diversity and biological diversity of countries worldwide (in Maffi 2005): Harmon and Loh describe in depth the limitations of their study, and stipulate that it is meant to be a general look at overall trends, and a tool to promote political action to protect biocultural diversity, not as an exact predictive model. I hope that trying to blend the vocabulary of science with the nuance of anthropology will help make cultural concepts accessible to policy-makers, aid agencies, and other decision-making bodies unfamiliar with the importance of biosocial diversity.

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Appendix 1:

Table 1. Description of Anthrome Classes (From Ellis and Ramankutty 2010)

Dense settlements: Urban and other dense settlements

11	Urban	Dense built environments with very high populations
12	Mixed settlements	Suburbs, towns and rural settlements with high but fragmented populations

Villages: Dense agricultural settlements

21	Rice villages	Villages dominated by paddy rice
22	Irrigated villages	Villages dominated by rainfed agriculture
24	Pastoral villages	Villages dominated by rangeland

Croplands: Lands used mainly for annual crops

31	Residential irrigated croplands:	Irrigated cropland with substantial human populations
32	Residential rainfed croplands	Rainfed croplands with substantial human populations
33	Populated rainfed cropland	Croplands with significant human populations, a mix of irrigated and rainfed crops
35	Remote croplands	Croplands without significant populations

Rangeland: Lands used mainly for livestock grazing and pasture

41	Residential rangelands	Rangelands with substantial human populations
42	Populated rangelands	Rangelands with significant human populations
43	Remote rangelands	Rangelands without significant human populations

Seminatural Lands: Inhabited lands with minor use for permanent agriculture and settlements

51	Residential woodlands	Forest regions with minor land use and substantial populations
52	Populated woodlands	Forest regions with minor land use and significant populations
53	Remote woodlands	Forest regions with minor land use without significant populations
54	Inhabited treeless and barren lands	Regions without natural tree cover having only minor land use and a range of populations

Wildlands: Lands without human populations or substantial land use

61	Wild woodlands:	Forests and savanna
62	Wild treeless and barren lands	Regions without natural tree cover (grasslands, shrublands, tundra, desert and barren lands)