DISSERTATION

CULTIVATING THE SAVANNA: IMPLICATIONS OF LAND USE CHANGE FOR MAASAI LIVELIHOODS AND WILDLIFE CONSERVATION IN EAST AFRICA

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY STACY JOY LYNN ENTITLED CULTIVATING THE SAVANNA: IMPLICATIONS OF LAND USE CHANGE FOR MAASAI LIVELIHOODS AND WILDLIFE CONSERVATION IN EAST AFRICA BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

CULTIVATING THE SAVANNA: IMPLICATIONS OF LAND USE CHANGE FOR MAASAI LIVELIHOODS AND WILDLIFE CONSERVATION IN EAST AFRICA

People and animals have co-evolved with intact, unfragmented rangelands in most drylands of the world, where pastoral livestock-based economies have existed for thousands of years. In East Africa, however, Maasai pastoral land use is changing so that cultivation is increasingly incorporated into the repertoire of livelihood regimes. The Tarangire-Manyara Ecosystem (TME) of northern Tanzania includes two national parks (Tarangire NP (TNP) and Lake Manyara NP (LMNP)), but these protected areas cover only 15% of the ecosystem. The remainder of the ecosystem is comprised of village lands where people and wildlife share the landscape. Managers assume that cultivation in the village lands of the Simanjiro Plains east of TNP will interfere with wildlife migrations into the villages to access important wet season water and forage resources. However, to date no research has explicitly measured the response of local wildlife to cultivation. Additionally, the local history of non-participatory wildlife administration and past land evictions, combined with fears of potential park expansions, has led to decades of tension between TME wildlife managers and local residents. If native species will tolerate levels of fragmentation currently assumed to be detrimental, then there may

be flexibility to balance landscape and livelihood sustainability, as well as an opportunity to ease conservation-livelihood conflict.

In 2003 I conducted 207 household interviews in three Simanjiro villages (Sukuro, Loiborsoit and Emboreet) on the topics of land use, household demographics and livelihoods, human-wildlife conflicts, and perceptions of conservation and wildlife. In the wet season of 2004, after wildlife had dispersed onto village lands, I conducted a multi-method and multi-scaled wildlife study to determine species-specific wildlife responses to cultivation in Simanjiro. The species of interest were primarily zebra, wildebeest and Grant's and Thompson's gazelle. Data were also collected on livestock so that the impact of livestock densities could be considered in the interpretation of wildlife density distributions.

Six 5-10 km^2 sampling areas (SAs) were selected across a 500 km2 portion of the village landscape to cover a gradient of cultivation density. Animals were counted from a vehicle approximately every three weeks, and each group's location was triangulated to a point on the landscape. Eight 1m x 1^{+}km exterior transects originating at the edge of cultivated fields in the study SAs were also walked to obtain print counts along a distance-to-edge gradient to attain information on unobserved nighttime movements. A paired interior 1m x 50m interior transect was also walked. Using a geographic information system (GIS) I developed a distance-weighted cultivation density metric, *cultivation intensity* (CI), which I used to compare observed wildlife distributions to a null model composed of 30 randomized re-distributions of the observed data to detect landscape-scale wildlife responses to cultivation. I then analyzed transect data both to detect edge effects of cultivation, and to identify problem crop-raiding species and landscape-level patterns of raids.

Integration of multiple scales of analysis, plus information on human-wildlife conflict obtained from interviews, suggests that dense cultivation repels migratory wildlife at the landscape scale, but benefits cultivators due to less wildlife ingress and damage. Conversely, scattered cultivation allows wildlife passage but encourages crop invasion. Interview data reveal that despite the risk of crop failure in this semi-arid ecosystem, cultivation is an important component of contemporary pastoral livelihoods, boosting food production, maintaining livestock herds, and buffering household vulnerability. The conservation of wildlife generates monetary benefits for the country of Tanzania, but these benefits rarely reach local people who bear the costs of wildlife through land loss and direct and indirect conflicts with the predators and herbivores that threaten their safety and livelihoods. As a result there is no incentive, monetary or otherwise, for people to conserve wildlife. The costs are too high. Conversely, the benefits of cultivation are felt primarily at the local level and costs perceived at the national level in terms of wildlife conservation.

Emergent research findings suggest that concentrating cultivated plots in large clusters on the landscape would allow subsistence farming to continue with potentially minimal impact on wildlife beyond the boundaries of the clusters. Concentrated plots would also produce less edge, reducing wildlife intrusions with effective guarding. However, the combination of weak land rights and expectations of further land dispossession encourage dispersed cultivation as a means to claim land ownership. In addition, risk to patchiness of rainfall may be accentuated through a clustering arrangement.

The cumulative change to the TME landscape over the last decade has been astonishing, and will only continue in the absence of conservation planning that is truly collaborative and provides for the livelihood of local people.

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Dedication

This dissertation is dedicated to Jim Ellis: advisor, mentor, and friend.

You have been greatly missed on this journey, but your words still inspire.

Thank you.

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CHAPTER 1

INTRODUCTION

LAND-USE CHANGE AND CONSERVATION IN AN EAST AFRICAN PASTORAL LANDSCAPE

BACKGROUND

Around the world, expansion and intensification of human land-use outside of protected areas is resulting in changes in ecological function and biodiversity within protected areas, and sub-optimal management and conservation outcomes (DeFries et al. 2007; Hansen and DeFries 2007). The use of land to provide goods and services for human use results in an extensive human alteration of the Earth system, impacting the structure and function of ecosystems (Vitousek 1997). In particular, clearing native vegetation to plant crops is one of the most important and extensive anthropogenic causes of natural habitat loss worldwide (Myers 1980).

Protected Areas (PAs) are typically established to protect one or more resources from over-exploitation by people. Not even the largest protected area is ecologically isolated from surrounding activities and conditions (Freemark 2005). Because PAs are often parts of larger ecosystems, land-use change in the unprotected portion of the ecosystem may lead to changes in system function and biodiversity inside of the protected area boundaries (Hansen and DeFries 2007).

This relationship works conversely as well, since human-inhabited ecosystems that pre-date creation of a protected area may see a decline in function and access to diverse and widespread resources with PA establishment. African protected areas in particular have expanded significantly in the past 30 years, but the capacity of these areas to support viable populations depends on human influences both inside and outside of reserves that can lead to reserve degradation and isolation (Newmark 2008). Improved access to scientific information could help decision makers anticipate potential consequences of land-use change, and thus avoid unintended ecological effects (Theobald et al. 2005). Unintended effects may include social consequences as well. Understanding of the inevitable tradeoffs between human land-use and biodiversity conservation is essential for effective conservation planning and sustainable land management (Huston 2005).

Across East Africa, the relationship between land-users and governments/conservation agencies is characterized by debate regarding the impacts of land-use on the landscape, wildlife, and biodiversity in general. This is particularly true in areas of high wildlife concentrations bordering protected areas where people and wildlife co-mingle and share the landscape and its resources. In many areas conflict has arisen among land-users and between land-users and land managers, since the consequences of changing land-use are felt by people, their livestock, vegetation, and wildlife alike.

Pastoralism has existed in East Africa since 3000 BC. While early Maasai did cultivate in addition to herding livestock, a series of droughts in the eighteenth and nineteenth centuries reinforced specialized Maasai livestock herding under the difficult conditions (Spear and Waller 1993). Complex exchange networks assisted in insuring against catastrophic losses by scattering herds amongst associates (ibid). Access to other resources was maintained through multi-cultural exchange and networks outside of Maasai society (ibid) These relationships and semi-permeable social and ethnic boundaries became the primary control of access to critical resources (ibid). These negotiated relationships still exist today, but colonialism, new policies, education, development and modernization have all influenced trajectories of change for Maasai.

Today, Maasai pastoralists reside in the plains of semi-arid southern Kenya and northern Tanzania. Other cultures including agriculturalists and hunter-gatherers are interspersed with Maasai and other pastoralist groups in this area, but the semi-arid plains are primarily occupied by Maasai livestock herders. The focus of this study is the 20,000 km^2 Tarangire-Manyara Ecosystem (TME) of northern Tanzania, an ecosystem comprised of management zones ranging from two strictly protected national parks, Tarangire National Park (TNP) and Lake Manyara National Park (LMNP), to the largely unregulated (at the national level) pastoral village lands of the Simanjiro Plains east of TNP. The primary shift in land-use in Simanjiro has been an increase in cultivation that has precipitated a change in landscape appearance and likely function.

The reason that land-use change in this area is so interesting is that migratory wildlife spend greater than six months of any given year outside the protected areas during the wet season, grazing alongside domestic livestock in the ‘unprotected’ pastoral rangelands. Since forage inside park boundaries is insufficient to sustain these wildlife year-round, maintenance of wildlife access to these pastures has been a focus of Simanjiro conservation initiatives for decades. At the same time, these pastures sustain pastoral livestock herds and support intermittently-successful dryland cultivation by both locals and outsiders.

Most Maasai pastoralists do not realize direct benefits from conservation, or perceive its relevance to their livelihoods (Galvin 2009). But that does not mean that they do not recognize benefits of protecting the natural resource base that their livestock, and in turn they, depend upon. While Maasai themselves historically did not cultivate, there is a long history of trade with agriculturalists to obtain grain foods (Spear and Waller 1993). Cultivation by pastoralists themselves, while bringing this land use to a more marginal and variable environment, also brings it within the control of the household, increasing the number of available options for food production, thereby increasing adaptability and resilience to livelihood threats. However, cultivation in these arid and semi-arid zones may negatively impact wildlife, depending on the effect that cultivation has on wildlife access to foraging landscapes, and the contribution that it may actually make to their diets.

There are many anecdotal accounts of Maasai being "custodians of wildlife," yet few attempts to understand the practical relationship between Maasai and wildlife exist (Goldman 2003; Roque de Pinho 2009). These relationships are important in Simanjiro because, as in many areas of northern Tanzania and southern Kenya, wildlife move between seasonal zones that cross protected area boundaries and village lands, and depend on these extensive movements to maintain their access to necessary resources

(Western 1989; Voeten 1999; Voeten and Prins 1999). The impacts of land-use and land-use change for both livelihoods and wildlife, and the interactions between people and wildlife, are key to long-term ecosystem sustainability. The overall objective of this research is to measure the impacts that pastoral land-use change in Simanjiro villages has for household economies and wildlife distributions.

Arid & Semi-Arid Systems

Arid to semi-arid rangelands cover approximately one-third of the Earth's land surface (Galaty and Johnson 1990). Rangelands encompass vegetation formations that range from grassland with or without shrubs, bush, woodland, and savannas. The term "rangeland" recognizes the spatial, temporal and ecological continua across which these habitats occur in arid and semi-arid lands, as well as the often transitory state of the systems themselves (Homewood 2004). Vegetation structure varies from 100% grass cover, through woodlands with up to 80% canopy cover, to pastures within dense forest (Lambin et al. 2001). Some rangelands may be determined either edaphically or climatically (Sankaran et al. 2005), however the activities of resident and migratory wild grazers and browsers along with those of people and their livestock also impact vegetative structure. In fact, research has demonstrated that, rather than being a source of widespread degradation in tropical rangelands, grazing livestock actually serve to maintain these areas (Oba et al. 2000).

Rainfall is a dominant driver of semi-arid land cover and constrains human land-use (Ellis and Galvin 1994). Temporal rainfall patterns influence the balance of crop cultivation and pastoral land-use, as well as the degree of integration of these two land-uses. Whereas a unimodal rainfall regime favors agriculture due to a more concentrated and predictable growing season, a bimodal pattern of rainfall such as that found in the TME favors pastures, woody plants, and pastoral land-use (Ellis and Galvin 1994). In most African semi-arid savannahs, rainfall is highly variable and a major determinant of inter-annual variability of crop and livestock yields (Mace 1993; Ellis and Galvin 1994).

Mace (1993) created a model to ask when pastoralists will improve their livelihoods by diversifying into cultivation and, if they do, whether they should store the surplus grain or invest it in their livestock. The purpose of this exercise was to identify strategies that could maximize long-term survival. The resulting model indicated that for subsistence herders, diversification into cultivation was based on need, or the inability to meet minimum household production requirements from livestock alone. Herd recovery after a die-off can take years, with each year's growth potential dependent on population at the start of the year. Cultivation each year is independent of the preceding year, and therefore acts as an important safety mechanism for poor households. Rainfall unpredictability has not prevented most Maasai households in Simanjiro from cultivating, despite the financial losses and labor costs often incurred. Interviewees indicated that the financial payoff of past good years was a strong incentive to continue cultivating, and poor years were downplayed.

Because of the inherent environmental uncertainty of semi-arid rangelands that stems from shifts in resource availability across time and space, they are by definition non-equilibrial systems (DeAngelis and Waterhouse 1987; Ellis and Swift 1988; Westoby et al. 1989; Behnke and Scoones 1993; Behnke 1994; Perrier 1994). In non-equilibrial systems, frequent and unpredictable system shocks (such as drought) prevent wild and domestic animal populations from reaching a constant "carrying capacity", the point at which resource limitations spur competition for forage and water and density-dependent effects come into play. Extensive use of the landscape is crucial to accessing widespread but necessary resources in non-equilibrial systems. This pattern of use historically held true both for wild animals and for people and their domestic livestock.

A combination of disturbances from spatially and temporally variable rainfall, to fire, grazing, browsing, and other disturbances and land-uses create a dynamic and patchy rangeland landscape (Ellis and Swift 1988; Ellis et al. 1991; Behnke and Scoones 1993; Ellis and Galvin 1995; Swift et al. 1996). Biodiversity in these areas may do better under less protectionist regimes of management that incorporate some conservation-compatible land-uses rather than drawing lines around protected areas (Homewood 2004), since rangelands are so dynamic and dependent on disturbance to maintain their mosaic of resources. But the question still remains as to what land-uses are compatible with conservation in arid and semi-arid lands, and agreement on this question among diverse stakeholders is difficult to find. Some degree of hunting (Homewood 2004), cultivation, grazing, tree harvest and other land-uses may not necessarily be detrimental to conservation objectives, and in fact may have a positive influence on these agenda either through landscape mosaic maintenance and other disturbance effects, or as a result of reducing direct conflict between conservation and livelihood agendas. In recent years it has become more widely recognized that the need of pastoralists for large grazing areas is complementary with the needs of many of the wild ungulates that share the pastures (Nelson 2000). The idea of livestock compatibility with wildlife has, as a result, become more acceptable. However, the cultivation in these systems is still not believed to be consistent with wildlife conservation goals (McCabe 2003).

People and animals have co-evolved with intact, unfragmented rangelands in most of the drylands of the world, where pastoral economies have existed for thousands of years (Hobbs et al. 2008). Pastoral land uses reflect intimate knowledge of these landscapes, and the spatial and temporal complexity of pattern, process and the interactions between them that are inherent to these ecosystems (Coughenour 1991; Scoones 1995; Goldman 2003). Pastoralists access temporally and spatially-variable forage and water through reciprocal rights to common pool resources that may belong to other people (Galvin 2009). Exchange of resource access among spatially separated groups provides a mechanism of access to external resources that can buffer populations against widespread, catastrophic shocks that even regular movement regimes do not have the capacity to accommodate. Coughenour (Coughenour 1991; Coughenour 2008) further emphasized the important role that spatial heterogeneity and movement play in the maintenance of plant-herbivore systems, noting that the use of models that integrate plant growth, ungulate movement, and foraging can lead to more accurate and meaningful interpretation of plant-herbivore systems for management.

In the 1980s, studies such as the South Turkana Ecosystem Project (STEP) in northern Kenya began to bring together the social and ecological sciences to study both human and ecological components of ecosystems (Coughenour et al. 1985; Ellis and Swift 1988; Coughenour 1991; Ellis 1993). The STEP project investigated the interactions and energy flows among plants, domestic livestock, and people. More recently, both research and discourse have expanded from this research model to explicitly include humans as fundamental ecosystem components, rather than just being labeled as agents of disturbance. The Report of the 4th Regional Session of the Global Biodiversity Forum for Africa, entitled *Biodiversity and Livelihoods in Africa: Delivering on the Millennium Development Goals*, explicitly calls for taking an integrated landscape and ecosystem approach to research since mosaics of land-use across landscapes and ecosystems are fundamental to processes occurring within them.

Natural restrictions on wild ungulate distributions may include factors such as forage abundance, water availability, competitive or facilitative interactions with other wildlife or livestock, and risks of predation (Sinclair and Norton-Griffiths 1982; Sinclair et al. 1985; Fryxell 1995). But in addition to natural restrictions on distributions, since most large-bodied wildlife species range widely over diverse landscapes, human land-use within those landscapes may affect access to resources (Sundaresan et al. 2008; Groom and Harris 2010).

Ellis and Swift (Ellis and Swift 1988) concluded that in the Turkana ecosystem of northern Kenya, access to important spatially expansive resources allows local pastoralists to persist through periods of extreme stress with minimal degradation and famine. If these resources were not available, then the human and livestock populations would need to be maintained at much lower levels in times of stress in order to avoid extensive livestock losses and famines. In Simanjiro, disenfranchisement of extensive and historically important forage and water resources has limited the capability of local Maasai to endure prolonged and severe droughts (J. Ellis, pers. comm.).

Considerations of Scale in Arid and Semi-Arid Lands

Habitat changes that result from land transformation create the most significant impact that humans have upon other species, and pose the greatest threat of humans to ecosystem integrity and biodiversity (Malanson 2003). Maintenance of populations, species, ecosystems, and the flows of goods and services to humans is going to require increasingly active management as a result of these transformations (Vitousek 1997). In light of this, Sutherland et al. (Sutherland et al. 2009) identified the question of how to manage ecosystems to increase protection of humans and biodiversity from extreme events, as being one of the top 100 questions of importance for the conservation of global biological diversity. Changes in landscape structure may also make these areas more susceptible to extreme events.

Ecological barriers can have effects that range in scale from those that act at the level of individuals, to those at the level of populations or communities, or to those at the level of metapopulations (Dobrowolski et al. 1993). Barriers that act at the individual level do not fragment the population, but inhibit movement. Barriers at the population level actually act to fragment the population by strongly limiting movements, and have the potential to create distinct metapopulations.

When planning landscape policy, multiple stakeholders make different demands on the landscape and hold different perceptions of the benefits that landscapes must deliver to society (Termorshuizen and Opdam 2009). Knowledge about landscape pattern and process should be spatially explicit at a level of detail relevant to individual landscape elements. Having information at an appropriate spatial scale increases its credibility for collaborative landscape planning, as well as its relevance to the needs of the decision makers (Termorshuizen and Opdam 2009). Measurable indicators and knowledge about how they relate to ecological, social, and economic values and benefits are necessary (Termorshuizen and Opdam 2009). In order to reduce the impact of land-use disturbances on native species composition, population sizes and community structure, planners and managers generally aim to1) maintain corridors between tracts of native habitat, and 2) retain the largest sizes of remnant patches that is possible (August et al. 2002). These two key management principles of maintaining habitat area and connectivity are basic tenets of conservation biology that can be assessed through the application principles and metrics of landscape ecology.

Landscape ecology is the broadly interdisciplinary study of spatial variation in landscape patterns and processes at a variety of scales (Turner 1989; IALE 1998; Turner et al. 2001; Tress et al. 2005). The goal is not to describe systems, but to explain and understand the processes that occur within them (Haines-Young 2005), and ultimately to design and manage land-use to promote the well-being of both people and nature, as well as to maintain the overall sustainability of the landscape (Wiens 2009). As such, it is the framework that was used for this study.

Wiens (2009) outlined four considerations that are necessary for landscape ecology to contribute to conservation: 1) conservation-oriented protected areas exist within the context of landscapes that may influence movement into and out of the PA; 2) contents of the landscape outside of PA's may impact biodiversity within them, often as a result of human activities; 3) The scale of management may not coincide with the scale of patterns and processes that are necessary for species or ecosystem viability, presenting challenges to both landscape ecology and conservation, and 4) sustainability of conservation depends upon the consideration of tradeoffs between human use and biodiversity values of the landscape. Ecosystems consist of both biotic (living) and abiotic (non-living) components (Carpenter 1998) that interact through mutually-reinforcing feedbacks between landscape patterns and processes. The complex context of the patterns and processes under scrutiny must be thoroughly considered, or implications and cause and effect may be misinterpreted.

People and animals have co-evolved with intact, unfragmented rangelands in most of the drylands of the world, where pastoral economies have existed for thousands of years (Hobbs et al. 2008). Pastoral land-uses are reflective of intimate knowledge of these landscapes, and the spatial and temporal complexity of pattern, process and the interactions between them that are inherent in these ecosystems (Coughenour 1991; Scoones 1995; Goldman 2003). Coughenour (Coughenour 1991) further emphasized the important role that spatial heterogeneity and movement play in the maintenance of plant-herbivore systems, noting that the integration of plant growth, ungulate movement, and foraging can lead to more accurate and meaningful interpretation of plant-herbivore systems for management.

More recently, pastoral livestock and resident and migratory wildlife have been presented with the challenge of accessing all ecosystem components necessary for individual survival and population maintenance as landscapes become fragmented. Spatial isolation in grazing ecosystems limits the ability of people and both wild and domestic animals to exploit heterogeneity in vegetation (Coughenour 2008; Hobbs et al. 2008). By limiting access to resources, fragmentation potentially can increase vulnerability of wildlife and livestock (and hence people) by decreasing options to avoid risks such as disease, fire and floods. In effect, as a result of the loss of critical resources to conservation protections, pastoralists are forced to reconfigure the former highly functioning and resilient social-ecological systems into less optimal systems that may compromise the long-term sustainability and persistence of all system components. The process of enacting protections for one component, such as wildlife, acts to disrupt the integrity of the ecosystem as a whole, having disproportionately negative effects on other components (Lynn *In Press*).

While historic pastoral land-use did not include cultivation by pastoralists themselves, it did involve trade with agriculturalists to obtain grain foods (Spear and Waller 1993). Over recent decades, pastoralists in some of the more productive semi-arid areas have begun to cultivate themselves. There is a question as to the amount of profit (food and/or cash) that can be generated by cultivating in semi-arid rangelands (see Chapter 2 of this dissertation). As opposed to the existing grass and browse that must be converted to milk and meat by foraging livestock, cultivation may serve to increase the ability of inhabitants to acquire resources sufficient to support their families by providing another energy pathway for human subsistence. In addition, since livestock are allowed to forage in the fields after harvest, they benefit from the new landscape arrangement, while simultaneously depositing and concentrating livestock-generated nutrients in cultivated areas, possibly increasing crop productivities.

What is clear is that cultivation may affect the scale and availability of resources in semi-arid landscapes. Land tenure and land-use changes have precipitated fragmentation in these extensive pastoral rangeland systems (Galvin 2009). Fragmentation of once contiguously intact rangelands spatially isolates portions of the landscape, leading to compartmentalization of important components of the environment (Boone and Krohn 2000; Coughenour 2004; Hobbs et al. 2008; Reid et al. 2008; Galvin 2009). The actual physical arrangements of landscapes and the manifestations of change (such as fences, cultivation, or political boundaries) that are occurring within them are highly variable from place to place. But the reduction in the scale of landscape access and heterogeneity that results from fragmentation presents a real challenge to pastoral livestock and resident and migratory wildlife to access all ecosystem components necessary for individual survival and maintenance of populations.

Spatial isolation in grazing ecosystems limits the ability of people and both wild and domestic animals to exploit heterogeneity in vegetation (Hobbs et al. 2008; Reid et al. 2008). It also limits the ability of people and animals to access spatially and temporally variable water resources. The exclusion of key, predictable resources from use is particularly damaging during times of intense stress when those resources are absolutely needed. Mismatches in animal density and resource abundance arise both in the direction of excess animal density relative to resources at times of stress, when large die-offs can result, and in the direction of excess resource abundance after those die-offs, when the lower animal densities are not capable of utilizing a substantial proportion of the available resources after stress recovery (Coughenour 1991). In addition to limiting access to resources, however, fragmentation can also potentially increase vulnerability of these groups by decreasing options to avoid risks such as drought, disease, fire and flood. In effect, pastoralists are forced to reconfigure former highly functioning and resilient social-ecological systems into sub-optimal systems that may compromise the long-term sustainability and persistence of each and every system component.

Many of the actions that result in fragmented landscapes are intended to enhance human welfare, and often measurable enhancements in people's livelihoods and well-being are realized (Hobbs et al. 2008). However, there are also many cases of landscape fragmentation that have resulted from the placement of political boundaries, land tenure arrangements, or the creation of protected areas to protect wildlife and natural resources that have not served to benefit local livelihoods. Whatever the rationale behind the change in landscape arrangement and access in multi-sector social-ecological systems, multiple users may be impacted differentially, and the implementation of mechanisms to improve resilience in one sector may actually increase vulnerability in another (Lynn *In Press*).

The ultimate goal of landscape pattern analysis should be to gain better understanding and make better predictions of ecological responses, not to merely quantify pattern alone (Li and Wu 2004). The number of measurable landscape indices/metrics available to study is extraordinary, but the ecological relevance of these is often not established (Li and Wu 2004), and many of these are either irrelevant or highly correlated with each other (McGarigal and Marks 1995).

Of particular interest to ecologists and conservation biologists is the ease with which individuals and populations are able to move through landscapes (Malanson 2003). The effectiveness of links through landscapes needs to be quantified and examined (Malanson 2003). The propagation of material, information, organisms, or disturbance across landscapes in response to ecosystem pattern and resource availability is the subject of "percolation theory" (Stauffer 1985; Malanson and Cramer 1999). Percolation theory addresses ways in which habitat changes impact animal movements across landscapes (Malanson 2003). It predicts that there are thresholds of connectivity that distinguish landscapes that do allow animal movement versus those that do not. Unfortunately, because of their non-linear characteristics, thresholds often cannot be identified until they are crossed (Malanson 2003; Groffman et al. 2006; Hunter et al. 2009). Such non-linear thresholds are the outcomes of the combination of spatial landscape pattern and species population dynamics (Malanson 2003) and, as such, will be species-specific. The question of whether system thresholds can be identified before they are crossed may be approached using extrapolation from similar closely-related systems that have already crossed identifiable thresholds (Walker and Meyers 2004; Lynn et al. *In Press*).

Despite the plethora of landscape metrics associated with the patch mosaic paradigm prevalent in modern landscape ecology, in many situations it is actually more meaningful to look at continuous rather than discrete spatial heterogeneity (McGarigal et al. 2009). In Simanjiro, while cultivation forms clearly discrete patches on the landscape, the perception of cultivation by wildlife may not be so black and white; the matrix around cultivation may not be unvaryingly suitable, it may rather contain gradients of suitability. Furthermore, different wildlife species likely perceive different gradients of suitability. Therefore the best way to test wildlife responses to cultivation may be by looking at a continuous or multi-classed surface outside of cultivation to elicit what the species-specific responses may be. In this case, the landscape metrics of interest are distance to cultivation and some measure of cultivation intensity, a combination of cultivation distance and density. It is only in recent years that the application of surface metrics has been applied to analysis at the scale of entire landscapes (McGarigal and Cushman 2005).

The selection of the metrics to be measured should be based on the hypotheses being tested, they should be relevant to the organism and processes of interest, and should be based on characteristics of the landscape (Neel et al. 2004).

Most research on the effects of habitat loss and fragmentation on ecosystems has been based on observational studies (August et al. 2002). Results from this type of research should be categorized by organism so that it is most useful for interpretation and management (August et al. 2002). If native species will tolerate levels of fragmentation that were previously thought to be detrimental to these species, then land planners and managers will have more flexibility with developing plans and policies that do not have a negative impact on landscape integrity and sustainability (August et al. 2002).

Pastoral Land-use

Pastoralists are livestock herders who subsist wholly or in part upon their animals (Lamprey 1983). Livestock serve many roles in pastoral society: as both the means and outcomes of production, as sources and objects of labor, as values, and as social, cultural and capital goods (Galaty and Johnson 1990). Nomadic pastoralism is the dominant land use over one eighth of the Earth's land surface, and was once even more extensive (Lamprey 1983). The historical record shows that pastoralism extended its influence into eastern Africa 2000 or more years ago (Lamprey 1983; Homewood and Rodgers 1984).

The practice of animal husbandry among mobile peoples makes habitation of the world's more marginal and variable climatic zones possible (Galaty and Johnson 1990). This is particularly true in East Africa where the bimodal rainfall pattern does not support rainfed crop agriculture, yet does support range vegetation, livestock production and pastoral land use (Ellis and Galvin 1994). It is these drier areas that tend to be inhabited by the more purely pastoral people (Lamprey 1983). This makes possible the exploitation of areas that are too marginal for most other uses (Galaty and Johnson 1990). In these regions, livestock convert otherwise unusable forage plants into animal products for human consumption (Pratt and Gwynne 1977; Dyson-Hudson 1980; Lamprey 1983).

In arid and semi-arid ecosystems, traditional land-use practices are adapted to track temporal and spatial fluctuations in the availability of local resources, and as a result the impact that people have upon the ecosystem is spread across a large, contiguous area (Ellis and Swift 1988; McCabe et al. 1988; Coughenour 1991; Ellis et al. 1991; Behnke 1994; Ellis and Galvin 1994; Ellis and Galvin 1995; Scoones 1995; Swift et al. 1996; Coppolillo 2000; Coughenour 2008). Pastoralists traditionally reduce risk from spatio-temporal variations in resource availability through a multitude of adaptations. These include livestock movement and migrations to track forage and water availability, herd diversification to multiple species (spreads risk across species), and social programs such as stock associations and wealth re-distribution from wealthy to poor (Potkanski 1999).

Simanjiro Maasai herd cattle, goats and sheep, and employ multiple herd management techniques to buffer their losses in difficult times. These complementary herd species allow livestock to take maximum advantage of available resources in different ecological niches, similarly to wild species assemblages (Lamprey 1964; Campbell 1981; Swift et al. 1996). They also ensure that the herd owner is buffered against species-specific disease outbreaks (Lamprey 1983; Galaty and Johnson 1990; Reid et al. 2008). The ratio of species herded depends on cultural preferences, environmental parameters and the personal choices of the herders themselves (Cooke 2007). Generally Maasai prefer their cattle to their smallstock, but smallstock play a very important role in spreading risk and facilitating recovery. In the years following droughts, the proportion of livestock held in the smallstock herd will increase. Smallstock (sheep and goats) reproduce at 2-4 times the rate of cattle, one to two births per year as opposed to one birth every year and a half to two years for cattle (Lynn, unpublished data, Dahl and Hjort 1976; de Leeuw et al. 1991), so they are particularly useful and important after droughts and other disasters. Goats are frequently sold for cash, given as gifts, or slaughtered for food or ceremony because the amount of money and food generated by a single goat is optimal for day to day transactions.

Herd size is opportunistically increased during good years in anticipation of future losses (Campbell 1981; Sandford 1982; Galaty and Johnson 1990; Swift et al. 1996). While herd size can vary significantly from year to year based upon conditions, the herd structure of cattle herds is remarkably predictably managed to consist of a large proportion of females, in accordance with the aims of a enterprise focused on milk production. African Zebu (*Bos indicus*) is the tropical humped, small-statured cattle breed herded by the Maasai (Lamprey 1983). This breed of cattle is more tolerant of drought conditions than western breeds, can be moved quite long distances, and can go without water for two to three days (Pratt and Gwynne 1977, p.147). Though the ancestry of this species is not known, it appears to have originated in the Middle East and to have been domesticated in Iraq by 6500 B.P. (Lamprey 1983). Archaeological records show that several types of cattle, including the zebu, were brought into northeastern Africa by nomadic peoples from the Middle East and Mediterranean Basin (Pratt and

Gwynne 1977, p. 144). The different species then spread into suitable areas throughout the African continent.

Pastoral access to communal lands is based on complex social, cultural, and historical norms and conditions that historically have maintained flexible access to resources across space and time (Turner 1989; Ostrom 1990; Burnsilver et al. 2003). Pastoralists access temporally and spatially-variable forage and water through reciprocal rights to common pool resources that may belong to other people (Galvin 2009). Exchange of resource access among spatially separated groups provides a mechanism of access to external resources that can buffer populations against widespread, catastrophic shocks that even regular movement regimes do not have the capacity to accommodate. The creation of social alliances through marriage, friendships, family, and distribution of livestock to those in need within these groups also serve to buffer households against severe events (Galaty and Johnson 1990). Alliances are called upon in times of hardship to re-build herds that have been devastated.

Among Simanjiro Maasai, two additional common means of risk-spreading are livelihood diversification into cultivation and gem trading. Gem trading activities are important because of the indirect contribution to land use change that is created through cash inputs. This cash may be fed back into cultivation, or used to purchase tractors for the plowing of village fields. Wealth that is being generated through new diversification initiatives has in some cases undermined some social relationships in Maasai pastoral areas through a widening gap in social stratification; impacts are differentially negative for the poor because the options available to the poor are so few, and the poor can only afford to act on them primarily out of necessity or desperation (Thornton et al. 2007;

Galvin 2009). It is possible that the Simanjiro wealth gap is widening as a result of cultivation in this marginal area. Many regions of low food security rely on local agricultural production to provide their food supply, with local producers both consuming and selling their food products in local markets (Brown and Funk 2008). Simanjiro residents follow this pattern. Problems arise because of the fact that their production is tied to local climate. When production goes down, prices rise at precisely the time that need to supplement their home-grown foods with purchases to maintain consumption (Brown and Funk 2008).

Ecosystem function and sustainability of the Maasai livestock grazing system is dependent upon the availability of adequate land to distribute wet and dry season grazing pressure. If the landscape becomes fragmented or habitat area is lost, pastoral movement becomes restricted to smaller areas in which resources may be inadequate, unpredictable or not diverse enough. Historically when rains failed in one region herders were able to use social networks to negotiate a temporary move to more distant areas with green pastures (Spear and Waller 1993), but when areas are blocked from use or boundaries are established these moves may prove impossible. Pastoral mobility allows pastures that have been grazed to recover before they are needed again, but sedentarization and movement restriction do not allow this recovery and can therefore lead to changes in pasture quality (Cooke 2007; Coughenour 2008; Reid et al. 2008) as well as livestock condition and survivability (Ellis and Swift 1988).

Social-Ecological Systems

Hobbs et al (2008) make it clear that the state of the Earth's ecosystems cannot be fully understood without carefully considering the coupling between human societies and biological and physical processes. Conservation policy can only succeed by encouraging, or even facilitating, exchange amongst the diverse groups of stakeholders to give voice to concerns and knowledge, to manage conflict, and to bridge policy and practice (ibid). The trade-offs between environment and development outcomes are difficult to integrate into a consistent approach and set of priorities for management (ibid). Changes occurring for any component of an ecosystem, be it land tenure change, land-use change, climate change, disease, system shocks such as droughts floods and fire, or any other short or long-term change, are likely to have impacts for other system components. It is important both to ask the right questions, and to integrate a wide variety of multidisciplinary data to encompass both environmental and development dimensions in research and outcome evaluation (ibid).

Land cover change in tropical developing countries is commonly due to anthropogenic forces (Lambin et al. 2001), and the patterns of these changes is a mosaic that results largely from varying intensities of human use (Hartter and Southworth 2009). However, fragmentation studies, particularly ones that focus on areas that border protected areas, tend to focus on human causes and biodiversity outcomes, leaving out ecological drivers of change and human outcomes. Because many people living near protected areas depend on the land for their livelihoods (Hartter and Southworth 2009), this can greatly decrease the utility of research results by removing the social context from these social-ecological ecosystems. Ignoring the social context in effect increases the subjectivity and bias of data interpretation, and possibly the validity as well.

In addition, land-use policy that is created to protect biodiversity often creates conflict between authorities and residents because the local people have not been consulted (or have been consulted too late) in the research or decision-making process. In areas that border protected areas, the imposed boundaries are artificial stopping points in what was once continuous landscape with unrestricted access (Hartter and Southworth 2009). When a protected area is fenced, the boundary is completely impermeable for some species, and restricts the flow of both wildlife and human-related subjects (i.e. people and livestock) in both directions. When a protected area remains unfenced, the movement of wildlife is not physically stopped (though land-use change does have the potential to create barriers to movement), whereas the movement of people and livestock is.

Since protected areas are formed to protect natural resources from people for exclusive use by wildlife, restrictions on human use can be devastating for communities when the resources in question are critically needed. This effect is compounded in non-equilibrial systems that have inherently-high spatial and temporal variability of resources. In such extensive systems, the loss of area imparts a loss of heterogeneity that almost necessarily reduces management options, reduces effective carrying capacity, and increases risk to system shocks such as drought and disease (Boone 2007).

In order to best study land-use change and form reasonable management conclusions regarding both the control of change and the mitigation of impacts, key system components need to be incorporated explicitly into research to link social drivers and outcomes into the evaluation process. In the quest for ecological sustainability, it is easy to create a conservation management scheme that is unsustainable for local livelihoods, setting the stage for a community that fails to thrive. Conservation is a "noble cause" that many people from around the world pump money into in hopes of conserving beautiful spaces and wildlife, oftentimes in places that they have never seen for themselves. The problem with this is not the activism and initiative of these people to affect change, but rather it is that this is being done out of the in-situ context so that resident people are seen as a fundamental problem.

But land-use change is often a symptom of the greater problem of limited resources. The entire chain of components and impacts must be assessed to fully understand why the system is changing as it is. Only then can the root causes of change be confronted and policy and development properly informed. The integration of social and ecosystem sciences has brought scientists and decision-makers together to begin looking for solutions to problems that are difficult to approach from the perspective of a single discipline, and that benefit from exchange of insights among disciplines (Ojima et al. 2006). Sustainability science must transcend its foundational disciplines, focusing rather on understanding the complex dynamics of social-ecological systems with a focus on problem-solving to address urgent human needs (Clark 2007). In view of the sustainability of conservation and of communities, three critical factors must be considered: resilience, the capacity to cope and adapt, and the conservation of sources of innovation and renewal (Lebel et al. 2006). Resilience measures the amount of change a system can withstand while retaining similar structure and function rather than reaching a different state (Holling 2001; Walker et al. 2002; Lebel et al. 2006). One of the key questions raised by Clark (2007) is, "What factors determine the limits of resilience and sources of vulnerability for such interactive systems?"

Complex issues related to the relationship between environmental knowledge and political power can only be grasped by bringing together perspectives from several different disciplines (Martello and Jasanoff 2004). Land-use policies and projections of land-use change futures in Earth System dynamics must not only capture the complex socio-economic and biophysical drivers of land-use change, but also account for the specific human-environment conditions under which the drivers operate (Lambin et al. 2001). Integration of natural and social sciences as well as recognition of the increasing role of global factors is required to meet this challenge (ibid). Interdisciplinary research is defined as developing theory across boundaries of unrelated knowledge communities in order to achieve a common research goal (Tress et al. 2005). In crossed natural-cultural landscapes it is the interaction between the natural and social elements that actually creates the landscape and calls for a combined approach to its study (Lambin et al. 2001). It is the complementarity of diverse ways of knowing that provides richness and safeguards against the perils of a too-enthusiastic scientific reductionism (ibid).

Applications of Conservation Biology

There are many popular and steadfast assumptions regarding local land-use impacts on rangelands in sub-Saharan Africa that have not kept pace with data that document environmental processes and outcomes (Homewood 2004). Conservation policy can only succeed by encouraging, or even facilitating, exchange amongst the diverse groups of stakeholders to give voice to concerns and knowledge, to manage conflict, and to bridge policy and practice (Homewood 2004).

The European colonial administrations that were present in many African countries in the last century initiated conservation projects by following the western model of establishing large national parks and other protected areas (Nelson 2000). Restrictions on land and resource use were implemented. While these protected areas and restrictions on land-use may bring benefits to national economies, local people are the ones who bear the brunt of the cost of wildlife through crop losses, predation on livestock, and loss of human lives (Nelson 2000). Ecosystem services perceived as benefits at larger scales are rarely a simple compilation of finer-scale ecosystem services (Carpenter et al. 2006), and perceptions of what is valuable also do not necessarily transcend from local to broader scales or vice versa. Displacement is a major source of conflict over natural resources between local people and conservation authorities, as people lose control of and access to historically available resources (Chatty and Colchester 2002; Brockington et al. 2008). From the local perspective, conflicts with wildlife on village lands are difficult to reconcile with the local loss of control and options when it comes to use of natural resources. This is a manifestation of the mismatch between the scales at which natural and human systems organize, which can lead to failure in feedbacks so that costs are felt at one level and benefits at another (Carpenter et al. 2006). New indicators will help to integrate social, economic and ecological phenomena across multiple scales of space, time, and organizational complexity to highlight and attempt to reconcile such cross-scale effects and mismatches (Zurlini and Girardin 2008).

Community Based Conservation (CBC) and Community Based Natural Resource Management (CBNRM) are catchphrases for the movement to incorporate local people in the management of natural resources located in their immediate environment. Ideally, CBC/CBNRM programs arise from within the community rather than internationally or nationally (Western and Wright 1994). The focus of conservation shifts from exclusive state control of resources to community management through inclusive, participatory, community-based ventures (Goldman 2003). One rationale for devolving management to the local level is that if local people are involved in conservation programs and realize tangible benefits from the protection of natural resources, then they will place more value on these resources, and distribution of profits will be more equitable (Goldman 2003; Ribot 2006). As a result, they will be less likely to overuse or compromise the sustainability of these resources, and will be more likely to advocate their safekeeping and protection from external sources of harm (ibid).

It is frequently the case that ecological and economic studies are not carried out in tandem, leading to ecological and economic information that cannot be linked (Carpenter et al. 2006). However, the discipline of conservation biology is expanding rapidly to include economics and social sciences (Meine et al. 2006; Pullin and Knight 2009). "In interdisciplinary research, researchers are challenged at all stages during the research process to step out of their comfort zone by modifying their research to accommodate other disciplines in order to achieve a whole that is greater than the constituent parts." (Allsopp 2005, p. iii; also see Clark 2007) This approach is necessary to answer multi-faceted questions such as how to balance people's livelihoods with biodiversity concerns (Allsopp 2005).

Since it is increasingly required that conservation biology demonstrate that conservation of biodiversity can improve the quality of life for current and future generations, it is reasonable to ask questions that assess the costs and benefits of conservation (Pullin and Knight 2009). The challenge is to bridge disciplines in order to create an evidence-based framework for conservation and environmental management (Pullin and Knight 2009). This sort of systems approach to the study of ecosystems can be used to unite diverse system components by exploring interlocking theoretical and action frameworks (Westley et al. 2002). These interlocking frameworks are essential building blocks to true sustainability science, which has begun to transcend the motivations and concerns of its multiple foundational disciplines to focus on understanding the complex dynamics arising from interactions inherent to coupled human-environment systems in order to target problem-solving to urgent human needs (Clark 2007). One of the most ambitious goals of sustainability science research is to manage "places where multiple efforts to meet multiple human needs interact with multiple life-support systems in highly complex and often unexpected ways." (Clark 2007, p. 1737).

STUDY AREA: THE TARANGIRE-MANYARA ECOSYSTEM

Location & Ecology of the Ecosystem

The government of Tanzania established Tarangire National Park (TNP) in 1970 to set aside a vital permanent water source, the Tarangire River, for exclusive use by regional wildlife. Resident Maasai pastoralists were evicted from the 2642 km^2 of land within the boundaries of the Park and henceforth forbidden to enter or use its resources.

A longstanding conflict over land-use and land rights ensued between policymakers and the local Maasai. TNP forms part of the 20,000 km^2 Tarangire-Manyara Ecosystem (TME), along with nearby Lake Manyara National Park (320 km^2) and the pastoral Maasai Steppe that lies primarily to the east of these parks (TMCP 2002) (Figure 1.1).

The TME is classified as semi-arid, and receives on average 600 mm of rainfall per year (Voeten 1999). The coefficient of variation (CV), a measure of inter-annual variability, is extremely high, so drought or heavy rainfall years are not uncommon. This area is also characterized by a bimodal rainfall pattern. The first shorter rainy season occurs from approximately November to December. The second occurs from approximately March to May. Because of high seasonality and inter-annual variability in rainfall, pastoral sustainability is also contingent upon the existence of water and forage drought reserves. Grazing reserves are reliably good pastures that are used when neither wet nor dry season grazing pastures can provide adequate forage for livestock. Water reserves are often located in and around swamps, lakes or mountain streams (Igoe 2006) that are used when the customary perennial water sources dry up. In the study area the designation of these areas is undertaken at the Village or sub-village level, and the resources left alone in-between periods of drought to allow full recovery.

Vegetation in Simanjiro varies from wide expanses of open grassland, to savanna, dense shrubland and woodland. Classification of Simanjiro vegetation falls into seven vegetation types: short grassland, scrub-woodland grassland, *Acacia-Borassus*-woodland, *Acacia*-wooded grassland, riparian woodland, and agriculturally-induced tall-wooded grassland (Gamassa 1995). Settlements[1] are usually, but not always, located in savanna to grassland areas within a short distance to woodlands and shrublands that provide wood

[1] *boma* in Swahili and *enkang* in Maa

for building and fuel. The nearby open areas are reserved for grazing by calves, sick cattle, and smallstock that are typically herded by children, sometimes women. Adult cattle are always grazed some distance from the boma, typically herded by young men. They leave at daybreak and return at sunset, setting a cadence for daily life around which all other activities are arranged.

The TME eco-climatic optimal land-uses for the region are pastoralism and wildlife management because of the herbivores' co-evolution with plant communities, and adaptation to extensive migration to access ecosystem resources (Gamassa 1995). Most pastoral systems are strongly seasonal with extremes in temperature, precipitation or both. Maasai land-use in the TME is no exception. Movement is the fundamental underpinning of ecosystem function as animals move or migrate to access necessary water and forage resources. Boone et al (Boone et al. 2008) showed that livestock herds that moved more times per year improved their herds' access to green forage. Many additional strategies exist for both wild and domestic animals to cushion the stress of seasonality, but these strategies can fail when resource availability becomes increasingly irregular (Prins and Langevelde 2008).

The boundaries of the ecosystem are based upon the extent of annual migratory wildlife movements, particularly wildebeest. Land-use outside park boundaries is relevant to conservation inside because approximately 85% of the TME falls outside the National Parks and in the village lands of the Maasai Steppe's Simanjiro Plains. During the rainy season animals leave the parks to disperse over much of the pastoral zone to take advantage of widespread water resources and high quality forage (Borner 1985; Kahurananga and Silkiluwasha 1997; Rodgers et al. 2003). Loss of migratory corridors and wet-season grazing areas outside of TNP would be detrimental to migratory ungulate populations, since the concentration of wild ungulates inside the Park during both wet and dry seasons would result in forage of insufficient quantity and quality to satisfy the population's energy and nutritional requirements (Voeten 1999). TNP authorities are concerned that wildlife may lose access to the critical wet season village grazing grounds through a number of land-use changes, particularly increased cultivation. Indeed, a key objective of the TNP Management Zone Plan is to "maintain natural ecological processes that perpetuate the greatest degree of biological diversity and ecosystem integrity within the park and where possible within the larger Tarangire Ecosystem" (TANAPA 1994).

This study area includes the villages of Sukuro, Emboreet, and Loiborsoit 'A' which are all located within the Simanjiro area directly east of TNP (Figure 1.2). The study area was selected based upon a 2002 reconnaissance trip, Landsat TM images (February 2000), and existing data on wildlife movement and cultivation (TMCP 2002). The villages all appeared to be undergoing increases in cultivation and all have high wet season wildlife densities (TMCP 2002), but they were embroiled to different degrees in conservation initiatives and controversy.

Pastoralists across East Africa have become sedentarized to varying degrees due to both internal and external forces on their culture and livelihoods. Yet most if not all still move their livestock on a daily basis, and change grazing locations as resource availability fluctuates across the landscape. Pastoral land-use in the Simanjiro Plains is extensive - herders and their livestock track water and forage resources as the distribution of these resources changes with weather and climate patterns.

Simanjiro Maasai for the most part follow a transhumant pattern of seasonal herd movement away from a permanent home base. During the Simanjiro dry season, livestock go for water on an approximately every-other-day basis. During the end of the dry season, especially when water is extremely limited and distant from forage, animals may go for water only every third day. On watering days livestock are herded to water, and then to the dry season grazing grounds before returning to the boma before nightfall. On the opposite days livestock walk only to grazing pastures, allowing other herds to go for water. Movements and timing are very systematic, with a set schedule of who uses water on which day and at what time. When either water or forage are particularly scarce locally, entire cattle herds minus some milking cows (who are needed to feed the family that remains behind) and their calves, may be moved for extended periods to remote locations where resources are more abundant. Herds similarly often move farther afield when water resources are widespread in order to save nearby water and grazing resources for later use.

Decisions on water and land-use are generally made at the village and sub-village level. During the wet season ephemeral water sources are widespread. This allows herds to graze farther afield in the communally-designated wet season grazing pastures. Because of standing water, many herds do not need to utilize the permanent water source during the wet season, allowing the proximal grazing pastures to recover for use during the next dry season (Igoe 2006).

Drivers of Change

Newmark (2008) identified the most important mechanistic contributors to reserve isolation as habitat loss, movement inhibitors such as fences and roads, overhunting and disease. The drivers of these changes are ultimately population growth, economic expansion, social and environmental human displacement, and poverty. Human land-use strategies simultaneously shape and are shaped by ecological patterns and processes, with wider linkages to political and economic drivers (Burnsilver et al. 2003). The complex context of the patterns and processes under scrutiny must be thoroughly considered, or implications and cause and effect may be misinterpreted. The impacts of various land-use and cover-change drivers are difficult to disentangle in order to measure their proportional effects. The spatial and temporal scales of historical ecosystem drivers of TME land use changes correspond to the scales at which TME decisions are made (Figure 1.3).

In the nearby Serengeti-Mara Ecosystem that straddles the Kenyan-Tanzanian border, 60,000 hectares of rangelands were converted to mechanized agriculture over 20 years, and the total wildlife population declined by 58% during the same timeframe (Lambin 2003). Lambin's (Lambin 2003) study found that changes in land-use were driven by markets and national land tenure policies, and changes in wildlife numbers were driven by the location of cultivation in areas that provided resources critical to wildlife. In the TME, several forces have acted to disrupt historical ecosystem function, and possibly sustainability, thereby increasing the vulnerability of populations. Wildlife in and around Tarangire National Park had documented declines from 1988-2001, with wildebeest declining by 88%, hartebeest declining by 90%, and oryx declining by a full

95% in just those thirteen years (TAWIRI 2001). Newmark (2008) surmised that this is related to the expansion of agriculture adjacent to Tarangire National Park, and many wildlife managers concur. But the actual impact of cultivation on wildlife has not been measured in the Tarangire Ecosystem, and these suppositions are not conclusive. Forces are both external and internal, and at this time the effects cannot always be differentiated. They are both additive and interactive, creating a complicated set of outcomes for people, their livestock, the physical and vegetative environment, and wildlife. All of these forces influence the current trend of land-use change, creating the context for the household land-use and economic analysis undertaken in this study.

Land Tenure & Land-use History

While changing land tenure and conservation policies are not a focus of this research, they form an important context for current land-use patterns, as well as for household economics and livelihoods. These in turn have strong implications for ecosystem integrity and sustainability. The TME has been plagued with poor relations between local people and non-local land management decision-makers for decades. Land-use in the TME as a whole has been hotly contested since before the creation of the Parks four decades ago. Throughout the world, protected areas in the form of national parks have been created based on western ideologies in non-western systems. Generally the aim of a national park is to preserve an ecosystem’s local floral and faunal biodiversity in a ‘pristine’ state relatively untouched by human exploitation or occupation (Leader-Williams and Albon 1988), and to provide space for interacting and mutually dependent non-human species (Callicott et al. 1999).

Upon TNP's inception, resident Maasai pastoralists were evicted from the Park and henceforth forbidden to enter or use its resources, even in times of extreme hardship. A longstanding conflict over land rights and land-use has ensued between policymakers and local Maasai as land-use and the needs of local residents have changed. The threat posed by commercial agriculture to both pastoralism and wildlife should provide a common ground for pastoralists and conservationists (Igoe 2002), but local people have been alienated from the political process of ecological decision-making. Since the mid-1990's, pastoralists themselves have increased the scale of their farming, making the situation more contentious. Here I present a brief overview of relevant land tenure and conservation policies and history in the TME as a context to this study of landscape pattern and process.

The Designation of Tarangire National Park

The first external forces exerted on the TME over the past half-century were the designation of LMNP in 1960 and TNP in 1970. Since the focus of this study is the Tarangire-Simanjiro portion of the ecosystem, I will concentrate on this park, though similar effects have manifested from the creation of LMNP. The designation of TNP posed enormous implications for the ecosystem as a whole. Simanjiro Maasai bore the majority of the costs, though it has been postulated that negative effects have trickled down to wildlife as well due to vegetation changes from the altered grazing regime inside the park. The first outcome of the Park's designation was the eviction of local human residents. The relocation of households off of Park lands was experienced by at least several hundred dry season residents who were moved into the current pastoral zone of

Simanjiro (Igoe 2006). The impact of the boundary has been felt by these and all other Simanjiro Maasai who relied upon the excised Tarangire River and Silale Swamplands in times of drought, and the now off-limits annual dry season grazing grounds. Elderly informants referred to the loss of these occasional but critical resources that kept their herds alive in times of severe drought, and all who did remain angry to this day. Igoe (2002) discusses the deadly 1961 drought, and the fact that resources inside what is now TNP are what saved the herds of Simanjiro. In fact, informants of his throughout Simanjiro claimed to have relied upon these reserves during that landmark drought.

In effect, the loss of TNP lands from pastoral use represents both a loss of area and a reduction in options for pastoral movement. In heterogeneous landscapes, as accessible area is decreased, access to heterogeneity decreases as well (Boone et al. 2000). Villagers have been forced to alter the areas they use in wet and dry seasons. These altered land-use areas may be less able to provide access to resources of sufficient quantity and quality for herd maintenance compared to the historical seasonal land-use zones.

Naturally, the effects of this loss were delayed until the first major drought in Simanjiro after 1971. Igoe (2006) reported the nearly total loss of 30 households' livestock herds in the village of Loibor Sirret in 1994. During these difficult years, use of TNP resources by people and livestock was prohibited, and action was taken against herders found inside Park boundaries. Arrests and killing of livestock by rangers were reported by informants, but the informants said it was a choice they had to make: allow their livestock to die of starvation and thirst, or take livestock to graze inside the Park at the risk of arrest or shooting of the already doomed animals at the hands of rangers. Similar assertions were made during the course of this research.

These impacts are the outcome of a conservation scheme that aimed to protect critical dry season resources from people for the benefit of wildlife. Since concentrations of wildlife around permanent water sources are so great in the dry season, these resources form a natural centerpiece for conservation and tourism development (Igoe 2006). Yet they also form the centerpiece of historical pastoral land-use. The vital role that TNP resources historically played in long-term Maasai survival and livelihood sustainability was largely overlooked by the government of Tanzania when the Park was created and people evicted. Similar disputes between the conservation efforts of governments and the needs of local people have occurred all across the globe, in both developing and developed nations.

Another interesting outcome of the exclusion of livestock from TNP has been the widespread transformation of vegetation within the park from palatable grasses to less-palatable tall-grass species (Igoe 2006). In addition, the formerly savanna ecosystem has been transformed to less desirable scrubby, bush-dominated vegetation due to the simultaneous repression of fire (ibid). The large populations of migratory ungulates that reside in the park during the dry season subsist mainly on grassy vegetation. Concurrently, the concentration of livestock in the formerly ‘wet season grazing pastures’ on the Simanjiro Plains during both the wet and dry seasons taxes the vegetative resilience of these areas. Villagers have been forced to redefine their ‘wet’ and ‘dry’ season pastures, and these definitions may not always correspond to actual resource availability as well as the historically designated zones did.

The implications of TNP's creation for people, livestock, wildlife, and vegetation are very broad, affecting day-to-day lives, as well as intermittent needs of all of these ecosystem components. People's ability to cope with sporadic drought has been marginalized. Droughts are reported by informants to be occurring with greater frequency than they did historically, magnifying these effects. Wildlife must get by with lower-quality dry-season vegetation inside the Park. The relationships between local people and conservation organizations, both governmental and non-governmental, have become extremely antagonistic from both sides. So while TNP has created a beautiful and productive tourist destination and virtual oasis for wildlife, this has come at great cost to all living elements of the ecosystem.

Operation Imparnati

Another force of change for Tanzanian pastoralists was 'Operation *Imparnati*' (lit. "Operation Permanent Settlement" (M. Goldman, personal communication)), or villagization, which occurred during the period 1973-76. This program's goal was to settle pastoralists into centralized villages with government representatives and schools. One of the major tasks of Operation *Imparnati*' was to encourage cultivation in the hopes that peasant contribution to the national economy would increase, making the land more productive and valuable to the national economy than it was under subsistence livestock herding (ole Parkipuny 1979; Jacobs 1980; Ndagala 1982). This encouragement of cultivation in the 1970s creates confusion for the discussion of restricting cultivation that has occurred in recent years. Like many modern political efforts to impose boundaries of any form onto the landscape, villagization disregarded customary land rights, existing land-use patterns and management practices, and culture (Igoe and Brockington 1999; Igoe 2003). The landscape was broken up into village units that did not necessarily correlate with existing social structures. Fortunately, the pastoral population of Simanjiro has been able to preserve historical social structures and networks to some degree, and maintain intermittent access to resources in neighboring villages through negotiation. This ability to reach beyond the village has reduced the impact of artificial boundaries and their potential negative effect on the ability of local people to maintain extensive livelihoods.

Wildlife Management Areas

The planned establishment of conservation-oriented Wildlife Management Areas (WMAs) in the pastoral zone presents one of the most sensitive conservation issues of northern Tanzania (TANAPA 1994; Severre 2000; TWWG 2002; Goldman 2003). WMAs were officially proposed as the community-based wildlife management centerpiece of the Wildlife Policy of Tanzania in 1998. The three primary goals of WMAs are to 1) Promote wildlife conservation in buffer zones of critical wildlife habitat outside core protected areas, 2) give management responsibility of the areas to local communities, and 3) ensure tangible benefits from wildlife conservation for local Tanzanian communities totaling a population of more than 3.5 million people (Severre 2000). However, the true degree of local participation in and benefit from this program is under debate (see Igoe 2006 and Goldman 2009)).

Financial benefits of WMAs would be manifested in the form of income from hunting and other tourism activities, as well as employment of local people for these activities. Theoretically, the conservation of local natural resources will benefit people as well as wildlife by conserving grazing pastures for use by livestock, and by preventing unauthorized use of natural resources by outsiders. It is anticipated that the association of wildlife conservation with cash income will increase the value of wildlife in the eyes of local people, encouraging further protection of this resource.

An inspection of community-based conservation programs across Africa suggests that local people may be involved in the politics and policies of conservation within their communities, but that they remain peripheral to the ways in which conservation is perceived and nature managed (Goldman 2003). Despite the commitments outlined by the Director of Wildlife of Tanzania, extensive problems exist with the adoption of the program. While touted as Community-Based Conservation, WMAs will still be mandated by the State, guidelines and regulations for their implementation will be established by the State, and many interpret the policy as saying that the State will hold ultimate oversight in their location and management (Severre 2000). The procedures that must be followed to implement a WMA are prohibitively complicated and are not entirely participatory (Kallonga et al. 2003). This could lead to a combination of role confusion and imbalance of power among the WMA partners. In addition, current wildlife policy retains state ownership and control of wildlife resources, perpetuating the "wildlife-first" philosophy of old-school biodiversity conservation (Shauri 1999). This signifies distrust in local populations' ability to manage wildlife, and disenfranchises them of true control of this resource through ownership.

Local Simanjiro village communities feel they have not been asked to contribute their expertise to either overall WMA program structure or local WMA development, and this has led people to believe that WMAs are just another means of the government enlarging national parks. In addition, as Goldman (2003, p. 845) points out, "The consequences of denying the legitimacy of local knowledge claims goes beyond the political and social ramifications felt by the communities themselves. The landscapes created in the process are much less responsive to the local ecological processes to which local knowledge has adapted. This is particularly true in the semi-arid environments, where people and animals migrate in response to changes in local ecology."

Cultivation

There are physical and institutional limits to the amount of space available for cultivation. Grazing pastures must be left for livestock, and rules exist in every village, negotiated at the village and sub-village levels, regarding where cultivation can and cannot take place. Village governments are allocating land to individuals in the form of 99 year leases since in Tanzania all land is property of the State and cannot be legally owned by individuals. Allocation is occurring mainly to prevent both government interference in land-use and expropriation of additional grazing pastures and water resources to protected areas. In all three study villages newly allocated plots have become smaller over time as space becomes more limited. In some of the villages of Simanjiro, all available land has already been allocated to individuals (McCabe 2006, personal communication), so future generations of herd owners will need to subsist off of sub-divided plots inherited from their fathers.

The implications of village land allocation differ for the livestock and cultivation sectors. Currently, allocations are earmarked primarily for cultivation, and livestock movements are still communal. However, other areas of East Africa have undergone changes in land tenure from commons to various forms of privatized land that have led to the division of the landscape into increasingly smaller parcels. As control over land-use in these parcels is devolved from communities to individuals, land-use decisions are more likely to be made for the benefit of the individual, and this may come at the expense of the rest of the community. Traditional social networks and institutions may break down as communities become less involved in decisions regarding land management, and as decisions made at a higher level replace or obfuscate these traditional networks and institutions of common use. Fragmentation may isolate individuals as resources within parcels run out and routes to widespread resources of the former commons become blocked.

LARGE-SCALE COMMERCIAL CULTIVATION EASEMENTS

The 1980s marked the beginning of large-scale commercial easements to outside investors. These wealthy outside, and often foreign, investors began to establish large 1,000 to 25,000-acre commercial farms in Simanjiro's highlands in the 1980s and 1990s (Igoe 2006). These farms commandeered important water and grazing resources from village use, not surprisingly claiming lands with the earliest and highest rainfall. This has not only reduced the grazing area for both livestock and wildlife, but it has led to a significant loss of early, predictably-good grazing pastures. Additionally, now that cultivation has become a common household activity, the areas that would be most suitable and productive for this enterprise are no longer available for Maasai use.

SMALL-SCALE CULTIVATION BY MAASAI

Baxter (1975) outlined three general categories of pastoralists: 1) 'pure' pastoralists who do not cultivate, 2) those people who consider themselves pastoralists but rely upon other means to supplement their pastoral production, particularly cultivation, and 3) people who rely primarily upon agriculture for subsistence, but maintain strong pastoral values. Simanjiro Maasai tend toward category two, though there may be instances in which herds are lost due to drought or disease, and families may temporarily fall into category 3. Very few Simanjiro households fall into category one, since nearly all households that took part in this study were cultivating in 2003.

Cultivation has not only become an important part of Simanjiro household economy and food production, but is also becoming part of the cultural identity and one measure of Simanjiro Maasai wealth (J.T. McCabe, personal communication).[2] Simanjiro Maasai were encouraged to begin cultivating as part of Operation *Imparnati* (Igoe 2006), since cultivation was seen as a more 'proper use of the landscape' (M. Goldman, personal communication). This changed the face of the landscape, as well as that of household economies. As people began cultivating, labor resources were diverted away from livestock herding to planting, weeding, guarding, and harvesting of the fields. This meant that it was necessary for households to remain sufficiently proximal to their fields in order to tend to them. The number of mobile people and distances that could be traveled in search of livestock forage and water was at times restricted by the needs of the fields.

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[2] During the time of this study 2003 few individuals mentioned cultivation as an indicator of wealth, only livestock and children were counted. However in 2006 during fieldwork conducted by J.T. McCabe, cultivation was mentioned as one of the means through which individuals could attain wealth, in addition to the more traditional measures of number of livestock and number of children that I encountered in 2002-2004.

The area under cultivation has continued to increase. At the time of this study nearly every informant in the study cultivated at minimum a small garden, with most cultivating several acres. A few wealthier Maasai households have been able to invest in fields of 50-100 acres or more. The financial implications of cultivation are many. In good years with good timing, adequate rainfall and minimal pest destruction (by both wildlife and insects), losses are small and net income from cultivation (in either food or cash) is positive. Many years, however, rains are late or fail, the timing of the planting is wrong, or crops are destroyed by pests. Some years all of these occur at once. In these years most households are left total loss of their investment in planting. Unfortunately, poor conditions for cultivation usually mean poor conditions for livestock, leaving households with weak and dying livestock, little or no grain, high grain prices, and low livestock prices. This combination can wreak havoc on household economies.

While many Simanjiro residents farm to alleviate poverty and hunger, even those who do not need to farm for food are encouraged to do so by the local village government to protect the land from outsiders (Cooke 2007). Cooke discusses how, unlike economic diversification which is a decision based on household and family group needs, the decision to subdivide land and [strategically] cultivate is collectively made at the sub-village and village levels (Cooke 2007). The development of conservation zones to protect wildlife has unintentionally forced land use choices that are detrimental to wildlife preservation in critical areas outside protected areas (Cooke 2007). Demonstrating this, in 2003 I sat in on a meeting of several Sukuro Village elders who were discussing the very urgency of completing the subdivision of Sukuro lands and strategically cultivating them to protect land holdings from potential acquisition by conservation interests. This pattern of agricultural expansion is more apparent in the villages of Loiborsoit 'A' and Emboreet, likely because of their closer proximity to TNP.

IN-MIGRATION OF SMALL-SCALE AGRICULTURALISTS

An increasingly important segment of the cultivating population is being formed by small-scale agriculturalists who are moving into Simanjiro as space in wetter agricultural areas runs out. In 2002-2003 after the creation of the new Manyara Region (of which Simanjiro and TNP are a part), non-residents were encouraged to move into Simanjiro. Typically, these agriculturalists sub-lease plots from Maasai who do not have the labor, cash, or know-how to cultivate large plots that they may have been allocated by their village. These outsiders are also often hired by Maasai to cultivate in key areas that Maasai are attempting to secure from the threat of conservation easement or other external land acquisition threat. Agriculturalists who have been in the villages for a long period of time and participate actively in the community are often given their own land allocation to use as they wish, but the allocation of land to outsiders is not looked favorably upon by locals.

Since interviews were undertaken in 2003, the proportion of Maasai in the study villages who sublease patches of land to agriculturalists to cultivate has increased dramatically (McCabe 2006, personal communication). This trend presents implications for the rate of land-use change as local residents not only cultivate plots for themselves, but also allow outsiders to cultivate additional portions of their land for a fee.

Gem trading

Tanzanite is the most common gem that is traded by enterprising Maasai, though occasionally other gems are found. Tanzanite is found only in the village of Mererani in northern Tanzania. While this gem at times can be found scattered on the landscape, most of these loose stones have been picked up and the most common means of acquiring tanzanite is through deep mining. Tanzanite was discovered in 1967, and the tanzanite mines were opened in Mererani soon after. It was not until the early 1990s that Maasai from Simanjiro became active in the gem trade (McCabe 2007, personal communication), normally acting as traders or middlemen. Herd owners that want to try gem trading will typically sell a sheep or goat for cash to bring to Mererani himself or to send with a teenage son. The cash is used to purchase stones from a digger, and these stones are then taken to the town of Arusha to sell to distributors who cut and re-sell the finished product either loose or set in jewelry. Success at this venture is based largely upon the individual’s skill at recognizing a good stone without any formal training combined with a good bit of luck.

Conservation and Livelihoods

In northern Tanzania, the problem of how to balance sustainable land management and conservation with meeting resident human welfare needs has been debated fiercely. In addition to Simanjiro (Borner 1985; TANAPA 1994; TCP 1998; Igoe and Brockington 1999; van de Vijver 1999; Voeten 1999; Igoe 2002; Goldman 2003; Igoe 2003; Kallonga et al. 2003; Igoe 2006; Cooke 2007; Hansen and DeFries 2007), conflicted areas across the region include the Ngorongoro Conservation Area (ole

Parkipuny 1981; Mascarenhas 1983; Arhem 1985; Makacha and Frame 1986; Homewood and Rodgers 1991; McCabe et al. 1992; McCabe et al. 1995; Perkin 1995; Kijazi 1997; Perkin 1997; Smith 1999; Lynn 2000; Boone et al. 2002; Galvin et al. 2002), the Loliondo Game Controlled Area (LGCA) east of Serengeti National Park (SNP) (Smith 1999; Lynn 2000; O'Malley 2000), the western side of SNP (Hilborn 1995; Sinclair 1995).

August et al (August et al. 2002) suggest that carefully constructed zoning regulations can prevent destructive land-uses in sensitive ecosystems. However, political decisions that are made at a higher-than-local level divide communities from nature conservation, and may partition the landscape along new, and not necessarily ecologically-relevant, lines (Goldman 2003). In highly variable non-equilibrial ecosystems, strict land-use zoning regulations may prove counter-productive as they restrict the efficient tracking of resources by wildlife and domestic livestock. Compression of pastoral territory has resulted in declines in wealth and the ability of families to survive on cattle alone; thus land loss and poverty can be seen as closely correlated (Cooke 2007), and a proportion of cultivation expansion, though not all, can be attributed to these changes.

Analyses by Burnsilver et al. (Burnsilver et al. 2003) have demonstrated that some areas of the landscape are, over time, more productive than other areas despite variation over time. But productivity is just one of many important system qualities that can be concentrated in particular areas of the landscape. Other system qualities that are or can be consistently more available in defined areas include high-mineral soils, high quality forage (for grazing or browsing), higher elevation early rainfall zones, and permanent water. Within large regions of low productivity, the small proportion of the landscape that is highly productive is extremely important to regional biodiversity and critical for the survival both of local endemic species and of widespread species that depend on these refuges during critical times of the year. (Huston 2005). Key resources are also critical to maintenance of livelihoods in these regions. For cultivators, soil texture and quality are highly variable across landscapes, making some areas more conducive to cultivation success. When desirable landscape attributes for one type of land-use overlap with the desirable attributes for another, then conflict can occur (Figure 1.4). When these areas get "used up" by one land-use, they are often less available – or no longer available – to the others. This is what is happening at the interface of wildlife conservation, pastoralism and cultivation in Simanjiro.

In order to be locally appropriate, land-use policies and development interventions need to be designed with the fundamental spatial and temporal dynamics of target system resources in mind so that interventions and policies facilitate rather than constrain local strategies of access (Ellis and Swift 1988). If not made in a collaborative manner, the bureaucratic requirements of politically-made land-use decisions may in essence take community lands out of the control of local people to put them under the control of district authorities (Goldman 2003). Similar concerns were revealed by informants of this study, that outside decisions are made to pursue national financial agenda rather than to protect the interests of local people (anonymous conversations with the author).

As noted by (Gamassa 1995), "The Tarangire River that bisects the park from north to south is the only source of water for wildlife in the dry season. From the dry months of June to October wildlife congregates in the park for grazing and watering." But what is often not recognized by the wildlife management stakeholder group is the fact that to this day the Tarangire River and associated swamps remain the only predictably perennial water source in the whole of Simanjiro. Prior to the creation of Tarangire National Park livestock followed the same seasonal migration. But as far back as the 1980s research was being done to explore and recommend land-use options to balance sustainable wildlife conservation and simultaneously reduce human-wildlife conflicts (see Gamassa 1995).

It is also true that in Tanzania important wildlife corridors and other important wildlife resources located outside of national parks are not protected by law (Gamassa 1995). The combination of lack of wildlife protections and lack of human land tenure security creates a condition of juxtaposed vulnerabilities that is very difficult to address. This is particularly true because the value of cultivation for Maasai pastoralists and the cost of cultivation to wildlife have not been measured. Rather land-use regulations are largely founded on the belief that wildlife are negatively affected by cultivation, and that people can find alternate means of subsistence. While it may be true that either or both of these assumptions are true at times, they are not necessarily both true all of the time.

STUDY FRAMEWORK AND JUSTIFICATION

Breaking up the pastoral landscape stresses the ability of both people and wildlife to acquire necessary resources, as well as the ability of the resources to recover from use. Conservation programs that discount indigenous land management practices may have exactly the opposite effect of that intended; resources that policies intend to protect can be compromised by the failure of institutions to consider the resources as part of a greater, functioning ecosystem that includes people and their evolving land management practices. This interdisciplinary research project allows consideration of the intricate feedbacks among multiple system components that all contribute to the structure and function of the ecosystem. The trade-offs between environment and development outcomes are difficult to integrate into a consistent approach and set of priorities for management (Homewood 2004). It is important both to ask the right questions, and to integrate a wide variety of multidisciplinary data to encompass both environmental and development dimensions in research and outcome evaluation (Homewood 2004).

A scientific basis must be developed for objective management decisions that involve all ecosystem stakeholders and components, while protecting rights and addressing needs. An integrated assessment of the interface between the human and wildlife components of the TME forms the foundation of this dissertation. Landscape-scale studies are needed in agricultural areas to understand the effects of different landscape arrangements on spatio-temporal patterns in species distribution and demographics (Freemark 2005). While this dissertation was not intended to analyze demographics and population trends (the study would have needed to be much bigger), the study of distribution patterns in response to cultivation is essential. But in order to get a true picture of the impact of conservation on the ecosystem, impacts on human well-being and livelihoods also need to be studied. Knowledge regarding both species distributions and livelihood impacts are necessary for effective and sustainable conservation planning in Simanjiro. The overall objective of the study is to quantify the impact that pastoral land-use change and resulting landscape patterns and processes in the Simanjiro Plains have for household economies and wildlife distributions (Figure 1.5).

Research has shown that patterns of diversity-heterogeneity relationships vary by scale, and responses are generally specific to taxons (Gonzalez-Megias et al. 2007). The need to investigate the relationships between process and pattern at multiple scales is more of a rule than an exception (Gonzalez-Megias et al. 2007). Doing so will help to elucidate the scale at which species respond to landscape patterns, and this may have important implications for conservation ecology and community management (Gonzalez-Megias et al. 2007).

The identification of thresholds and scales of responses are made even more difficult by both temporal and spatial variability (Groffman et al. 2006) within and across ecosystems, and by the overlap of multiple ecological continua that are difficult to disentangle (Hunter et al. 2009). This does not prevent policymakers from enacting laws and restrictions on land-use to prevent the crossing of these ecological thresholds, oftentimes using subjective assessments to determine arbitrary thresholds that do not necessarily match ecological impacts (Hunter et al. 2009). While policies that are developed along a continuum make more sense heuristically, resulting complicated laws would be difficult to legislate and enforce (Hunter et al. 2009).

Information that is credible, salient and legitimate is more likely to lead to action (Cash et al. 2003); information at an appropriate temporal and spatial scale increases the credibility of that science for collaborative landscape planning, as well as its salience for decision-making (Termorshuizen and Opdam 2009). Legitimacy is gained through respect of stakeholder values and elimination of bias, transparency, and keeping the interests of the end-users in mind (Cash et al. 2003).

The objective of the wildlife component of this study was to determine whether cultivation in the pastoral-wildlife landscape influences wildlife distributions, and if so at what scale and to what extent. Not only are many Simanjiro stakeholders interested in this question, but Simanjiro also provides a gradient of cultivation intensity that allowed the selection of sites to study this interaction for multiple species at multiple scales. Levin (Levin 1992) explains that the concept of scale, and the inter-related processes and patterns that occur at different spatial, temporal, and organizational scales is fundamental to the development of proper principles of management. He emphasizes that not only is environmental heterogeneity fundamental to the coexistence of species, but that the description of the distributions of species across space and time is by definition a description of pattern.

In Simanjiro, at the local to landscape to regional spatial scales, there occur embedded and interacting patterns of wildlife movement. For this study I focused on the spatial scale of movement patterns over the course of a single rainy season in 2004, while recognizing the fact that in Simanjiro temporal changes in resource availability play an important role in overall movement patterns. Both seasonal and year-to-year differences in large-scale movements are quite important. The construction of this study is based upon three general patterns of movement occurring at different spatio-temporal scales: 1) migratory species move seasonally at a *broad scale*, migrating out of TNP and into the village areas during the wet season, and out of the village lands back to TNP (to access the permanent water source of the Tarangire river and dry season grazing grounds) in the dry season; 2) within a particular season animals move among grazing pastures as forage quality and quantity change over time, but in areas with very large pastures available these *mid-scale* location changes tend to happen over the course of weeks rather than days, and; 3) individuals and groups of animals move at a *finer-scale* within pastures every day, both approaching and moving away from cultivation as they search for forage and water to meet their daily nutritional requirements.

The three scales of wildlife analysis form a natural progression that matches, at least to some degree, the temporal scale of movements of the species under scrutiny as I observed them over the course of 1.5 years spent in the study area. While of course there is variation in these movements by individuals, by species, and from day to day, the combined study of three scales of response revealed some overarching relationships to patterns of cultivation across the study area. The location of the wildlife study area was selected to correspond spatially with the interview study area, though, out of necessity, the wildlife study occurred in a central subset of the three villages rather than across the entire three villages. It is important that the spatial scales of both human and wildlife studies consider the scale of land-use decisions by both people (with respect to their livestock herding decisions) and wildlife within and between years in this area. Since Maasai socially- and ecologically-defined boundaries often cross official village boundaries within which bureaucratic land-use decisions are made (Goldman 2003), collecting data across three villages was important to recognizing the fact that as cultivation alters landscape patterns at the local level, there may be implications for ecosystem processes at the ecosystem level due to the spatial fluidity of movement responses.

How wildlife choose to move both within and between pastures depends on the availability of necessary resources and the spatial arrangement of those resources. But it also depends on their abilities to work around hard and soft movement barriers that fragment or consume portions of the landscape, making those areas unusable, inaccessible or less appealing sources of resources. A species may show positive, negative, intermediate and neutral responses to landscape features such as cultivated areas depending upon the type of boundaries encountered (Ries and Sisk 2004). Different species could demonstrate different responses, and their response patterns may vary with spatial scale (Figure 1.6). A positive response to landscape features indicates that the feature is attractive at the scale of observation, and populations tend to be denser closer to the feature. A negative response to landscape features indicates that the feature is repellent at the scale of observation, and populations tend to be less dense closer to the feature. An intermediate response indicates that while some characteristic of the feature is attractive, some other characteristic is simultaneously repellant at the scale of observation. This leads to a hump-shaped population distribution response. A neutral response is essentially no response at all; population densities remain similar at all distance intervals.

Land-use and land cover changes affect the Earth System at all spatial scales, from the local, to the regional, and to the global (Lambin et al. 2001). Land cover changes that result from land-use change are widespread (Lambin et al. 2001). But over-simplifications of cause and effect relationships are rampant, and these myths have actually gained enough public support to influence policies on environment and development (Lambin et al. 2001). Corry (Corry 2004) discussed the idea that there is a need to shift conceptual thinking about landscapes towards a multi-scaled approach, since fragmentation that is obvious at one scale may be less apparent at another scale. This is an extremely important consideration for Simanjiro, as wildlife and pastoral movement patterns occur in response to resource availabilities that change over multiple scales of space and time.

INTRODUCTION OF CHAPTERS

It is often assumed that all agriculture is incompatible with conservation of large mammalian wildlife in the rangelands of Africa (see Sachedina 2006). Yet, the actual spatial responses of large-bodied wildlife species to cultivation are not fully understood. It must be assumed that for these species there is some threshold at which a combination of habitat loss, the actual loss of pasture area available to grazers, and fragmentation, the physical loss of access to still-existing grazing pastures due to movement barriers, will have a negative impact on wildlife. But where is this threshold, and are migratory wildlife necessarily negatively impacted by less widespread cultivation as many wildlife advocates believe? At what scales do wildlife respond to cultivation? The answers to these questions, combined with information on the consequences of cultivation for livelihoods, should provide a basis for land-use and land-use policy decision-making. This knowledge will improve our capability to objectively balance the resource needs of people with those of wildlife.

Chapter two presents an investigation into the consequences of Maasai cultivation for their livelihoods. The first part of the chapter looks at the relative contributions of cultivation and livestock to livelihood incomes and expenditures. The second part of the chapter calculates the cultivation profit and loss margins for participating households, and explores whether the result is related to herd health. Findings are framed within the context of Maasai vulnerability and resilience to changes that have occurred over the past half-century, as well as anticipated future changes and risks.

Chapter three investigates species-specific wildlife responses to cultivation at the scale of the individual cultivated plot. These cultivated plots are located within four of the six grazing pastures located across the landscape investigated in Chapter 4. This chapter also discusses the seasonality and intensity of human-wildlife conflicts encountered by villagers, paying particular attention to conflicts occurring in cultivated fields as evidenced by both field data and interviews.

Chapter four investigates species-specific wildlife responses to cultivation at the scale of individual 5-10 km^2 pastures, as well as at the landscape scale of approximately 500 km^2. The pastures under investigation contained (or were bounded by) the cultivated plots that were studied in Chapter 3, and were located across a gradient of cultivation intensity. By comparing observed wildlife densities with randomized densities, I examine responses to both *Euclidian distance* from cultivation, and *cultivation intensity*, a distance-weighted measure of cultivation density. By comparing observed wildlife densities with densities of null models composed of points randomized across the landscape, I assess the responses of various wildlife species to cultivation at the landscape scale.

Chapter five presents a summary of the preceding chapters, integrating the major findings and implications to present land use management and policy options for the Tarangire-Manyara Ecosystem. Findings are discussed in the historical context of land tenure and land use change, as well as in the future context of climate change and risk.

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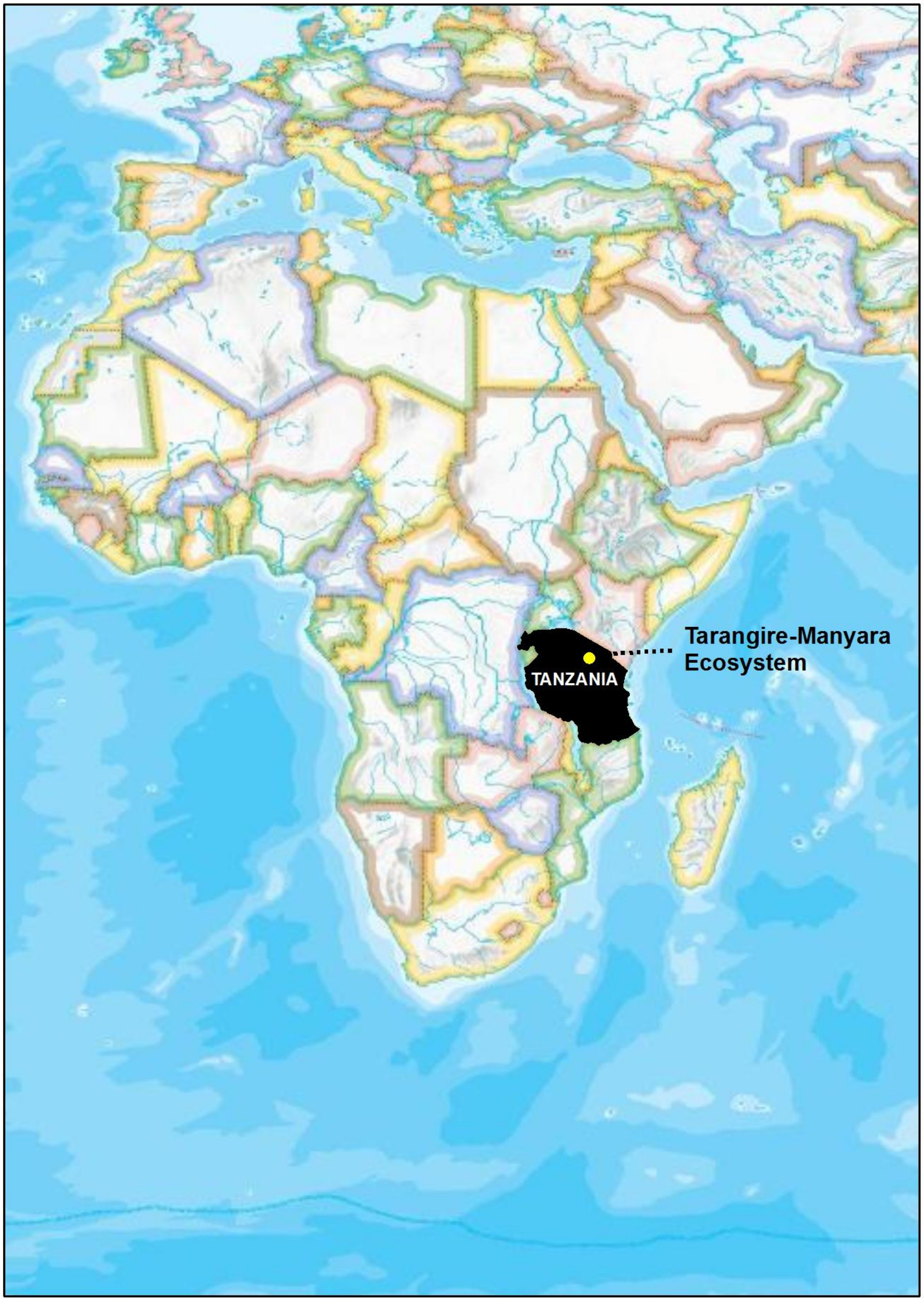

Figure 1.1. Map of the Tarangire-Manyara Ecosystem (TME) and its location in Tanzania and Africa.

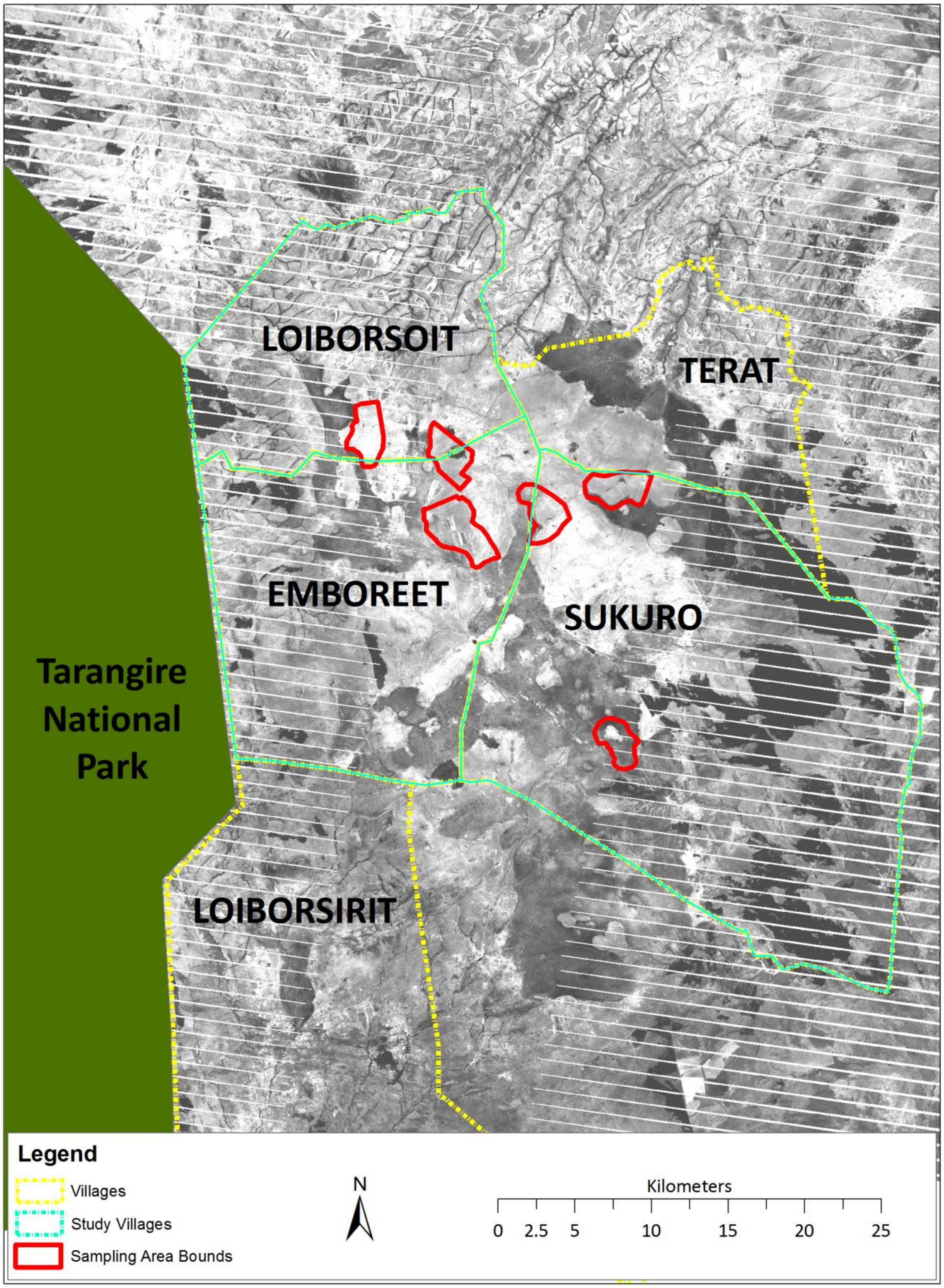

Figure 1.2. Map of the study area and surrounding Villages.

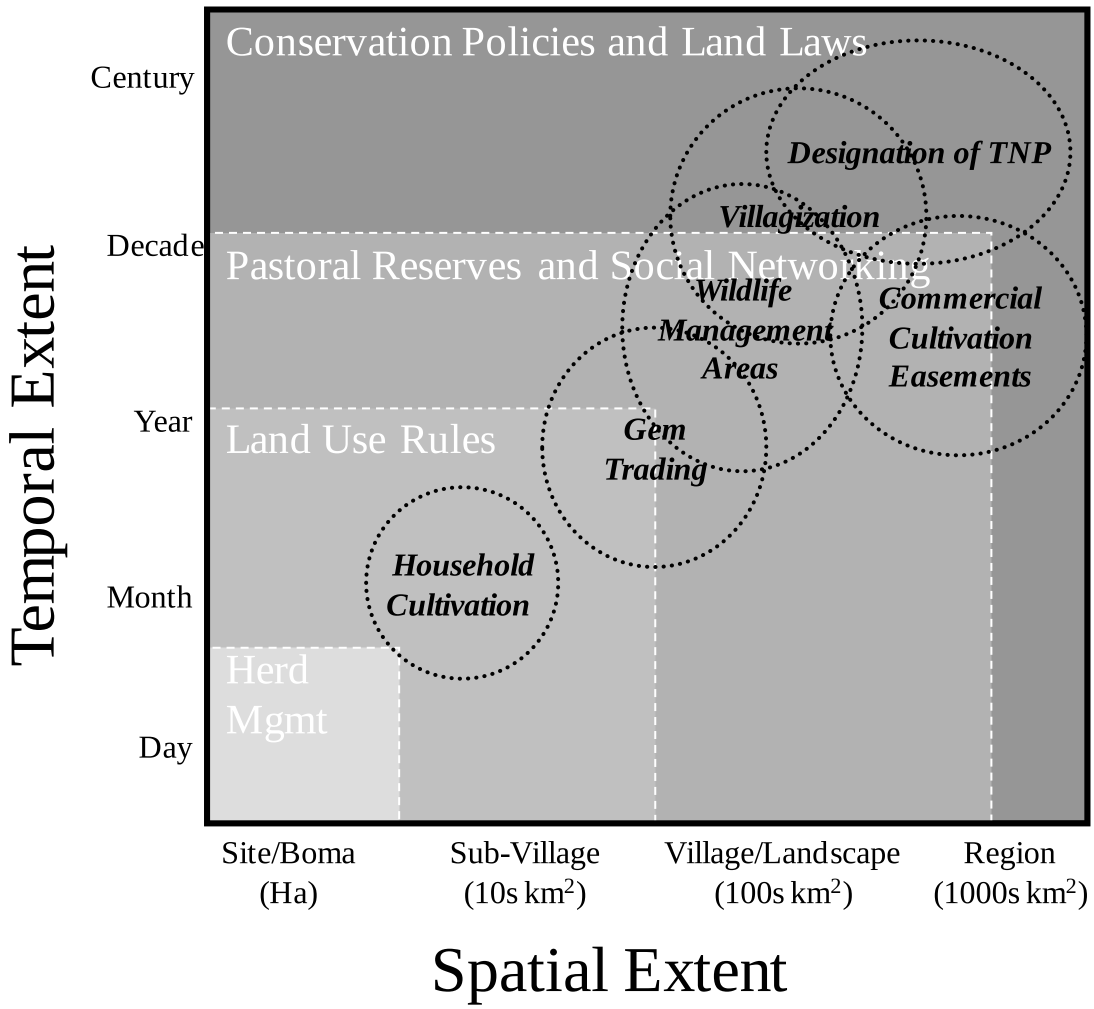

Figure 1.3. The spatial and temporal extent of historical ecosystem drivers of land use changes in the Tarangire-Manyara Ecosystem (TME) (after (Forman 1995)), and how they correspond to the primary spatio-temporal levels of various TME decision-making processes.

Landscape Needs and Values of Local People

- Grazing pastures
- Water for livestock
- Land tenure security
- Access to veterinary services
- Access to healthcare
- Water for people
- Areas for cultivation
- Access to markets
- Access to education

Landscape Needs and Values of Conservation

- Grazing pastures
- Water for wildlife
- Security/Protection from poaching

Landscape Needs and Values of Tourism

- Wildlife populations
- Clean environment
- Cultural/Historical resources
- Infrastructure/Accessibility

Figure 1.4. When desirable landscape attributes for one type of land-use overlap with the desirable attributes for another, then conflict can occur. Resources that get "used up" by one land-use are often less available – or no longer available – to the others.

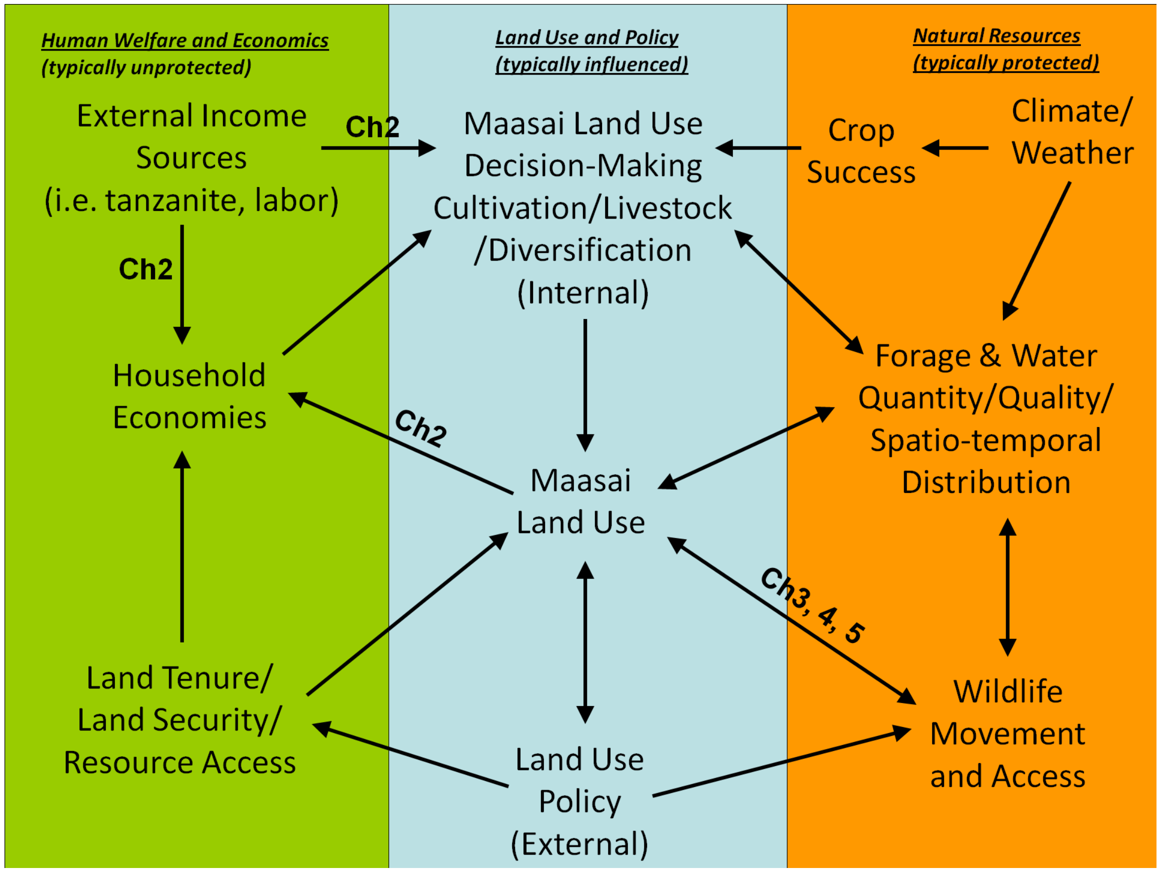

Figure 1.5. Schematic of interactions between human welfare and economics, land use and policy, and natural resources in the TME.

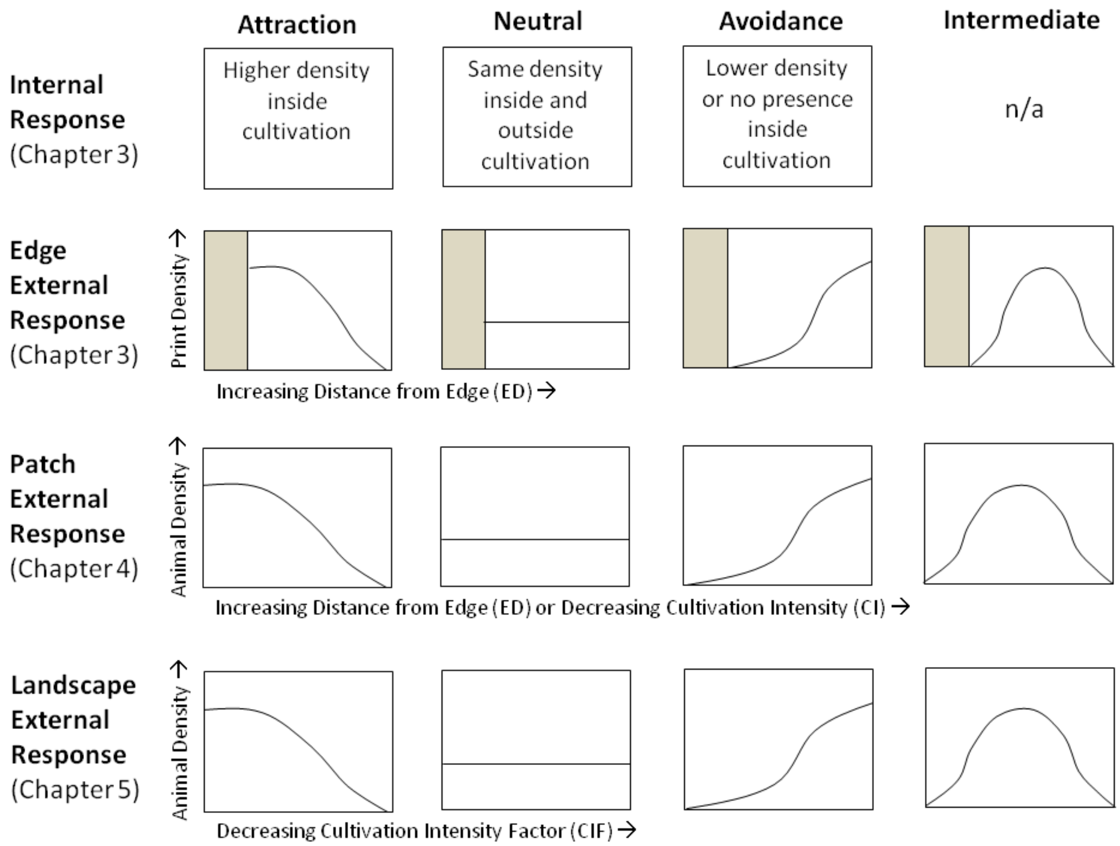

Figure 1.6. Hypothetical set of possible species-specific wildlife responses to cultivation at three different scales of study covered by this dissertation.

CHAPTER 2

CRISIS AVERSION IN AN UNCERTAIN WORLD: CULTIVATION BY EAST AFRICAN PASTORALISTS

ABSTRACT

In multi-sector social-ecological systems, the implementation of mechanisms to improve resilience in one sector may increase vulnerability in another. Pastoralism has been practiced alongside wildlife in semi-arid East Africa for millennia, but conflict is intensifying between wildlife conservation policy and Maasai pastoral land use. In Simanjiro, northern Tanzania, key resources were excised from Maasai use and incorporated into Tarangire National Park (TNP) in 1970 with the goal of wildlife conservation. The elimination of these important areas from the Maasai repertoire has been devastating during droughts. From the Maasai perspective, conflicts with wildlife on village lands are difficult to reconcile with wildlife's exclusive use of perennial water inside TNP.

Despite regionally high temporal and spatial variability of rainfall, most Simanjiro Maasai have diversified their land use to include cultivation. This study finds that cultivation profits are largely positive, raising some below-subsistence pastoralists above the subsistence threshold and others toward it. Resilience is increased as a product of both intermittent food production and a quick potential food pulse following drought while livestock populations recover. Cultivation success is correlated with herd wealth in two villages. Data from a third village showed widespread crop failures across the entire wealth gradient, demonstrating that success is also highly variable across space, likely due to uneven rainfall. The opportunity to cultivate may prove increasingly important if rainfall variability increases as predicted by climate change models. Future wildlife conservation may either enhance or compromise pastoral resilience. Strictly limiting cultivation in Simanjiro would remove a subsistence alternative, but allowing use of Tarangire's restricted perennial water and early-rainfall zones during drought would help communities mitigate risks associated with climate change. Policymakers should involve local pastoral stakeholders and incorporate objective predictions of both wildlife and livelihood impacts to best maintain system resilience.

Keywords

Vulnerability, Resilience, diversification, livelihoods, pastoralism, wildlife, Tanzania

INTRODUCTION

In multi-sector social-ecological systems attempts to improve resilience in one sector may in fact increase vulnerability in another. Such a situation is occurring in East Africa as conservation policymakers establish national parks, and then attempt to extend their management influence to areas outside parks with the goal of maintaining migratory wildlife populations. Land managers worry that the intensity of human impacts on ecosystems will be amplified as populations increase. Land use decisions involve weighing consequences of use for both meeting short-term human demands and maintaining ecosystem function (DeFries et al. 2004). These decisions also need to balance the resilience and vulnerabilities of both social and ecological system components.

Ecological resilience theory was developed by C.S. Holling (Holling 1973) to describe trajectories of change in ecological systems and ecosystem responses. Resilience “determines the persistence of relationships within a system and is a measure of the ability of systems to absorb changes of state variables, driving variables, and parameters, and still persist [in its current form]” (ibid, p. 17). Over the years the ecological resilience discourse has continued to refine this definition; however the fundamentals have remained unchanged.

In more recent years, the resilience discourse has expanded to embrace the social component of ecosystems, as humans participate in determining the structure and function of most ecosystems. In fact, the first step in managing for resilience is to recognize that people and their institutions are integral components of ecological systems (Chapin et al. 2004). The importance of governance, and its contribution to a society’s ability to manage resilience, resides in its actors, social networks and institutions and how they function and make decisions (Lebel et al. 2006). Decisions are based upon priorities among social and environmental objectives that are weighed in a necessarily political arena (Goldman 2004). Oftentimes governance structures and processes actually pass over the needs of livelihoods and minorities in the interests of maintaining ecological resilience (ibid).

Vulnerability is defined as a state of susceptibility to harm from exposure to stresses associated with multi-scaled environmental and other changes, combined with an absence of capacity to adapt to these changes (Adger et al. 2009). The vulnerability of systems is the balance between accumulated resilience derived from social and ecosystem services, and the shorter-term sensitivity to social and ecological change (Chapin et al. 2004). Vulnerabilities are nested, so that changes and shocks at the global scale (such as climate change) cascade down to the local level to impact livelihoods and human welfare, and likewise local responses to change may trigger vulnerabilities in other locations (ibid).

Across much of East Africa, relations between land users and governments/conservation agencies are characterized by controversy regarding the impacts of land use on the landscape, wildlife, and biodiversity in general (Brockington 2002). The potential for conflict is perhaps greatest in regions that border protected areas (PAs) in arid to semi-arid lands (ASAL) where migratory wildlife often share the landscape with people. Declines in wildlife populations have been found in many areas of East Africa (Homewood et al. 2001). Per-capita livestock holdings also appear to be declining (Kijazi et al. 1997; McCabe et al. 1997; Lynn 2000; Boone et al. 2006). The long-term sustainability of both pastoral livelihoods and wildlife on pastoral lands is in question.

Rainfall is a dominant driver of semi-arid land cover, constraining human land use. Extensive livestock grazing is well-suited to the bimodal pattern of rainfall found in East African ASAL (Ellis and Galvin 1994), as livestock can convert unpalatable forage materials into foods for human consumption (Pratt and Gwynne 1977; Dyson-Hudson 1980; Lamprey 1983) and make it possible to exploit areas that are too marginal for most other human uses (Galaty and Johnson 1990). Both domestic and wild animals track resources spatially and temporally across the ASAL landscape by moving to access these resources where and when they occur.

Drought and unpredictability are fundamental characteristics of ASAL, and both wildlife and humans have developed coping mechanisms to accommodate variation that occurs at scales from the intra-annual rainfall cycle to inter-annual and multi-year shocks. In addition to mobility, pastoral populations utilize several other mechanisms to accommodate resource variability. These include multi-species herds that spread risk, and social programs such as stock associations that re-distribute resources from wealthy to poor in times of need (Potkanski 1999). Herd size is opportunistically increased in semi-arid and non-equilibrial systems in anticipation of future losses, buffering herdowners from drought and disease die-offs (Campbell 1981; Sandford 1982; Ellis and Swift 1988; Galaty and Johnson 1990; Swift et al. 1996; Schwartz 1999).

Climate change is expected to increase both the frequency and magnitude of extreme weather events in many parts of East Africa, particularly savannas (Barker 2003; Boko et al. 2007). Although pastoralists and wildlife are accustomed to fluctuations of well-being in these non-equilibrial ecosystems, an increasingly extreme climate regime may compromise the capacity of the system to recover between shocks. After a single year of drought, animals (domestic and wild) will not only suffer the ill-effects of drought-past, but will also become more vulnerable to future events, whether a cold rainfall (Ellis 2001) or another year of drought. Add to this a diminished capacity to relocate because of changes in landscape and resource structure (e.g.: cultivation or fencing), availability (e.g.: water diverted for irrigation), or access (e.g.: protected area or other boundary), and there is enormous potential for the system to "tip" into a condition where the sustainability of East African pastoral systems becomes doubtful.

Study Area: The Tarangire-Manyara Ecosystem

The Tarangire-Manyara Ecosystem (TME) is located in northern Tanzania and incorporates two national parks – Tarangire National Park (TNP) and Lake Manyara National Park – as well as the village lands of the Simanjiro Plains to the east (Figure 2.1). The primary shift in land use in Simanjiro villages has been an increase in cultivation over recent decades, and this appears to be accelerating (Voeten and Prins 1999; TMCP 2002). Hostility and resentment among various stakeholders have escalated due to both real and perceived violations of pastoral land rights, the fear of future violations, and a potential crash of the migratory wildlife and/or pastoral livestock populations.

Diversification may increase resilience of populations by providing alternative pathways that allow people to cope with adversity. Alternative subsistence pathways may prove to be particularly important if climate change exacerbates adversity. Actions to diversify are simply attempts to compensate for or pre-empt anticipated changes in pastoralists' ability to maintain their livelihoods through pastoralism alone, in either the long- or short-term. The rationale for diversification varies across wealth classes; poor herders are pushed into diversification to survive, the wealthy diversify as an investment scheme, while mid-wealth herders lack either the need or motivation to diversify and are likely the last to do so (Little et al. 2001). Opportunity, need, and local conditions must come together to make diversification an attractive and viable option. Increasing vulnerability of (and professed by) Simanjiro Maasai may be a key factor in changing attitudes towards cultivation. Conversations with Maasai indicate that people feel more vulnerable to drought in recent years, in part due to loss of land to Tarangire National Park and outside agricultural interests. People have also mentioned a perceived increase in drought frequency, and fears that additional land will be taken away to expand Tarangire National Park. Real and perceived stresses are increasing, and capacity to cope with environmental variability has decreased with the loss of important natural resources such as the Tarangire River in TNP, the Silale Swamps in TNP, and early-rainfall zones that have been largely converted to large-scale cultivation schemes by foreign investors.

The risk of crop failure is high in Simanjiro. But residents believe that cultivation helps maintain their livelihoods. Policymakers are concerned that increasing cultivation negatively impacts wildlife, particularly migratory species that alternate residence between Park lands in the dry season and pastoral lands in the wet season. Since the creation of TNP, wildlife have continued to migrate between these two zones, but livestock are now restricted to Simanjiro year-round, compromising pastoral livelihoods (Igoe and Brockington 1999; Goldman 2003). In Simanjiro, stress is felt particularly during drought. Additional land use restrictions, including cultivation limitations, are now proposed for many parts of Simanjiro as part of village-based land use plans (Goldman 2003).

Since the early 1990’s Simanjiro Maasai have also diversified into the tanzanite gem trade (McCabe 2009). Herdowners typically sell a sheep or goat for cash to purchase stones from a digger, then resell the stones to cutters. The gem trade is important to this study because of how it affects land use change. Both cultivation and gem trading may spread economic risk, reducing pastoralists' vulnerability to fluctuations in the livestock sector. This will become increasingly important as resource use becomes more limited by changes in landscape structure, access and availability.

Research Questions

The objective of this section of the research study is to determine the contributions of livelihood diversification activities to Maasai households in the Simanjiro Plains of the Maasai Steppe. Several research questions are addressed:

I. Does livestock herding remain the most important income-generating activity for Simanjiro households? I hypothesize that while cultivation and the gem trade may be becoming an important component of Simanjiro livelihoods, that livestock are still the most important income-generating activity.

II. Does cultivation make a positive net contribution to household economies? I hypothesize that cultivation profits are highly variable due to highly variable environmental conditions, but that on average households are making a profit with cultivation. The rationale for this hypothesis is that it would be counter-intuitive for people to continue with an activity that loses money year after year as it would be detrimental to their livelihoods.

III. Is cultivation success correlated with household herd wealth? I hypothesize that households with greater herd wealth make higher profits. I believe this to be the case because wealthier (in livestock) households are likely to have more discretionary livestock to sell in order to cover the costs of cultivation.

IV. Is the gem trade facilitating increased cultivation? I hypothesize that the large influxes of cash generated by the gem trade increases the rate of cultivation change. This would be brought about by gem trade profits providing cash for people to spend on plowing, and possibly the equipment purchases.

The answers to these questions will contribute information important to future conservation and land use policy, as well as to village and household-level land use decision-making. Quantifying the role of cultivation in modern Maasai livelihoods allows the incorporation of human welfare needs into the complicated equation of conservation in this pastoral ecosystem.

METHODS

Household Data Collection

For the purpose of this study, I define a *household* as a male herdowner, his wives and children, and any other dependent family members (following Lynn 2000; Galvin et al. 2001; Galvin et al. 2002; Thornton et al. 2003)). *Bomas*, or settlements, consist of one or more male herdowners and their associated households. Bomas are grouped into subvillages, and villages are formed of multiple subvillages (Figure 2.2). I selected three villages – Sukuro, Loiborsoit 'A' and Emboreet – for study. Loiborsoit 'A' and Emboreet border Tarangire National Park, Sukuro is located to the east of these two villages. These villages are varyingly affected by Park proximity, and encompass varying degrees of cultivation.

We conducted a census of each village's bomas with the assistance village leaders including the Village Executive Officer, and Village and Subvillage Chairmen. Each village consists of multiple subvillage units, so I stratified interviews across both subvillages and villages to get a representative sample of all locations. A total of 70 bomas were randomly selected from the pool of censused bomas using a random number generator in Microsoft Excel. This process eliminated any chance of bias in selection as all bomas were chosen randomly rather than subjectively or opportunistically. In five instances the head of a selected boma was not reachable after three to five attempts, and a substitute boma was randomly selected from the remaining bomas. 31bomas were interviewed in Sukuro (33% of bomas, 96 interviews total), 28 in Loiborsoit 'A' (20% of bomas, 65 interviews total), and 11 in Emboreet (25% of bomas, 46 interviews total).

Two interview teams (two individuals each) conducted simultaneous semi-structured interviews with different household heads within a single boma. We conducted all interviews in Maa, and recorded responses in Swahili. A detailed interview was conducted with at least one herdowner per boma (n=107), and a shorter version of the interview was conducted with all other available herdowners (n=100). The purpose of the short interview was to get a large sample size for data that would be processed using methods most sensitive to sample size. The long interview allowed collection of additional time-consuming data from at least one household per boma. Interviewing all available herdowners in each boma allows analysis at either the boma or household level. While it is important to look at wealth at the household level, boma-level wealth is also important since sharing and decision-making sometimes occurs within individual bomas (Lynn, unpublished data). Interviewees were asked questions on a broad range of topics, including household income and expenses, livestock herd dynamics and movement, livestock disease, land allocation, household demographics, and wildlife conflicts and conservation.

Data Processing and Analysis

Livestock numbers were converted to Tropical Livestock Units (TLUs) to standardize cattle, goats and sheep. One TLU is equal to one 250kg animal. The equivalencies used to convert to TLUs were 1 head of cattle = 0.71 TLU, and 1 head of smallstock (sheep and goats) = 0.17 TLU (McCabe et al. 1997; Lynn 2000; Galvin et al. 2002). Households (within bomas) that shared resources were pooled for analysis. Relative rankings of household income sources and expenditures were assessed, and net household income from cultivation calculated.

We collected two years of cultivation production data via recall from each interviewee. Total harvest information (kg) was recorded for one good year (2001-2002) and one marginal (2002-2003) year. Herdowners who participated in the gem trade were asked to detail their cumulative profits and losses, and classified into 5 categories: "loss" (invested money in attempting to trade, and never regained it), "broke even" (regained investment, but did not profit), "small profit" (regained investment and then enough to buy a few livestock or some food), "large profit" (made enough profit to purchase a large number of livestock, into the hundreds of animals, and/or to plow large fields), and "very large profit" (made enough money to purchase not only livestock or to cultivate, but also vehicles such as land rovers or tractors that often led to continuing profits from renting out vehicle services).

I used SPSS version 15.0 for Windows (SPSS, Inc., Chicago, IL) to conduct all statistical tests, using a variety of tests to analyze data. One one-way ANOVA was performed to determine if the mean acres cultivated differed by village. I used frequency analyses to rank the economic importance of various household activities. I was unable to achieve normal data distributions of herd and cultivation wealth through transformations, so Kruskal-Wallis non-parametric tests were performed on non-normal data to compare group means and determine the significance of their differences (significant $p<.05$). I performed both parametric and non-parametric linear regressions were performed to investigate the strength of relationship between herd wealth (per-capita TLUs) and both number of acres cultivated and cultivation profits (per capita US dollars earned).

RESULTS

Maize and beans were the only crops grown by the households interviewed. 93% of study informants (n=193) cultivated at minimum a small garden, with many cultivating several acres and two Sukuro households cultivating fields of 200 acres (80.94 hectares (ha)). Mean acreage per household was small at the inception of cultivation (3.15 acres, 1.28 ha) regardless of the year cultivation was started, but in 2003 the average household cultivated 13.5 acres (5.46 ha). This suggests that individuals tend to increase plot size over time. Mean acreage was highly variable, and not significantly different between villages ($p=0.419$).

Does livestock herding remain the most important income-generating activity for Simanjiro households?

While Maasai are diversifying, they still specify that livestock are most important to them, both economically and culturally. In the wet season, 64% of respondents ranked livestock as their primary source of income, and 32% ranked it second (Table 2.1). Cultivation was reported as the primary wet season income source by 36% of households, and second by 62%. While 47% of households participated in the gem trade, it was ranked as the least important income source by nearly everyone. In the dry season, as milk becomes scarce and fields are harvested, cultivation becomes more important to household income through both food production and cash from sales. 49% of households ranked cultivation as the most important dry season income source, and 38% ranked it second. 44% of respondents ranked livestock as most important, and 51% ranked it second (Table 2.1). The importance of gem trade to income increased in the dry season to 6% ranking it as their primary source of income, and 8% ranking it second.

The three most important household expenses across all seasons were supplemental food, livestock herd maintenance, and cultivation (Table 2.2). Supplemental food purchases were ranked the most important household expense for both wet and dry seasons. Livestock were still ranked as the most important income source, but other foods were used to supplement livestock products to sustain the average household's food needs. While supplementary products appeared to become more important during the dry year, they make an important contribution to household food regardless of the state of the livestock sector.

Does cultivation make a positive net contribution to household economies?

All cultivating households planted crops in both 2001-2002 (average) and 2002-2003 (dry), but the crop failure rate was much greater in the second year. The number of acres cultivated per household did not change from 2002 to 2003. However mean household harvest totals decreased dramatically (Table 2.3). Mean net production (combined maize and beans) of 126 kg/acre in 2003 was nearly half the 237 kg/acre harvested in 2002. Maize appears to be quite sensitive to rainfall, as the difference from 2002 (1915 kg per household) to 2003 (810 Kg per household) is striking. Beans appeared to be less sensitive to the difference between years (Table 2.4). Approximately 40% of the variation in total harvest between these two years can be attributed to the difference in year ($r^2 = 0.408$, $p<.001$).

The total amount of grain consumed each year and proportion from supplemental food were calculated using reports of kilograms eaten (versus sold or saved for seed) and kilograms purchased. Harvest quantity and proportion of total diet made up of supplemental foods were inversely related. The ratio of purchased to harvested foods increased from 33% in 2002 to 58% in 2003, demonstrating high variability in food security across years as a function of rainfall.

Low production comes at high cost, including lost investment (i.e. plowing costs, labor diverted from livestock, and caloric cost of labor), less to eat, less surplus to sell, and outlays for more supplemental food. Mean market prices for both maize and beans increased greatly from 2002 to 2003. The price of maize rose from $0.09/kg to $0.14/kg, and the price of beans rose from $0.21/kg to $0.25/kg, negatively impacting those households that did not produce grain. Food and other expenses in these households had to be covered by herd sales.

Almost all respondents stated that they cultivate every year. Reasons for cultivating every year include that they do not know when good or bad rainfall years will occur, so they take the chance of cultivating every year. Cultivation success in Loiborsoit 'A' and Emboreet did vary across years, but 90% of households in these villages broke even or made a profit in the end (Figure 2.3), while in Sukuro 56% of households failed to break even over the course of the two years (Figure 2.4). These results demonstrate both spatial and temporal variation in rainfall and its importance for cultivation success. While in some years and in some locations poor rainfall leads to a poor harvest, in successful years cultivation does appear to make a positive contribution to net household income.

Is cultivation success correlated with household herd wealth?

Cultivation success was correlated with herd wealth in Loiborsoit 'A' and Emboreet ($r = .50$, $p<.001$) (Figure 2.5). Six TLUs per person is a commonly referenced minimum number of TLUs necessary to maintain a pastoral subsistence (Brown 1973; Lynn 2000; Galvin et al. 2002). But Simanjiro Maasai are not pure pastoralists. Some number of livestock can be subtracted from this number for each equivalent unit of grain produced, and these equivalencies will vary according to markets and livestock condition. However, cultivation lifts a number of households above the subsistence threshold. Four classes of households may be distinguished from Figure 2.5. Segment A households are wealthy and do not need to cultivate, but do anyway (and are making a decent profit at it). Segment B households are lifted into subsistence by cultivating. Segment C households made a profit cultivating but remain below subsistence. Segment D households not only have insufficient herd wealth to maintain a purely pastoral existence, but also are losing money to cultivation. Herd wealth may initially facilitate cultivation, but because cultivation profits also often feed back into the livestock sector, cause and effect cannot be assumed. Direct and indirect inputs from cultivation into the livestock sector include such things as taking some of the food production burden off of livestock therefore leaving more milk for calves, providing an alternative source of cash to purchase items that otherwise would require the sale of an animal to acquire. This cash can be used to pay for items such as animal drugs as well as household items, hospital or school fees, cultivation costs. Occasionally people will use this money to purchase livestock, directly increasing their herd size as a product of cultivation.

In Sukuro there was much more widespread crop failure, with only 44% of households breaking even over the course of two years (Figure 2.6). In fact, the population segmentation demonstrates that there were a number of Sukuro households that dropped into negative subsistence as a result of cultivation during these two years. No correlation was found between herd wealth and cultivation success in this village (r^2 = 0.035, p=0.198). This emphasizes the impact that spatial variability of rainfall has across this semi-arid system. While herds can be moved to access spatially-variable forage and water, cultivation cannot, and is thus more susceptible to drought or patchy rainfall. While harvest success may be greater for wealthier households, as demonstrated in Loiborsoit 'A' and Emboreet, cultivation provides no guarantees due to the patchiness of rainfall distribution and timing.

Is the gem trade facilitating increased cultivation?

Approximately 50% of study households participated in gem trading, most breaking even or making a small profit. Gem trading has become an important cash source in Simanjiro, despite the fact that many individuals give up because the effort is not worth the profit. Only 2% of interviewees gained a very large gem trade profit. While these individuals invest in large-scale village projects such as shops, dams, schools, and dispensaries, the purchase of a tractor is the means through which one person's profits have the potential to impact land use change across a village as purchased tractors are rented to other villagers to cultivate their plots.

Nearly all respondents (96%, n=171) indicated that they used a tractor to cultivate their fields in 2003, the year the interviews were conducted, with the remainder using either a hand-plow or oxplow. Most people began plowing in the late 1980's and 1990's. Although tractors were available as early as the 1960's, tractors purchased with gem trade profits increase availability, allowing individuals to cultivate larger plots at their initial onset of cultivation (i.e. they 'start bigger'). A one-way ANOVA indicates that the number of acres cultivated at cultivation onset was significantly related to plowing method at that time ($p<.0001$). The maximum number of acres cultivated at the onset of cultivation was 7 for handplows, 5 for oxplows, and 40 for tractors. The proportion of households breaking their first fields with plows declined as the initial use of tractors increased. The timing of this coincides with the onset of the gem trade in the early 1990s (Figure 2.7).

Nearly all respondents who traded gems did rank this as their least important income source. However, the cumulative value of gem trading to some of these households cannot be overestimated, and the contribution to land use change through tractor purchases appears to be quite important. Maasai with resources to hire a tractor to plow their fields are more likely to have large fields than if they had to plow by hand or with an oxplow. Most respondents estimated that they would be able to plow only two to three acres without a tractor, in contrast to the actual average of 13.5 acres per household. Available cash appears to be the factor most limiting household plot size, as most interviewees indicate they would plow more acres if they "became lucky". The implications of this are important. 45% of respondents indicated that they plan to cultivate their entire land allocation, 45% plan to divide their allocation between cultivation livestock, and only 2% plan to use their allocation exclusively for livestock (Table 2.5). The mean acres (2003) cultivated by the 39 respondents who would "cultivate it all" was 14.6. The mean land allocation assigned to these interviewees was 35.8. Cultivating the entire allocation would more than double the current area under current household cultivation. At this time the gem trade is the most likely source of resources adequate to reach this goal.

DISCUSSION

In the ASALs of East Africa varying degrees of change are occurring in population growth, land tenure, land use, and excision from use. All of these factors act to increase the vulnerability of pastoral populations and their livestock to extreme events such as drought by restricting movement possibilities. Wildlife populations are also threatened by area loss and landscape changes that are a result of human population growth and land use change. Low net primary productivity and high variability are characteristic of these ecosystems (Colding et al. 2003), but both wildlife and nomadic and semi-nomadic pastoral systems evolved over millennia to utilize widespread forage and water through extensive movement, mitigating these risks. Historically, smallstock are important means to recovery as they reproduce more quickly than cattle.

Economic diversification is a risk management technique commonly used by East African pastoralists to cope with this increasing vulnerability of the livestock sector (Little et al. 2001). Both cattle and smallstock herds decrease during drought as a result of increased outputs (particularly deaths, but also sales and slaughters as animals lose condition and need to be culled before they become useless) combined with decreased inputs (primarily births and purchases). ASAL conditions make cultivation an unpredictable and risky enterprise, the success and failure of which is determined largely by the quality and timing of each rainy season (Ellis and Swift 1988). In good years of adequate and timely rainfall and minimal pest destruction (wildlife or insect), net income can be quite high, particularly for wealthier pastoralists. Maize can be either grown or purchased. If it is grown successfully then livestock do not need to be sold to purchase it. Respondents frequently commented that cultivation not only provides food directly for consumption, but also has the effect of maintaining herds. But when crops fail the plowing investment is lost, market prices increase, and households struggle to find cash to meet their food needs. Since the productivity of a given year cannot be forecasted at the onset of the growing season, variations in production must be offset by an increase or decrease in compensatory grain purchases (see also Galvin et al. 2004). Purchases are usually financed through livestock sales. The financial implications of cultivation are thus many.

The relationship between the three income-generating activities of livestock, cultivation and gem trading is synergistic (Figure 2.8). Livestock enable cultivation through monetary inputs that increase plowing potential. Cultivation provides income for animal purchases and animal drugs (which in turn reduce disease deaths), and decreases sales of livestock to purchase grain foods. Individual success in the gem trade facilitates livestock and cultivation sectors within the household, but also throughout the village. Though only a small fraction of people obtain enough money to purchase a tractor, many hire the tractors purchased with the gem trade profits of a few.

The addition of cultivation to livelihood regimes has added a new pathway of food and income production to the pastoralists of Simanjiro. Cultivated maize and beans are directly edible by people, unlike grass which must be converted into livestock products for people to consume. Livelihood resilience is increased as a product of intermittent food production and profits in good years. But cultivation can also provide a quick potential food pulse following drought while livestock populations recover. When herds experience die-offs from drought, disease, or other shock, a single good rainy season may lead to successful cultivation harvest. Of course other factors are involved other than rainfall, such as crop raiding by wildlife, but rainfall is key to a successful harvest. The success of cultivation in one year is not dependent upon the success or conditions of the year(s) before. Conversely, smallstock herds can take several years to reproduce to achieve their former numbers, and cattle herds even longer. Products of cultivation act as an important interim source of food for herdowners who may no longer have livestock sufficient to feed their families. This rescue mechanism can help households to recover from bad years, and relieve the pressure that would otherwise be concentrated on the livestock herd.

The economic, social, and ecological dimensions of sustainability and adaptation must be balanced for conservation strategies to succeed in places where the needs of these dimensions intertwine and conflict (Munasinghe and Swart 2005; Yohe et al. 2007). Wildlife and pastoral livestock herds depend largely on the same resources for survival, and as space becomes more limited, competition for these resources is escalating. Ecosystem structure and function are bound to change with land use, and this will likely have implications for wildlife, but the shared need for pasture and water should provide common ground for management.

Pastoralists and wildlife have adapted to the inherent and historical risk of climate variability in ASAL. However, land excisions and other restrictions on resource access present new risks that decrease resilience and system stability. Depending on regional economic activity, expansion of national parks and other protected areas actually may reduce both the degree of wildlife conservation as well as local human welfare (Johannesen 2006). Climate change is expected to increase variability, further amplifying these risks. Maasai pastoralists of Simanjiro bear these layers of risk by relying on three livelihood sectors that form pillars of risk mitigation (traditional pastoralism, cultivation, and gem trading). If stability of any of these pillars of support is compromised, the system may destabilize from the weight of layered risk. Future land use and conservation policies may either present an additional layer of risk, further restricting mitigation options (thereby increasing vulnerability), or provide an additional support for pastoral livelihoods by assisting with risk mitigation (thereby increasing resilience) (Figure 2.9). Strictly limiting cultivation in Simanjiro would remove a subsistence alternative, whereas negotiating use of protected resources such as the permanent water and early rainfall zones within TNP during drought may help communities mitigate risks associated with a highly variable climate and uncertain futures. Policymakers should involve local pastoral stakeholders in management decision-making and incorporate objective predictions of both wildlife and human impacts to best maintain system resilience, and to reduce vulnerability to change.

ACKNOWLEDGMENTS

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TABLES AND FIGURES

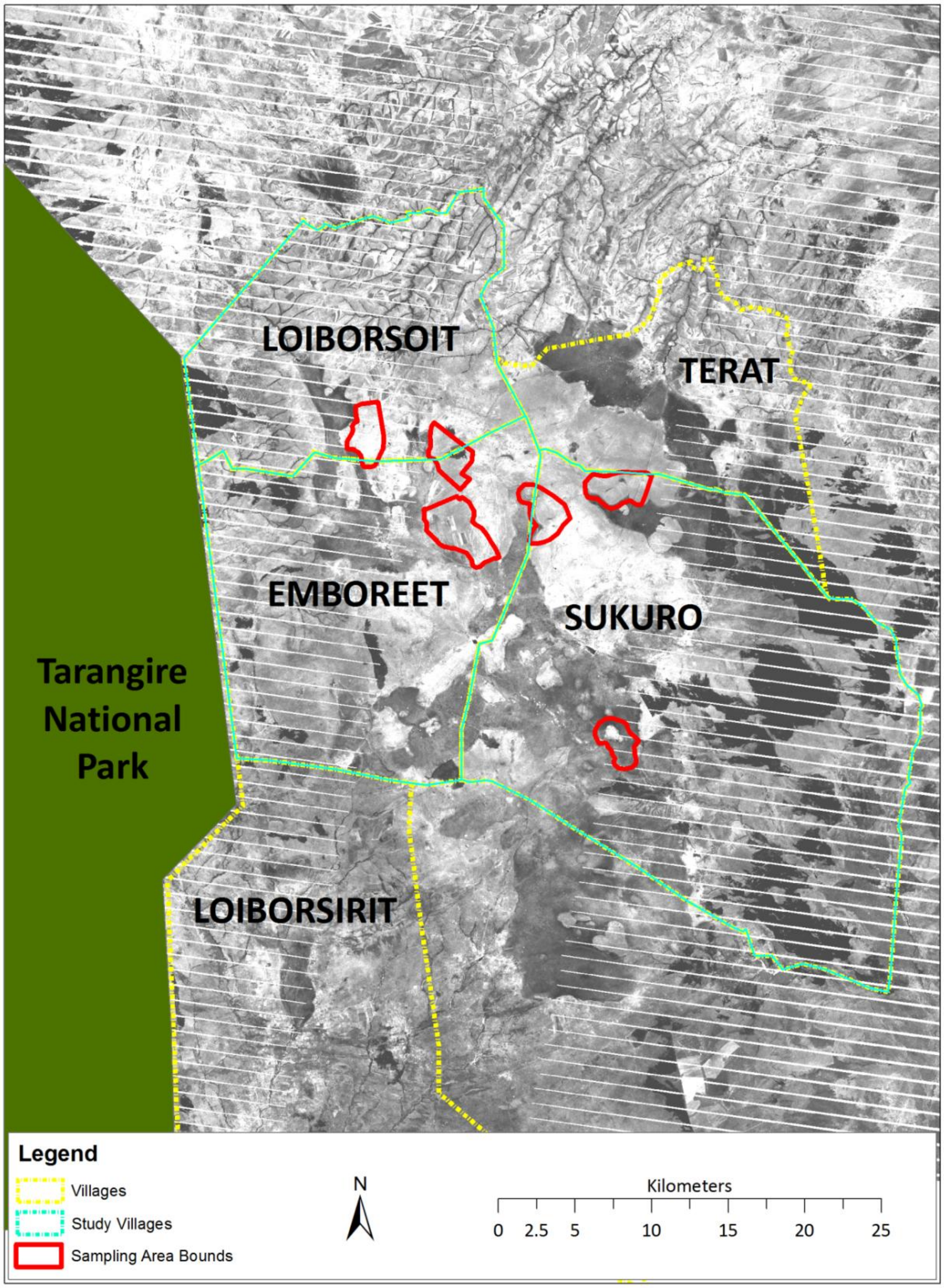

Figure 2.1. Map of TNP and nearby Villages. This map demonstrates the locations of the wildlife sampling areas in relation to the village boundaries. The study villages are Loiborsoit 'A', Sukuro, and Emboreet. Interview bomas were spread across the entirety of the three villages.

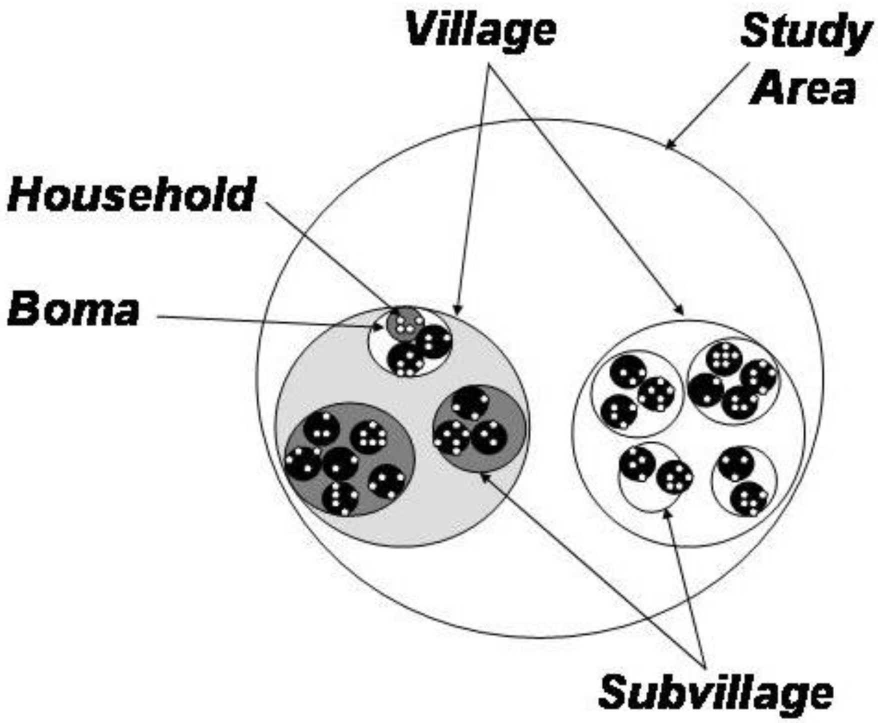

Figure 2.2. Schematic of the interview design, stratified to allow analysis at the household, boma, subvillage, and village levels.

Table 2.1. The relative importance of income activities was ranked by herdowners (n=107), where 0=No Participation, 1=Most Important, 3=Least

	Relative Importance of Income Activities					
	Wet Season			Dry Season		
RANK	Livestock	Agriculture	Mining	Livestock	Agriculture	Mining
1	**63.60%**	35.50%	0.90%	43.90%	**48.60%**	5.60%
2	31.80%	**61.70%**	5.60%	**50.50%**	38.30%	8.40%
3	4.70%	1.90%	**40.20%**	4.70%	5.60%	**31.80%**
0	0.00%	0.90%	**53.30%**	0.90%	7.50%	**54.20%**

Relative Importance of Household Expenditures												
	Wet Season						Dry Season					
RANK	Lvstk	Agric	Clothes	Hospital	School	Food	Lvstk	Agric	Clothes	Hospital	School	Food
1	13.1%	**29.0%**	0.9%	8.4%	0.9%	**46.7%**	4.7%	0.0%	0.9%	0.0%	0.9%	**93.5%**
2	**33.6%**	**29.0%**	4.7%	13.1%	0.0%	18.7%	**68.2%**	0.0%	4.7%	19.6%	2.8%	3.7%
3	**29.9%**	**24.3%**	15.0%	16.8%	2.8%	9.3%	11.2%	0.9%	20.6%	**58.9%**	4.7%	0.9%
4	13.1%	8.4%	21.5%	**43.0%**	1.9%	9.3%	13.1%	0.0%	**57.9%**	15.0%	10.3%	0.0%
5	6.5%	2.8%	**46.7%**	15.0%	10.3%	12.1%	0.9%	6.5%	10.3%	3.7%	**49.5%**	0.0%
6	0.9%	0.9%	7.5%	1.9%	**52.3%**	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0	2.8%	5.6%	3.7%	1.9%	**31.8%**	1.9%	1.9%	**92.5%**	5.6%	2.8%	31.8%	1.9%

Table 2.2. Relative rankings of household expenditures.

Table 2.3. Additive values were calculated for the relative rankings of livestock, agriculture, and supplemental food expenditures for the wet and dry seasons. Higher values connote greater perceived contributions to household expenditures.

Additive Rankings of Household Expenditures			
	Wet	Dry	Average
Livestock	421	455	438
Agriculture	448	17	232
Supplemental Food	465	583	524

Table 2.4. Mean household production of maize and beans in 2002 (average year) and 2003 (dry year) were dramatically different. Approximately 40% of the variation in total harvest between these two years can be attributed to the difference in year ($r^2 = 0.408$, $p<.001$)

Mean Household Production (Kg)		
	2002	**2003**
Maize Produced	1915	810
	n=189	*n=191*
Beans Produced	890	688
	n=118	*n=103*
Total Harvest	2445	1176
	n=191	*n=192*

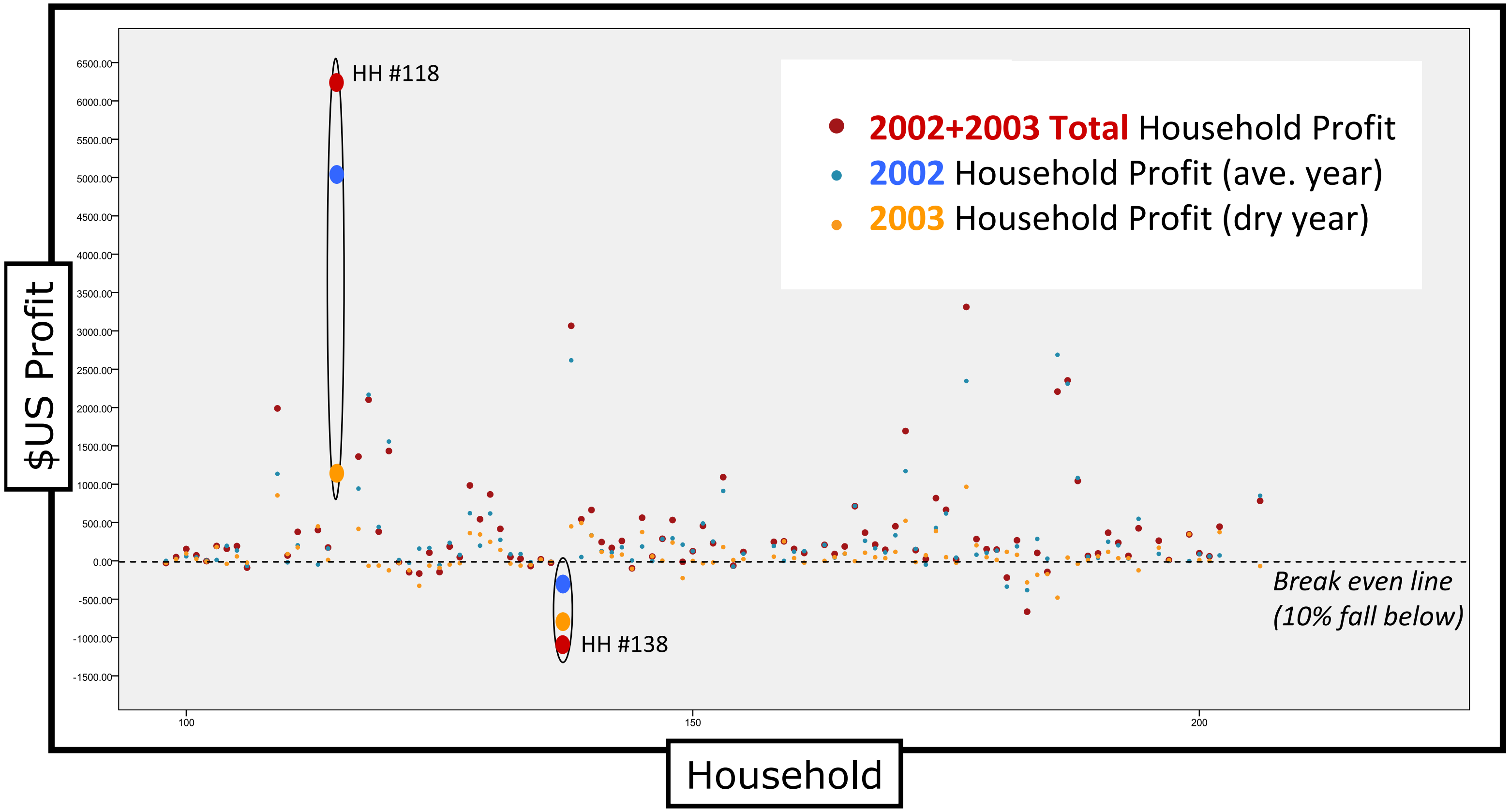

Figure 2.3. Profits and losses from cultivation in the villages of Loiborsoit 'A' and Emboreet.

Figure 2.4. Cultivation profits and losses in the village of Sukuro.

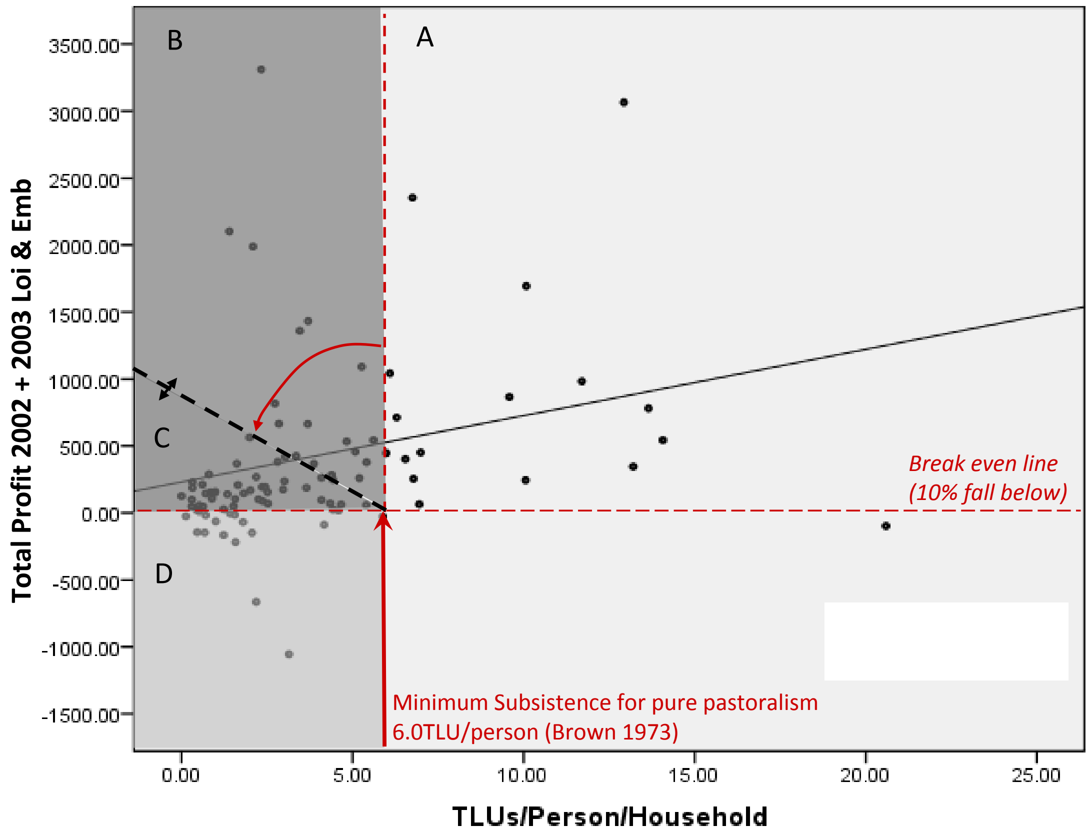

Figure 2.5. Cultivation in Loiborsoit 'A' and Emboreet is correlated with herd wealth (r2= .25, p<.001). Most households that have >6 TLUs/person (A) made a two-year profit. Some households were lifted into subsistence through cultivation profits (B). Others remained below subsistence but their livelihoods improved (C). Some of the poorest households lost further money through cultivation (D).

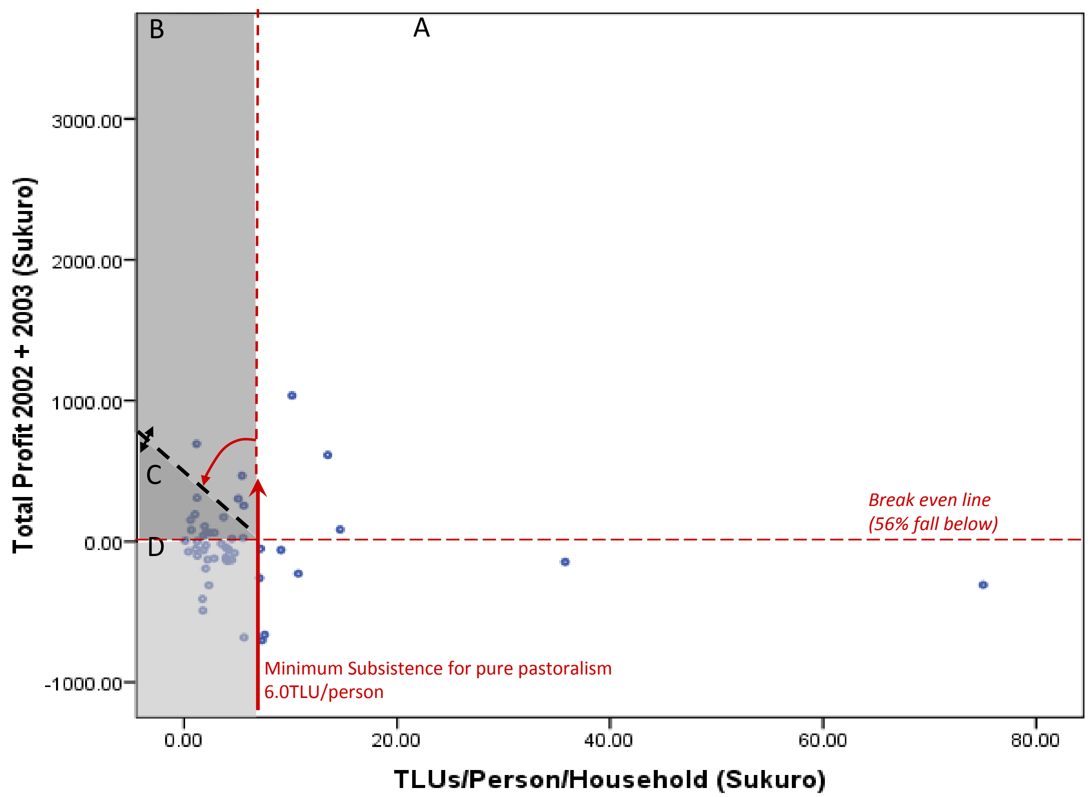

Figure 2.6. Cultivation in Sukuro is not correlated with herd wealth (r^2= .035, p=.198). Some households were lifted into subsistence through cultivation profits (B). Others remained below subsistence but their livelihoods improved (C). Some of the poorest households lost further money through cultivation (D). Many wealthier herdowners lost money to cultivation (A).

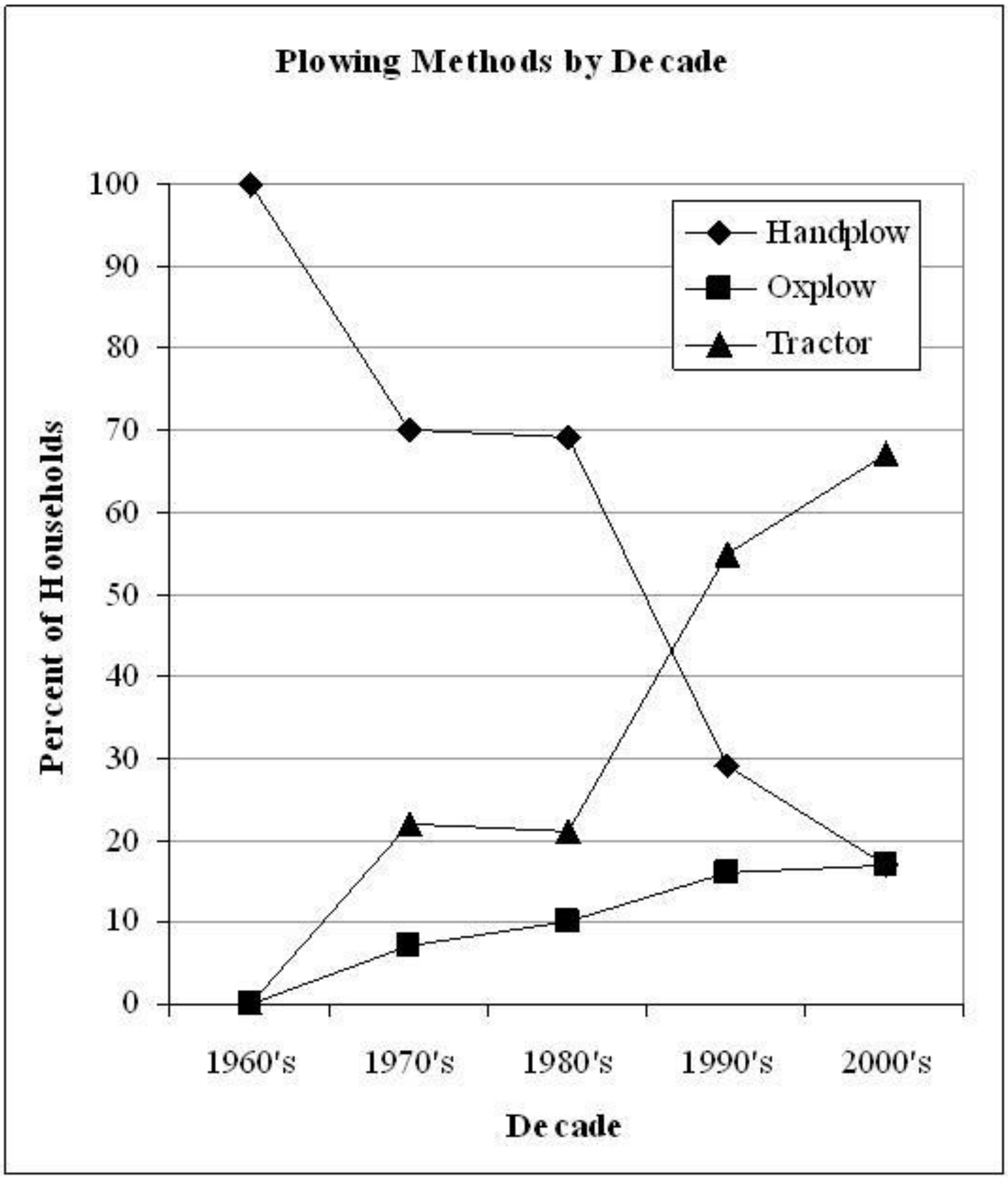

Figure 2.7. A steep increase (1980's to 1990's) in the proportion of new fields cultivated with tractors, and decrease in the use of handplows, coincide with the onset of the gem trade in the early 1990's.

Table 2.5. Interviewees were asked their future plans for their allocated plot of land. 98% of respondents mentioned cultivation to some extent, with nearly half of respondents planning only to cultivate.

Land Use Plan	Percent
Cultivate Only	44.9%
Livestock Use Only	2.0%
Livestock and Cultivation	45.9%
Cultivate and Build Boma	4.0%
Cultivate, Livestock, and Build Boma	3.0%

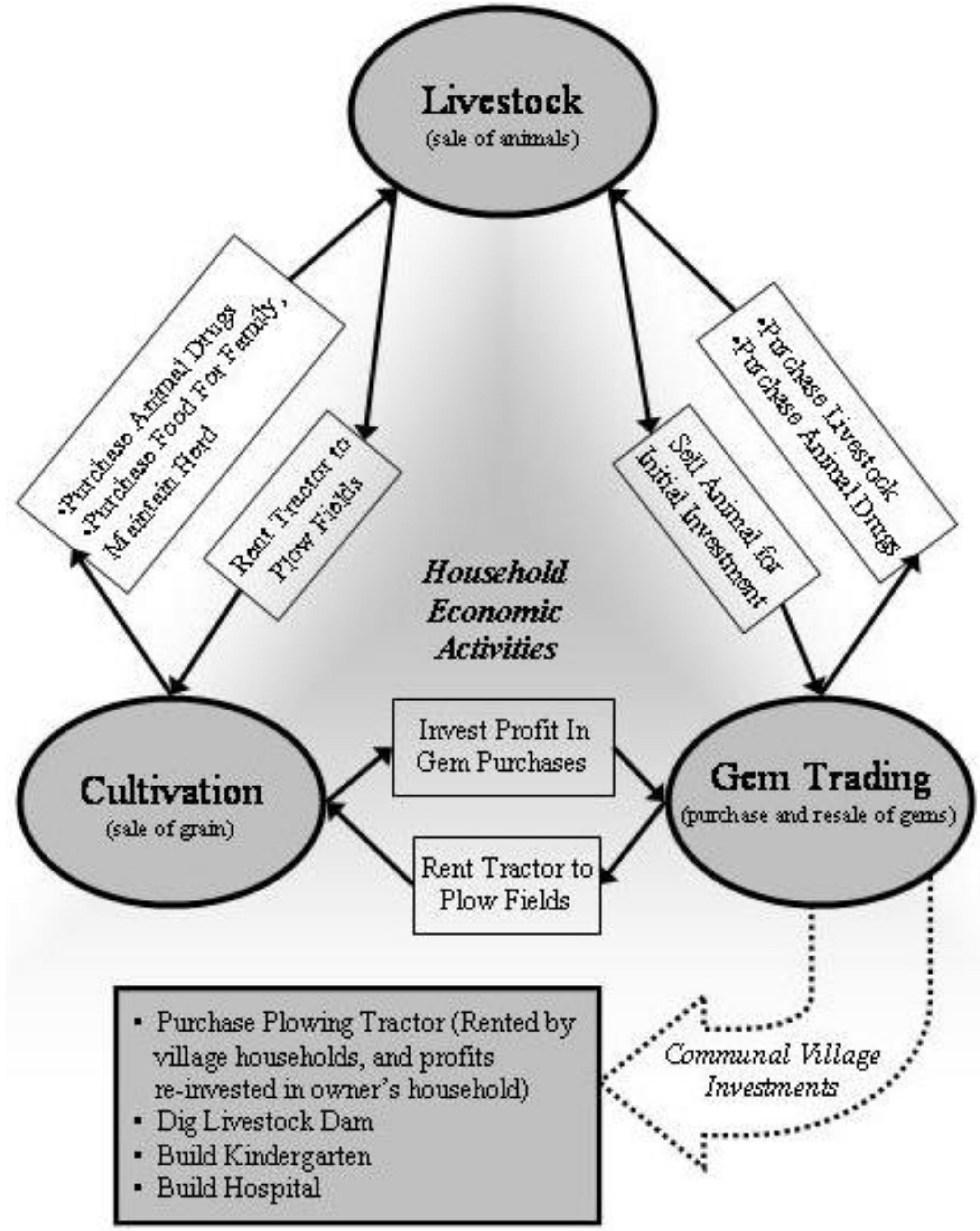

Figure 2.8. Simanjiro's three primary income-generating activities are economically synergistic, each supporting the other. Large gem trading profits were invested in several things that benefited village communities as a whole.

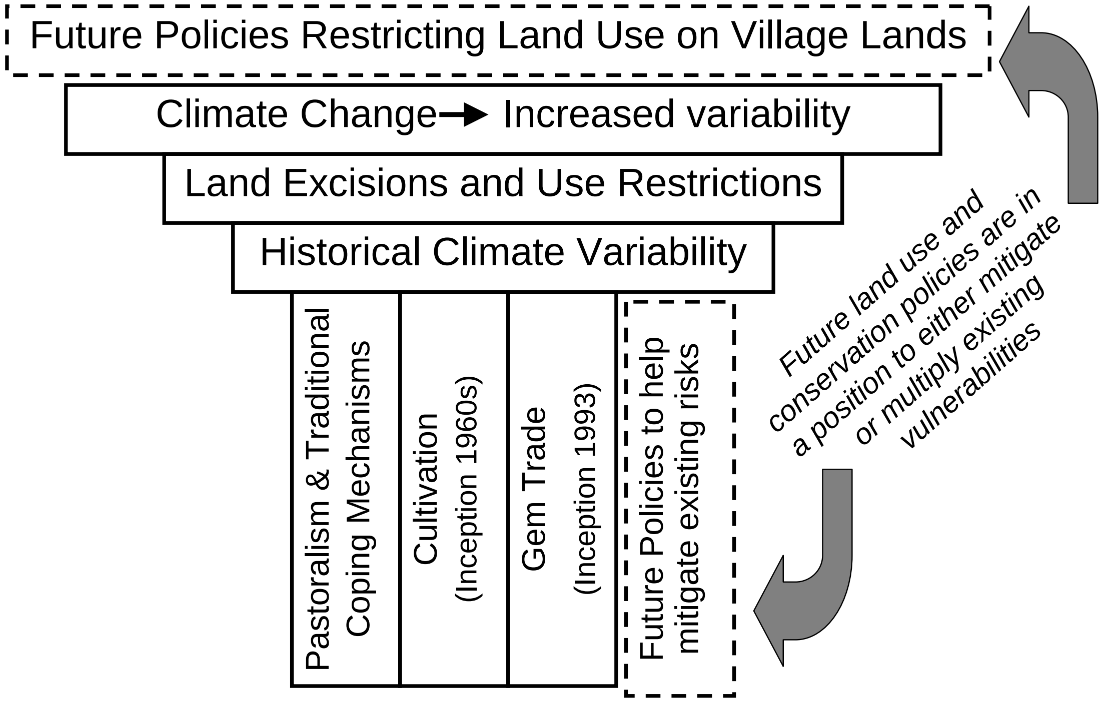

Figure 2.9. Future land use and conservation policies are in a position to either mitigate or multiply existing layers of vulnerability

APPENDIX 2.1: INTERVIEW TOOL IN SWAHILI

Kijiji ______
Numba ya Boma ______
Numba ya Mahojiano (Boma Hili) ______
Tarehe ______
Watafsiri ______
Ukoo ______
Usianu mwenyeboma ______
Umri ______ Rika ______
Jinsi anavyofikiri hali ya maisha ya chumi **T W F**
Jumla ya familia ilizopo bomani ______

NOTES

KAYA

Jedwali: Orodhesha makadirio ya umri wa wake, watoto na ndugu wengine wanaotegemea mifugo iliyopo kwenye kaya. Onyesha watu waliondoka au wasiotegemia (tumia *) kwa sababu Fulani mifugo iliyopo kwenye kaya.

MKE →	**1.**	**2.**	**3.**	**4.**	**5.**
Mtoto #1	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
Mtoto #2	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
Mtoto #3	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
Mtoto #4	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
Mtoto #5	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
Mtoto #6	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
Mtoto #7	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
Mtoto #8	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)
	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)	(Me Ke)

Watoto wangapi wameenda shuleni?

Watoto wangapi wameenda chekecheya?

Ni kwa miaka mingapi boma lako limeishi hapa hapa?

Ni kwa miaka mingapi boma lako limeishi kwenye kitongoji hiki? Umetoka wapi? Kwa nini?

UCHUMI WA KAYA

Je, mnatafsirije kati ya mtu tajiri wa wastani na fukara? (Kipimo chake hasa nini? Na mipaka kati ya tabaka hizi ni ipi?) *Kama hajasema numba ya n'gombe, uliza hii baadaye.

	# N'gombe
TAJIRI:	
WASTANI:	
FUKARA:	

Ni njia gani za mapato kaya yako inapata mbali na mifugo?

Je, mapato haya mengine yanaathirije familia yako pamoja na wewe?

Mererani: Watu wa kaya yako wameenda Mererani?
NDIYO HAPANA

Kama ndiyo, ulihitaji kufanya nini kuwapeleka? Nani ameennda? Lini? Umepata faidha?

Mapato

Ni njia gani zinazochangia *kipato* cha familia yako? Njia ipi muhimu kuliko zingine wakati wamasika? Njia ipi muhimu kuliko zingine wakati wakiangazi? Zitaje kwa umpangalio kufuatana na umuhimu wenyewe.

Kipengele cha mapato	Masika	Kiangazi
Ufugagi		
Kilimo		
Mererani		

Matumizi

Ni njia gani zinazochangia katika *matumizi* ya kaya yako. Njia ipi muhimu kuliko zingine wakati wamasika? Njia ipi muhimu kuliko zingine wakati wakiangazi? Zitaje kwa umpangalio kufuatana na umuhimu wenyewe.

Kipengele cha maumizi	Masika	Kiangazi
Nguo		
Hospitali		
Kilimo		
Shule		
Dawa ya mifugo		
Chakula		

Matumizi za chakula. Taja numba ya gunia kwa mwaka mzima.

	# Gunia umenunua mwaka huu	Bei 2002-3	# Gunia ulinunua mwaka uliyopita	Bei 2001-2
Mahindi				
Maharage				

MIFUGO (mtu moja tu)

	Tamko	Jumla ya boma	Hesabu
Ngombe wasio kamwa (>2mk)		--	
Mitamba (1-2mk)		--	
Mafahali (>1mk)		--	
Madume (>1mk)		--	
N'gombe wa Naokamwa (>2mk)		--	
Ndama (<1mk)			
Jumla ya n'gombe (bila ndama)			
Mbuzi (bila watoto)			
Kondoo (bila watoto)			
Punda			

Mifugo wadogo: Watoto wanozaliwa kwa mwaka moja:
Mbuzi: _________ *Kondoo:* _________
Watoto wangapi wamezaliwa mwaka huu (jumla)?
Mbuzi: _________ *Kondoo:* _________
N'gombe: N'gombe wangapi wamezaliwa mwaka huu?
Waliohai ________, Waliokufa ________

MAGONGWA YA MIFUGO (Mwaka mzima)
N'gombe wnagapi wamekufa mwaka huu (bila ndama)? _____________
Mbuzi? _____________ Kondoo? ______________

Magonjwa Gani	Mifugo Gani	Wagonjwa Wangapi	Waliokufa Wangapi	Miezi Mibaya	Mwaka huu mbaya sana, wastani, au simbaya
ORKIPEI	Ndama				
	N'gombe				
	Mbuzi				
NDIGANA	Ndama				
	N'gombe				
	Mbuzi				
EMONYWA	Ndama				
	N'gombe				
	Mbuzi/Kondoo				
ORMILLO	Ndama				
	N'gombe				
	Mbuzi				
NDOROBO	Ndama				
	N'gombe				
	Mbuzi/Kondoo				
OLODOKOLAK	Ndama				
	N'gombe				
	Mbuzi				

MIFUGO WALIOUZWA (Mwaka mzima)

Mifugo Gani	Wangapi	Mwezi	Bei	Kwa Nini
N'gombe				
Mbuzi				
Kondoo				

MIFUGO WALIONUNWA (Mwaka mzima)

Mifugo Gani	Wangapi	Mwezi	Bei	Kwa Nini
N'gombe				
Mbuzi				
Kondoo				

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MIFUGO WALIOCHINJWA (Mwaka mzima)

Mifugo Gani	Mifugo Wangapi	Mwezi Gani	Kwa Nini
N'gombe			
Mbuzi/Kondoo			

MIFUGO KUPEANWA (Mwaka mzima)

Mifugo Gani	Mifugo Wangapi	Mwezi Gani	Kwa Nini
N'gombe			
Mbuzi/Kondoo			

MIFUGO KUPEWA (Mwaka mzima)

Mifugo Gani	Mifugo Wangapi	Mwezi Gani	Kwa Nini
N'gombe			
Mbuzi/Kondoo			

MALISHO YA MIFUGO
Kwa mtizamo wako kuhamisha mifugo ni maamuzi ya kaya, boma, au majirani?

Unahamisha mifugo pamoja na maboma mengine?
NDIYO HAPANA
Kama ndiyo, boma gani?

Watu wote wa boma lako wanachunga pamoja? Kila siku?
NDIYO HAPANA

Taja majina ya **malisho uliyoyatumia kwa mifugo yako** kwa muda wa miaka mitano ulioyopita au zaidi? Onyesha kama ni *kila mwaka, baadhi ya miaka au akiba* **(KM/BM/A)**, kama *ni wakati wa masuka ama kiangazi* **(M/K)**, na kama eneo linatumika kuna *boma la kudumu au la muda* **(BK/BM)**. Kama ni BM, taja jina la boma na matumizi yake ya msingi (kwa ajili ya ngombe, kondoo na mbuzi ama mkulima). Je, Malisho haya hutumiwa na mifugo pamoja na wanyama pori kwa wakati mmoja au kwa nyakati tofauti?

____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM

Taja majina ya **sehema zenya maji ulizowahi kuwanywesha mifugo yako** kwa muda wa miaka mitano ulioyopita au zaidi? Onyesha kama ni *kila mwaka, baadhi ya miaka au akiba* **(KM/BM/A)**, kama *ni wakati wa masuka ama kiangazi* **(M/K)**, na kama eneo linatumika kuna *boma la kudumu au la muda* **(BK/BM)**.

____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM
____________________________ KM/BM/A M/K BK/BM

Mnaangalia nini kubadilisha eneo la malisho? Unajuaje kuhama/kusogea?

Ni vitu/mambo gani mnajaribu kukwepa mnapochagua malisho bora?

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KILIMO WA KAYA

Wewe unalima? NDIYO HAPANA

Ulianza kufanya kazi ya shambani mwaka gani? ______

Ulianza na eka ngapi? _______ Ulipandaje? _________

Mashamba/Bustani ukubwa wake sasa: ______________

**Mashamba/Bustani ukubwa uliopima:* ______________

Mmeanza kupanda mahindi lini mwaka huu? Kwa nini muda huu? Kama hajapanda, kwa nini?

Maharage? Kwa nini muda huu? Kama hajapanda, kwa nini?

Je, unapandaje mazao yako? Trekta, ngombe, mikono?

Unapandaje? Kama trekta, trekta ni yake nani?	**Nani wanapanda?**	**Eka Ngapi?**	**Bei kwa eka moja**

Ukitumia trekta, bila trekta unaweza kupanda eka ngapi?

Je, unasafirishaje mazao yako?

Unapata faida gani ya mazao ya shamba?

Unapata hasara gani usipo pata mazao ya shamba?

Unagawana mazao na watu wangine wa boma lako?

Unagawana mazao na boma lengine?

	Mwaka Huu				**Mwaka Uliyopita**			
	# gunia umepata	# gunia umekula	#gunia mbegu	# gunia umeuza	# gunia ulipata	#gunia ulikula	# gunia mbegu	# gunia uliuza
Mahindi								
Maharage								

Ulifanya nini na shamba mwaka wa ukamwe?

Wanyama (mifugo au wa pori) wanaingia shambani?

Nyama	Miezi	Asubuhi, Mchana, au Usiku	Wanafanya nini?	Wastani wa uharibifu

Mahali pa shamba yako inaathirije uzalishaji?

Unalinda shamba yako? Kama ndiyo, nani analinda? Taja numba.
Mchana:
Usiku:

GPS Shambas Ukubwa

______________________ ______________________ __________

______________________ ______________________ __________

MIFUGO cont.

Kaya yako wanatumia boma ngapi?
NDIYO HAPANA

Kama ndiyo:

- Ni kila mwaka?
  NDIYO HAPANA
- Lini na kwa nini?
- Je, mifugo wangapi wanao baki kwenye boma la kudumu wakati unapohamisha wengine kwenye boma la muda?

Je, Umeshawahi kuwapa mifugo yako vyakula vya ziada?

Mifugo na Wanyama Pori

Elezea jinzi mnavyoisihi na wanyama pori na ni kwa vipi wanyama hao wanavyoathivi kaya yako.

Matokeo mazuri	Matokeo Mabaya
Masika	*Masika*
Kiangazi	*Kiangazi*

HIFADHI

Mawakala gani wahifadhi unayo ufahamu?

Mawakala wahifadhi wanongea na jumwia yako na kuhusisha uhifadhi?

Mawakala wahifadhi mawakala wanaogopa athari zitakazoletwa na kazi za uhifadhi kwa wanakijiji?

Faidha gani umepata na uhifadhi?

Sera za uhifadhi zinaadhirije mifugo wakati mapotaki kwenda kupata maji na majani? Unaathirika vipi?

ARDHI

Unayo ardhi uliyogaiwa na kijiji?

Eka ngapi?

Wapi? GPS: ________________
____

Unajua mpaka ya ardhi yako sasa? NDIYO HAPANA
Kama ndiyo, unajuaje?

Mnafanya nini kuweka eneo kijijini? Ni kiwango gani unaweka mnapohitaji kugawa ardhi. Kwa nini?

Unatumia vipi ardhi hiyo sasa?

Umepanga kutmianje ardhi yako kwa muda wa baadaye?

Ardhi uliyogaiwa inaadhirije mifugo yako wakati wa kwenda kupata maji na majani?

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KILIMO WA KIJIJI

Taja athari zinazoletwa na kilimo kwa mifugo na kaya yako?

Taja faida zinazoletwa na kilimo kwa mifugo na kaya yako?

Taja hasara na faida zinazowapata wanyama pori kwa ajili ya kilimo?

Kilimo cha watu wengine kinaadhiri vipi mifugo yako wakati wa kwenda kupata maji na majani?

Ni maamuzi gani unaweka mnapohitaji kulima?

Kijiji kimetenga eneo kwa ajili ya kuchunga mifugo?
Taja eneo hilo.

-________________________ - ________________________
-________________________ - ________________________
-________________________ - ________________________
-________________________ - ________________________
-________________________ - ________________________

Watu wanafanya nini kuweke eneo? Wanachaguaje eneo kwa ajili ya kuchunga mifugo?

Kijiji kimetenga eneo kwa ajili ya kulima?
Taja eneo hilo.

-________________________ - ________________________
-________________________ - ________________________
-________________________ - ________________________
-________________________ - ________________________
-________________________ - ________________________

Watu wanafanya nini kuweke eneo? Wanachaguaje eneo kwa ajili ya kilimo?

Mtu akivunja sheria mnamfanyaje?

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APPENDIX 2.2: HOUSEHOLD SIZES

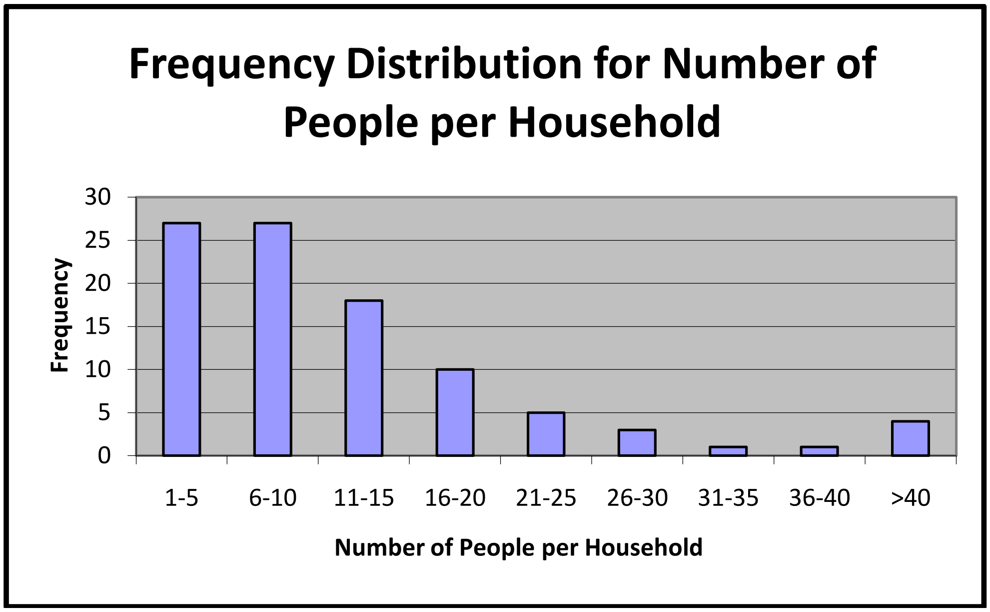

Figure A2- 2. Frequency distribution of number of people per household surveyed.

APPENDIX 2.3: LIVESTOCK GAINS AND LOSSES 2003-2004

Table A2-4. Mean change in number of household cattle, smallstock (goats plus sheep) and Total TLUs from 2003 to 2004. Mean change (#/household) are based upon all households with all relevant data and are therefore not additive.

Livestock Ins and Outs	**Cattle**	**Smallstock**	**Total TLUs**
(+) Births	18.33	29.74	15.96
(+) Purchases	2.26	3.23	3.72
(+) Gifts In	1.60	2.49	1.54
(-) Deaths	14.18	26.16	14.92
(-) Sales	4.90	5.98	4.47
(-) Gifts Out	0.92	1.81	0.96
(-) Slaughters	0.91	6.23	1.70
Net Gain/Loss	**0.88**	**-2.11**	**0.52**

APPENDIX 2.4: SUPPLEMENTAL FOOD PURCHASES

Table A2-5. The quantity of supplemental food purchased was higher in the year when harvests were lower. Food purchases roughly doubled from comprising 33% of mean family food consumption in 2002 to comprising 58% in 2003.

Agricultural Sales and Consumption				
	2002		2003	
	Kg	%Total	Kg	%Total
TOTAL HARVEST	2445		1176	
Maize Eaten	1588	82%	1131	88%
Maize Seed (saved)	34	20%	20	20%
Maize Sold	696	12%	278	10%
Suppl. Maize Purchased	828		1637	
Beans Eaten	166	27%	102	16%
Beans Seed (saved)	203	25%	291	26%
Beans Sold	1035	49%	1140	59%
Suppl. Beans Purchased	34		91	
Total Consumed	2616		2961	
% Consumption Purchased	33%		58%	

APPENDIX 2.5: GEM TRADE SUCCESS PATTERNS

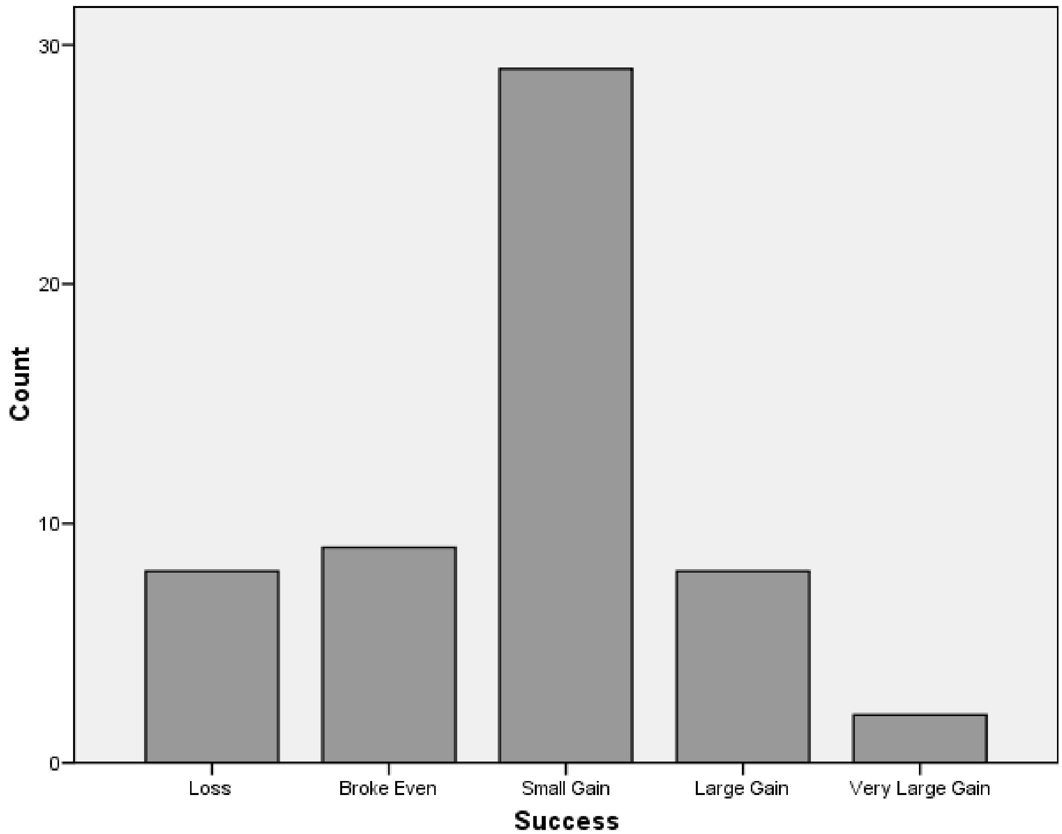

Figure A2-6. Long-term rating of success achieved by households who have participated in gem trading activities (n=56).

APPENDIX 2.6: CULTIVATION INITIATION AND AGE

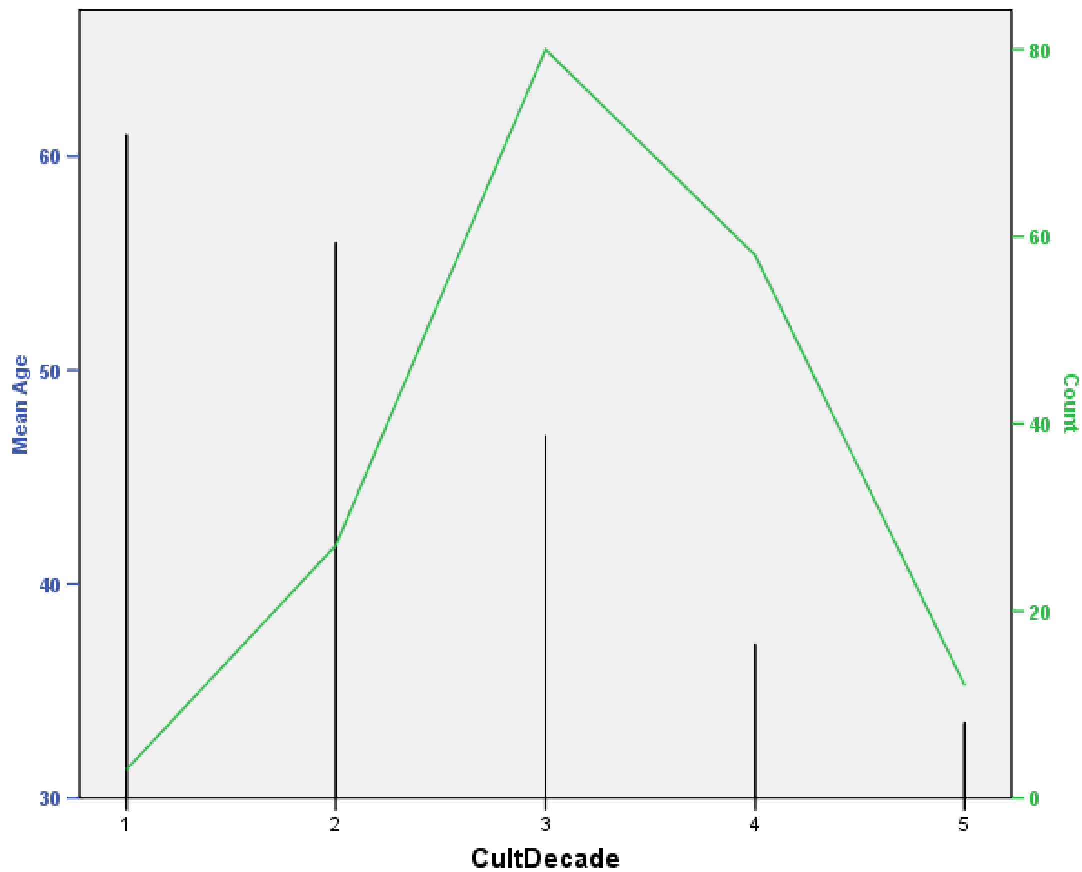

Figure A2-7. The decade in which respondents initiated cultivation is linearly related to their mean age at the time of the interview (noted by bars), indicating that age impacts timing of initiation. The respondents who are still initiating cultivation are those who are young and establishing their households. Note that the decade "2000s" consists of only three years, so the count is artificially low.

Note:

1 = 1960's
2 = 1970's
3 = 1980's
4 = 1990's
5 = 2000's

APPENDIX 2.7: PER CAPITA TLU HOLDINGS AND ACREAGE

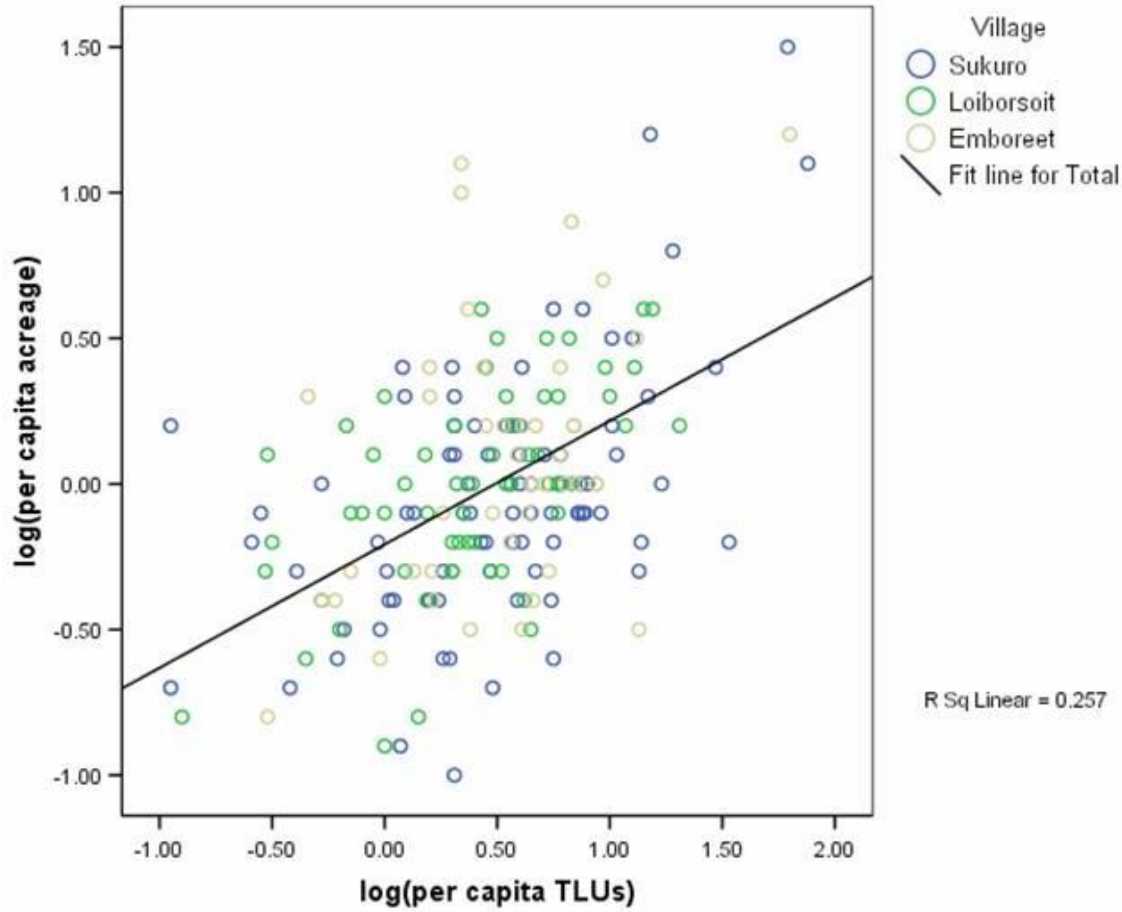

Figure A2-8. The relationship between per capita TLU holdings by household and per capita acres cultivated by household ($p<.001$). There is no detectable difference between villages.

CHAPTER 3

HUMAN-WILDLIFE INTERACTIONS ON THE EDGE: WILDLIFE RESPONSES TO CULTIVATION BOUNDARIES IN AN EAST AFRICAN PASTORAL SYSTEM

INTRODUCTION

Human transformations of the Earth system will require more active management responses in order to maintain populations, species, ecosystems, and the flows of goods and services to humans (Vitousek 1997). Land use policies and projections of land use change futures in Earth System dynamics must not only capture the complex socio-economic and biophysical drivers of land use change, but also account for the specific human-environment conditions under which the drivers operate (Lambin et al. 2001). Integration of natural and social sciences as well as recognition of the increasing role of global factors is required to meet this challenge (ibid). Interdisciplinary research can be defined as the development theory across boundaries of unrelated knowledge communities in order to achieve a common research goal (Tress et al. 2005). In mixed natural-cultural landscapes, interactions between the natural and social elements are what transforms the landscape, thus, an interdisciplinary approach to research is required (Lambin et al. 2001).

When planning landscape policy, multiple stakeholders make different demands upon the landscape and hold different perceptions of the benefits that landscapes must deliver to society (Termorshuizen and Opdam 2009). Knowledge about landscape pattern and process should be spatially explicit at the level of detail relevant to individual landscape elements. Identification of the appropriate scale of information increases the credibility of the information for collaborative landscape planning, as well as its relevance to the needs of the decision makers (Termorshuizen and Opdam 2009). Measurable indicators and knowledge of their relationships to ecological, social, and economic values and benefits are likewise necessary (Termorshuizen and Opdam 2009).

Pastoral access to arid and semi-arid communal lands is based on complex social, cultural, and historical norms and conditions that historically have maintained flexible access to resources across space and time (Turner 1989; Ostrom 1990; Burnsilver et al. 2003). Analyses by Burnsilver et al. (Burnsilver et al. 2003) have demonstrated landscape-level heterogeneity in average green vegetation biomass production through time using GIS and remote sensing analyses; some areas of the landscape are, over time, more productive than other areas despite the variation occurring over time. But vegetation productivity is only one of many important system qualities that can be concentrated in particular areas of the landscape. Other system qualities that are or can be consistently more available in defined areas are soils with high mineral content, high quality forage for grazing or browsing, and permanent water (S. Lynn, unpublished data), as well as woody cover for shelter (Coughenour 2009)**.** These qualities often drive movement patterns of both wild and domestic animals. For cultivators, soil texture and quality are highly variable across landscapes, making some areas more conducive to successful cultivation. When and where the desirable landscape attributes for one type of land use overlap with the desirable attributes for another, then conflict can occur. When these areas get "used up" by one land use, they are less available, or no longer available, to the others.

Natural restrictions on wild ungulate distributions may include factors suh as forage abundance, water availability, competitive or facilitative interactions with other wildlife or livestock, and risks of predation (Sinclair and Norton-Griffiths 1982; Sinclair et al. 1985; Fryxell 1995). But in addition to natural restrictions on distributions, since most large-bodied wildlife species range widely over diverse landscapes, human land use within those landscapes may affect access to resources (Sundaresan et al. 2008; Groom and Harris 2010). Over the course of 20 years in the Serengeti-Mara Ecosystem that straddles the Kenyan-Tanzanian border, 60,000 hectares of rangelands were converted to mechanized agriculture, and the total wildlife population simultaneously declined by 58% (Lambin 2003). Lambin et al (2003) found that changes in land use were driven by markets and national land tenure policies, and cultivation increases occurred in areas that provided resources critical to wildlife.

Rangelands encompass vegetation formations that range from grassland with or without shrubs, bush, woodland, and savannas. The term "rangeland" recognizes the spatial, temporal and ecological continuums across which these habitats occur in arid and semi-arid lands, as well as the often transitory state of the systems themselves (Homewood 2004). Vegetation structure varies from 100% grass cover, through woodlands with up to 80% canopy cover, to pastures within dense forest (Lambin et al. 2001). A combination of disturbances from spatially and temporally variable rainfall, to fire, grazing and browsing, and other disturbances and land uses create a dynamic and patchy landscape (Ellis and Swift 1988; Ellis et al. 1991; Behnke and Scoones 1993; Ellis and Galvin 1995; Swift et al. 1996). Biodiversity in these areas may do better under less protectionist regimes of management that incorporate some conservation-compatible land uses rather than drawing lines around protected areas (Homewood 2004), since rangelands are so dynamic and dependent on disturbance to maintain their mosaic of resource patterns.

But the question still remains as to what land uses are compatible with conservation, and agreement on this question between diverse stakeholders is difficult to find. Some degree of hunting (Homewood 2004), cultivation, grazing, tree harvest and other land uses may not necessarily be detrimental to conservation objectives, and in fact may have a positive influence on these agenda either through landscape mosaic maintenance and other disturbance effects, or as a result of reducing direct conflict between conservation and livelihood agendas. In recent years it has become more widely recognized that the need of pastoralists for large grazing areas is complementary with the needs of many of the wild ungulates that share the pastures (Nelson 2000). The idea of livestock's compatibility with wildlife has as a result become more acceptable. However, the idea of cultivation in these systems is still not believed to be consistent with wildlife conservation goals (McCabe 2003).

Many of the actions that lead to fragmented landscapes are taken to enhance human welfare, and often measurable enhancements in people's livelihoods and well-being are realized (Hobbs et al. 2008). However, there are also many cases of landscape fragmentation that have resulted from the placement of political boundaries, land tenure arrangements, or the creation of protected areas to protect wildlife and natural resources that have not served to benefit local livelihoods. Whatever the rationale behind the change in landscape arrangement and access in multi-sector socio-ecological systems, multiple users may be impacted differentially, and the implementation of mechanisms to improve resilience in one sector may actually increase vulnerability in another (Lynn In review).

Hobbs et al (2008) make it clear that the state of the Earth's ecosystems cannot be fully understood without carefully considering the coupling between human societies and biological and physical processes. There are many popular and steadfast assumptions regarding local land use impacts on rangelands in sub-Saharan Africa that have not kept pace with data that document environmental processes and outcomes (Homewood 2004). The trade-offs between environment and development outcomes are difficult to integrate into a consistent approach and set of priorities for management (ibid).

The Tarangire-Manyara Ecosystem (TME) is a 20,000 km^2 ecosystem that incorporates two national parks, but that is primarily comprised of village lands in the Simanjiro Plains to the east of the parks. Lake Manyara National Park (LMNP) (320 km^2) was created in 1960 during the British colonial rule. Tarangire National Park (TNP) (2642 km^2) was created in 1970 to set aside a vital permanent water source, the Tarangire River, for exclusive use by regional wildlife (TMCP 2002). Resident Maasai pastoralists were evicted from the Parks upon their creation and henceforth forbidden to enter or use Park resources. A longstanding conflict over land use and land rights ensued between policymakers and local people. This conflict has centered upon the combination of lack of access to Park resources, human-wildlife conflicts taking place outside the Parks, and fear of additional future land disenfranchisement in the name of conservation.

The effective size of the TME extends well beyond the boundaries of the National Parks. These boundaries are based upon the extent of annual migratory wildlife movements, particularly wildebeest. Land-use outside park boundaries is relevant to conservation inside because approximately 85% of the TME falls outside the National Parks and in the village lands of the Maasai Steppe's Simanjiro Plains. During the rainy season animals leave the parks to disperse over much of the pastoral zone to take advantage of widespread water resources and high quality forage (Borner 1985; Kahurananga and Silkiluwasha 1997; Rodgers et al. 2003).

In the past, Tanzanian wildlife corridors and other important wildlife resources located outside of national parks were not protected by law (Gamassa 1995). The new Tanzanian Wildlife Policy of 2008, however, includes provisions that the President, after consulting the relevant local authorities, may use discretion to "declare and prescribe regulations to govern the management of any area of Tanzania" to be a protected area (Tanzania Ministry of Wildlife 2009, Part IV). The status of any area is in effect at the discretion of the President and the Minister of Wildlife. In addition, while there is mention of community and local benefits and protections from wildlife in this document, benefits the ability to protect life and livelihoods are essentially stripped away by other lines of legislation. For instance, Section 73-1 of the Act states that "Nothing in this Act shall make it an offence to kill any animal in defense of human life or livestock". Yet the associated sub-sections state that this does not apply if the animal's death was found to be due to deliberate provocation or other offence, and that "the court shall presume that the animal was killed or wounded in the cause of it being intentionally hunted by the accused person, unless the person proves [otherwise]". In effect, individuals are guilty until proven innocent, bringing no incentive to individuals to report such occurrences. In addition, while consolation payments for losses of life, livestock, crops or injury by wildlife may be decided on by the Minister of Wildlife in conjunction with the Minister of Finance (Tanzania Ministry of Wildlife 2009, Part VIII), payments related to the destruction of crops should be limited to a maximum of five acres. When individuals receive no direct benefit from wildlife, and cannot get full compensation for losses due to wildlife, this actually creates a disincentive to conserve wildlife.

The actual impact of cultivation on wildlife has not been measured in the Tarangire Ecosystem. Rather land use regulations are largely founded on the belief that wildlife are negatively affected by cultivation , and that people can find alternate means of subsistence. While it may be true that either or both of these assumptions are true at times, they are not necessarily both true all of the time.

Most research on the effects of habitat loss and fragmentation on ecosystems has been based on observational studies (August et al. 2002). Results from this type of research should be categorized by organism so that it is most useful It is often assumed that all agricultural conversion is incompatible with conservation of large mammalian wildlife in the rangelands of Africa (see Sachedina 2006), yet the actual spatial responses of large-bodied wild species to cultivation have still not been thoroughly investigated. It must be assumed that for these species there is some threshold at which a combination of habitat loss – the actual loss of pasture area available to grazers, and fragmentation, the physical loss of access to still-existing grazing pastures due to movement barriers, will have a negative impact on wildlife. But where is this threshold, and are migratory wildlife necessarily negatively impacted by less widespread cultivation as many wildlife advocates believe (August et al. 2002)? If native species will tolerate levels of fragmentation that were previously thought to be detrimental to these species, then land planners and managers will have more flexibility with developing plans and policies that do not have a negative impact on landscape integrity and sustainability (August et al. 2002).

Levin (1992) explains that the concept of scale, and the inter-related processes and patterns that occur at different spatial, temporal, and organizational scales is fundamental to the development of proper principles of management. He emphasizes that not only is environmental heterogeneity fundamental to the coexistence of species, but that the description of the distributions of species across space and time is, by definition, a description of pattern. At the local to landscape to regional spatial scales, there occur embedded and interacting patterns of wildlife movement. Daily movements tend to happen at the local scale as animals go on their daily search for forage in a local space that incorporates both the cultivation edge and whole pastures. In the TME, a "breathing" of the system happens at this daily level from daytime to nighttime as animals move across this space, approaching and then moving away from cultivated fields**.** Crop raiding by wildlife occurs primarily at night, so that is when wildlife in general are known to be near and when crops need to be guarded (S. Lynn, unpublished data). Cultivation may impact the wildlife component of the system, acting as either an attracting or detracting force and thereby patterns of movement and hence wildlife access to resources on the landscape.

A question of particular interest to ecological study is how well species can move through landscapes (Malanson 2003). The effectiveness of movement pathways through landscapes need to be quantified and examined (ibid). This pattern of movement, which varies from species to species in response to ecosystem pattern and resource availability has been addressed by “percolation theory” (Stauffer 1985; Malanson and Cramer 1999). Percolation theory shows that habitat destruction negatively impacts animal movement non-linearly, only after a threshold has been reached in landscape (Malanson 2003). Such non-linear thresholds depend upon a combination of the spatial pattern of the landscape and species population dynamics (ibid), and as such will be species-specific. Unfortunately, because of their non-linear characteristics, thresholds often cannot be identified until they are crossed (Malanson 2003; Groffman et al. 2006; Hunter et al. 2009). This makes it difficult for regulatory thresholds (such as land use regulations) to correspond to clear ecological thresholds (Hunter et al. 2009). The question of whether system thresholds can be identified before they are crossed may be approached by extrapolating from similar closely-related systems (Walker and Meyers 2004; Lynn et al. *In Review*).

Despite the plethora of landscape metrics associated with the patch mosaic paradigm prevalent in modern landscape ecology, in many situations it is actually more meaningful to look at continuous rather than discrete spatial heterogeneity (McGarigal et al. 2009). In the Simanjiro Plains east of TNP**,** while cultivation forms clearly discrete patches on the landscape, the perception of cultivation by wildlife may not be so black and white - the matrix around cultivation may not be unvaryingly suitable, and it may rather contain gradients of suitability. Furthermore, different wildlife species likely perceive different gradients of suitability. Therefore the best way to test wildlife responses to cultivation may be by looking at a continuous or multi-classed surface outside of cultivation to elicit what the species-specific responses may be. The selection of the metrics to be measured should be based on the hypotheses being tested, they should be relevant to the organism and processes of interest, and they should be based upon characteristics of the landscape (Neel et al. 2004).

This study aims to quantify wildlife avoidance and attraction at the boundary of cultivation, and to identify species that enter, and possibly consume and therefore benefit from, cultivated crop fields. It examines the relationship between cultivation and five species groups: zebra, wildebeest, Grant's gazelle, small resident herbivores (including porcupine, dik dik, warthog and steenbok), and predators (including lion, hyena and leopard). The study addresses several related questions regarding the impacts of wildlife for household cultivation, as well as the impacts of cultivation for wildlife.

First, what benefits and costs do Maasai associate with sharing the Simanjiro landscape with wildlife? This characterization of the broad human-wildlife relationship forms a context for conflicts that occur related to cultivation. Second, what are the species that are reported to be the most frequent intruders and most damaging for household cultivation? Third, what are the species-specific responses of wildlife to cultivation? Can different species or species groups be identified as having a neutral, positive, negative or intermediate response to cultivation at the scale of individual plots, measurable by both differences between inside and outside densities, and differences along the gradient of distance to cultivation outside the fields (Figure 3.1)? A positive response indicates that cultivation is attractive at the scale of observation, and populations tend to be more dense closer to cultivated plots, or inside relative to outside. A negative response indicates that cultivation is repellent at the scale of observation, and populations tend to be less dense closer to cultivated plots, or inside relative to outside. An intermediate response indicates that cultivation is attractive, but that some characteristic of cultivation is simultaneously repellant at the scale of observation. This leads to a hump-shaped population distribution response. A neutral response is essentially no response at all; population densities remain similar at all distance intervals, or inside relative to outside. Finally, I examine these species-specific response patterns from the perspectives of both cultivators and wildlife by asking: what are the potential consequences of detected wildlife responses to cultivation at this local scale for cultivators and wildlife, and what are the implications for conservation and land use policies in Simanjiro?

METHODS

Study Area

Tarangire National Park (TNP) forms part of the 20,000 km^2 TME, along with nearby Lake Manyara National Park (320 km^2) and the pastoral Maasai Steppe that lies primarily to the east of these parks (TMCP 2002) (Figure 3.2). The boundaries of the ecosystem are based upon the annual movements of migratory wildlife, particularly wildebeest. Land use outside park boundaries is relevant to conservation inside because approximately 85% of the TMSE falls outside the National Parks and in the village lands of the Maasai Steppe's Simanjiro Plains. During the rainy season animals leave the parks to disperse over much of the pastoral zone to take advantage of widespread water resources and high quality forage (Borner 1985).

The study area incorporates three villages of Simanjiro: Sukuro, Loiborsoit 'A' and Emboreet. An approximately 500 km^2 area was selected at the nexus of these villages to perform wildlife transect print counts and pasture-level animal counts. This area covers six distinct grazing pasture Sampling Areas (SAs) and the matrix area between them. Conducting transects in this area allows integration of transect data with interview data, and integration of study results from the wildlife studies (this chapter and Chapter 4) with those of the livelihood study that was conducted in the same villages (see Chapter 2).

Study Design

The analyses undertaken for this study form part of a larger investigation of pastoral livelihood and wildlife responses to cultivation at multiple scales. In order to accomplish this, the overall study integrates several multiple methods that were coordinated over space and time. I collected data for this study through a combination of methods that included both household-level interviews, and strip-transects to survey wildlife signs at the boundary of cultivated plots. These plots are located within four of the six pastures investigated for the pasture scale and landscape scale study discussed in Chapter 4. Methodologies were developed to best coordinate the studies of wildlife responses at the boundary, pasture and landscape scales with each other and with the interview data.

I selected six sampling areas across a visible gradient of cultivation intensity based upon the criteria of: 1) vegetation physiognomy (primarily grassland/low vegetation with high visibility for counts), 2) a patch size of 5 km^2 to 10 km^2, 3) no cultivation visible in and around SAs to be designated as *no cultivation,* 4) permission from two individuals per SA *with cultivation* to enter cultivated plots to conduct walking transects (only one individual refused permission in Loiborsoit 'A', and I randomly selected an alternate plot for the transect), 5) mixed boundary types including vegetation shifts, roads, soils, village boundary, or random line, and 6) accessibility.

I used animal prints as a proxy for animal presence for two reasons. First, animal abundance was adequate for counting across large areas (such as was done for Chapters 4 and 5), but too low to acquire adequate numbers while walking short distances. Second, it is general knowledge that most crop raiding by wildlife happens during the night, which led me to believe that our morning counts might be missing at least 12 hours of movement patterns. Using prints allowed us to account for nighttime movement.

Data Collection

Household Surveys

For the purpose of this study, a *household* is defined as a male herdowner, his wives and children, plus any other dependent family members (following Lynn 2000; Galvin et al. 2001; Galvin et al. 2002; Thornton et al. 2003). *Bomas,* or settlements, consist of one or more male herdowners and their associated households. Bomas are grouped into subvillages, and villages are formed of multiple subvillages (Figure 3.3).

An existing census of bomas was updated in early 2003with the assistance of each village's leaders to identify the pool of bomas from which a random sample was chosen using a random number generator. I selected a total of 70 bomas: 31 in Sukuro (33% of bomas, 96 interviews total), 28 in Loiborsoit 'A' (20% of bomas, 65 interviews total), and 11 in Emboreet (25% of bomas, 46 interviews total). Interviews were stratified across subvillages. We conducted a longer version of the interview with at least one herdowner per boma (n=107), and a shorter version (n=100) with the others. Wildlife questions were contained only in the long version of the survey. We conducted the interviews in the Maa language, and translated responses into Swahili.

Interview questions regarding wildlife were open-ended and responses were un-prompted. Questions were asked about seasonal costs and benefits of wildlife to evaluate costs incurred at the local level along with benefits that could potentially offset them. Reports on all reported household wildlife costs and benefits by season and direction (positive vs. negative) were quantified. A second set of interview questions focused on wildlife-cultivation conflicts. Interviewees listed problem species in response to an open-ended question, then ranked the listed species in order of damage severity (1=worst). Number of species listed ranged from zero to ten species.

Wildlife Transects

Wildlife data were collected during the wet season March - June 2004, the time during which wildlife from Tarangire National Park had dispersed out in the villages. The transect data collection team consisted of a core team of 4 individuals, plus two individuals from each village to assist with data collection in their home village. This kept two-thirds of each team of three constant, while allowing me to spread the benefit of employment across all three villages. Field assistants were thoroughly trained to follow data collection protocol, but a single individual per team was responsible for navigating, maintaining course and recording observations as most individuals on the field team, despite their field skills, had not been to school and were not literate. Most Maasai who I encountered in Simanjiro were expert print identifiers, so identification training went in both directions. A print identification guide, "Tracks and Signs of Southern and East African Wildlife" (Stuart and Stuart 2000) was used in training to distinguish subtle differences between species and to be sure everyone was using similar criteria to identify prints.

Permission was gained to enter two cultivated fields in each of the four SAs that contained cultivation (SA1, SA2, SA3 and SA4).[3] A 1 m wide belt transect originating 50 m within the cultivated plot and extending outward into the grazing pasture for 1-2 km was located with a GPS, and direction of transect determined using GPS compass and visual guides on the horizon. Transects were labeled 1A, 1B, 2A, 2B, 3A, 3B, 4A and 4B to coincide with the SAs in which they were located (Figure 3.4).

Two teams of three walkers walked two paired transects located within a single SA simultaneously between approximately 9:00am and noon once every two to three weeks. The teams of three walked shoulder-to-shoulder, with the middle person (the team leader) responsible for maintaining course, recording observations, and helping with print identification as needed. Prints were counted for 0.5 m on either side of a central measuring tape. Observations were recorded in groups when less than 1 meter apart, and as individuals when more than 1 meter apart. Observations were taken for 50 m inside the cultivated plot, then on alternating 50-m intervals outside the cultivated plot beginning at the boundary (Figure 3.5). These intervals were referred to as "legs". Each transect contained 11 legs, each representing100m in length. Leg 0 is the interior leg, and

[3] Each of the pastures studied has a Maasai name given to the pasture by local residents. SA1 was located in *Loipolos* (Loiborsoit Village), SA2 in *Osilale* (Loiborsoit and Emboreet Villages), SA3 in *Alarramatihoreki* (Loiborsoit Village), SA4 in *Loltepesi* (Sukuro Village), SA5 in *Ndumo* (Sukuro Village), and SA6 in *Ilturuut Ooibor*(Sukuro Village). For the sake of simplicity I refer only to the code names throughout this dissertation.

Legs 1-10 are the exterior legs. These legs were established to compare print densities both across the external distance gradient from Leg 1 to Leg 10, and between internal leg and the mean of the external legs.

Each data record included information on GPS location, leg of transect, species, and number of prints if countable. When not countable, the group was coded as a "large group". A field guide on "Tracks and Signs of Southern and East African Wildlife" was used as a guide to differentiate between similar prints (Stuart and Stuart 2000).

Data Processing and Analysis

Interview Data

I conducted statistical tests of interview data were conducted using SPSS version 17.0 for Windows (SPSS, Inc., Chicago, IL). A mean damage severity rank was taken for each species across reporting households, which indicated the average severity of the problem for households encountering that species. A Problem Severity Index (PSI) was then calculated using the following equation:

$$PSI = PR * \frac{1}{MeanRank}$$

Where *PR* is the percent of interviewed households reporting the species, and *MeanRank* is the mean rank value attributed to the species by those households. This PSI combines two variables that have an inverse relationship; problem increases with increasing PR, and problem decreases with increasing Mean Rank. The resulting PSI allows these two values to be combined into a single variable that functions as an indicator of the overall significance of the species' problem in these villages, where PSI increases with problem severity.

Transect Data

Because three individuals walked a narrow transect, 100% accuracy in sighting of visible prints is assumed. We recognized that subsequent tracks usually erase the tracks of those that passed before, and this was an uncontrollable situation. Also, there is always some associated uncertainty regarding absence data since evidence for total absence is very difficult to obtain (Lobo et al. 2010). However, absences for this study indicate lack of presence at the time of the respective survey relative to other times and locations, not an absolute lack of potential presence in the study area or even the sub-location. I recognize that there is error in sampling through print counts in counting all of the presence data and introduction of false absences, however we did our best to minimize this error. Error should be relatively consistent across transects, so while an attempt to estimate true species densities would be fraught with error, comparative assessments of relative print densities should not be unduly affected.

Elith et al. (Elith et al. 2006) undertook an extensive study to review methods of predicting species distributions based upon occurrence data. Elith's study demonstrated that while models built with presence-only occurrence data are not necessarily well-calibrated, they are useful in their ability to rank sites for relative habitat suitability for the species of interest. For the purpose of my study, this suggests that the occurrence data analyzed for this study are adequate to test the responses of study species to varying degrees of cultivation across space, as was the goal of this study.

I integrated absence data for each species into the data on presence (Tsoar et al. 2007) using a script written to fill in zeroes for all transect legs with no occurrence of the species [Appendix 3.1]. Some of the less frequently observed species are of particular interest to this study due to their mention by informants during interviews. I analyzed these species in the functional groups of "predators", which included lion, hyena and leopard; and "small resident herbivores", which included porcupine, dik dik, warthog, and steenbok.

To minimize the error that would be introduced through re-counts of the same print(s), I processed only the second (April 2004) and fourth (May 2004) sets of data for analysis.[4] These two dates were chosen because: 1) The first date's data were the least reliable because it was the first time to implement the method across all transects outside of the training period, and 2) because lions in the cultivated plots created a safety issue during the last month of data collection. Data for all transects exceeding 1 km in length were then truncated to 1 km outside of the cultivated plots, or one leg inside, and ten legs outside.

I checked GPS coordinates of all observations for errors and then projected into ArcMap 9.3 (ESRI 2008), to view and check for points falling off of the line. I identified a small number of errors, and corrected them. I then imported this dataset into a Microsoft Access 2007 database to calculate the density of print groups and individuals

[4] Dates of transect print counts used in analysis include: 1A/1B: 4/23/2004 and 5/23/2004; 2A/2B: 4/29/2010 and 5/31/2010; 3A/3B: 4/25/2010 and 5/24/2010; 4A/4B: 4/21/2010 and 5/19/2010.

as number per 50 m^2 transect leg.[5] These compilations resulted in a single observed density for each species per leg walked, with leg 0 being inside cultivation, leg 1 being immediately outside of cultivation, and leg 10 being farthest away from cultivation. This compiled database consisted of 163 leg samples for each species. Ideally, the total sample size would have been 173 legs per species (11 legs x 8 transects x 2 dates), but there were times when transects could not be completed due to weather conditions (heat or rain). This difference in effort at the farthest legs of the transects was explicitly addressed during analysis.

In addition to comparing print densities across transect legs 0-10, I also categorized the legs into zones that represent “interior”, “proximal” and “distal”. The interior zone consists of leg 0, the proximal zone consists of legs 1-5, and the distal zone consists of legs 6-10. While the objective of the leg-based analysis is to pick up fine differences in densities across the cultivation gradient, the objective of the zone-based analysis is to pick up a coarser-scaled response to cultivation. Differences that are not significant at the fine scale may become apparent at the coarse scale, and vice versa.

Since the goal of the study was to assess relative density of species using prints as a proxy for animals, obtaining true densities was not the objective. I used simple comparisons of observed mean print densities/50 m^2 across the cultivation gradient by leg and zone to test the response of each species to cultivation boundaries. I conducted analyses for species and species groups with sample sizes adequate to demonstrate patterns, including zebra, wildebeest, Grant’s gazelle, combined small resident herbivores

[5] Access has a batching function (Query) that can calculate densities of both groups and individuals for animals recorded by group with a number of individuals per group. Access automates these calculations. Data were batched by: 1) leg, 2) date, and 3) species. The order of this batching system ensured that groups were properly defined for analysis.

(dik dik, warthog, porcupine, and steenbok), and combined predators (lion, hyena and leopard). Prints of wildlife species that were encountered infrequently were left out of this analysis due to inadequate sample size, including giraffe, eland, ostrich, hare, aardvark, jackal, mongoose, fox, buffalo, impala, and various bird species (which were also difficult to identify). Data were collected and analyzed for cattle and goats primarily to see whether they were ingressing into cultivation.

The dataset demonstrated a clear threshold of countability at approximately 7-10 animals per group. Groups of small resident herbivores and predators always consisted of fewer than 5 animals, hence I analyzed these species responses by individuals/50m^2. Species that occurred in herds I analyzed by groups to account for the fact that prints left by groups of greater than 7-10 animals were uncountable. As a result, groups ranging from 10 animals into the hundreds are indistinguishable in the dataset. This will lead to an underestimate of species that occur in large groups relative to species that occur in small groups, but because this problem exists across all SAs, it does not present a major problem in investigating relative print densities.

I analyzed the transect data using Systat 13 (Systat13 2009). I collapsed all eight transects collapsed into a single test transect both to increase sample size and to get at species-specific rather than transect-specific relationships. Data were checked for normality and found to be highly skewed, so transformations were applied. Transformations failed to achieve normal distributions of data, so I performed nonparametric Kruskal-Wallis tests to compare group means and determine the significance of any differences in species-specific animal abundances across the leg and zone-based cultivation gradients. I then performed Conover-Inman pairwise comparison tests for each species, since these individual comparisons are of greater interest to the questions at hand, and may get dampened by, the overall test of significance. I used a critical p-value of $p < 0.1$ for these analyses because I believed .05 would be too stringent of a p-value, potentially missing weaker but important differences in animal densities.

RESULTS

Interview Data

Interview data demonstrated a wide variety of interactions between people and wildlife, but reports were almost exclusively negative, even when the opportunity to list positive interactions with wildlife was explicitly presented. Two households mentioned positive interactions, both in the dry season. One interviewee responded that since there is no cultivation in the dry season, that wildlife are then nice and beautiful. The second interviewee responded that hunters built a local hospital.

62% of interviewees reported negative interactions with wildlife in the dry season (Table 3.1), 99% in the wet season (Table 3.2). In the dry season, two conflicts were reported frequently (by more than 30% of households): wildlife destroying water wells (37% reporting), and wildlife endangering people (41% reporting). The species responsible for well destruction were elephant and buffalo. Species endangering people included primarily buffalo (50%), but also lion (11%) and occasional reports of other species. Perceived costs and benefits did not need to be realized by a household for an interviewee to feel a personal benefit or threat. For instance, a lion attacking a neighbor accompanied by fear of future attacks is a cost that is perceived by more than the household that was attacked in that instance.

Problem severity (PSI) analysis revealed four species of concern: zebra (N=59, Rank=2.10, PSI= 28.10), porcupine (N=57, Rank=3.04, PSI= 18.75), warthog (N=44, Rank=3.09, PSI= 14.24) and eland (N=32, Rank=2.31, PSI= 13.85) (Table 3.3).

These values suggest that zebra were not only reported by a large proportion of respondents, but that they also were reported by those respondents to be causing a great deal of damage compared to other invading animals. This combination led to this species having the greatest PSI of all reported species. Porcupine were reported by a similar proportion of respondents, but damage severity was lower, leading to a somewhat lower PSI rating. Warthog were ranked similarly to porcupine in terms of damage severity, but fewer households reported this species so they ranked lower. Eland ranked relatively high in terms of damage, but only 1/3 of households reported eland damage. While elephant had a mean damage severity rank of 1, the overall PSI ranks toward the bottom of the set because only two households reported elephant damage. Informants have reported that zebra and elephant numbers and raids increased in the years 2009-2010. The number of households experiencing problems with particular species is likely to change over time as populations and migratory routes shift, and damage ranks could also change. As very destructive elephants are reported by more individuals the relative ranks of other animals will fall, but also as weather conditions and climate shifts forage availability, cultivated fields may be seen as more or less attractive by the various species. Therefore results should not be seen as definitive, but rather as reflective of conditions in the year of the interviews.

Transect Data

Total counts of wildlife and livestock species by both leg and zone demonstrated non-neutral patterns for zebra, wildebeest, and cattle (Table 3.4), small resident herbivores (Table 3.5), and predators (Table 3.6). Species demonstrating a neutral response were goats and Grants gazelle (Table 3.4).

Kruskal-Wallis tests with post-hoc Conover-Inman pairwise comparisons between zone and leg classifications (critical $p < 0.1$) revealed a significantly higher number of zebra in the proximal zone compared to the internal zone ($p=0.07$), but no other significant differences among zones (Table 3.7). Comparisons among legs demonstrated that only two differences were significant between leg 0 and legs 1-10. All comparisons of legs and zones outside cultivation were not significant. This result combined with the means by zone (Table 3.4) suggest that zebra responded to a weak barrier at the cultivation boundary, but that outside cultivation, they tend to concentrate in the proximal, as opposed to distal zone.

There were significantly more wildebeest prints in both the proximal and distal external zones than in the internal zone ($p<0.001$), and no difference between external zones (Table 3.8). All pair-wise comparisons of leg 0 to other legs were highly significant. Comparisons among external legs were not significant, suggesting that wildebeest responded strongly to cultivation boundaries, but not to the cultivation gradient.

Grant’s gazelle analyses revealed no significant differences among zones or legs (Table 3.9). These results imply that Grant’s gazelle responded to neither cultivation boundaries nor the cultivation gradient, an entirely neutral response to cultivation.

Small resident herbivore (combined porcupine, dik dik, warthog, and steenbok) analyses indicated a significantly higher number of these species inside cultivation in comparison with external zones ($p<0.001$), and no difference between the two external zones (Table 3.10). All comparisons of leg 0 to external legs 1-10 were significantly different ($p<0.001$). All other pair-wise comparisons among external legs were not significant, suggesting that small resident herbivores responded to cultivation boundaries in preference of cultivation, but not to the cultivation gradient outside of cultivated plots.

There were a significantly higher number of predators inside cultivation in comparison with external zones ($p<0.001$) (Table 3.11). All further tests demonstrate that pair-wise comparisons of leg 0 to other legs were all significantly different ($p<0.001$). Other pair-wise comparisons among external legs were not significant, suggesting that small resident herbivores responded to cultivation boundaries in preference of cultivation, but not to the cultivation gradient outside of cultivated plots.

There were a significantly greater number of cattle in the proximal zone compared to the internal zone, where none were observed ($p=0.02$), but no other significant differences among zones (Table 3.12). Pairwise comparisons demonstrated that in comparing leg 0 with all other legs, only three differences were significant. All other pair-wise comparisons by leg were not significant. The means by zone (Table 3.4) suggest that cattle responded to cultivation boundaries, and tended to be somewhat concentrated in the proximal zone.

There were no significant differences in goat numbers among zones or legs (Table 3.13). These results imply that goats responded to neither the cultivation boundaries nor the cultivation gradient, an entirely neutral response to cultivation.

DISCUSSION

The fact that only 2% of interviewees reported positive interactions with wildlife and 99% reported negative interactions indicates an imbalance in costs and benefits of wildlife for local people in Simanjiro. Financial benefits of wildlife tourism are funneled to the national level through remittances to national parks, yet the costs in terms of human-wildlife conflicts are borne by local villagers, primarily during the wet season when migratory wildlife share pastures with livestock and are near to cultivated fields. Although there are compensation programs in place to assist people who lose livestock to predation, individuals must travel to distant locations to make their claim, must bring evidence of the destruction with them, and compensation is limited to five acres of damage (Tanzania Ministry of Wildlife 2009). It is up to individuals to guard their cultivated fields, but for many people labor is short and the length of the boundary difficult to guard effectively. Toward the end of the growing season, predators in the fields act as guards, but even they cannot keep the herbivores out of the fields.

Grant’s gazelle and the small resident herbivores (porcupine, warthog, steenbok and dik dik) frequented cultivation, likely because their small size made it easier to traverse the thornbrush fence that many individuals erect around their fields. Interviewees reported porcupine, warthog and gazelle as problem species, but steenbok and dik dik were not listed, or were not listed frequently enough to include in statistical analysis. This could mean that these species are present but that they do not do damage to crops that makes them worth mention. Zebra, porcupine and warthog are the top offending species according to their interview problem severity index values (28.1, 18.75 and 14.24, respectively), and the transect data support this. Eland had the next highest

PSI value (13.85), but were encountered infrequently during the study. This could be due to eland favoring areas outside of the core wildlife study area, but inside of the three-village interview study area. Other animals that were reported to be problem species that were not encountered or were encountered infrequently during transects include buffalo, vervet monkeys, and elephants. While several bird species were reported to be a problem, prints left by birds could not be identified.

Print densities at the boundaries of cultivation demonstrate species-specific wildlife responses to cultivation. Since prints were used as a proxy for animal densities, absolute densities cannot be inferred. However, relative densities can be used to discern patterns that might be useful in land use planning to balance the needs of local people (to cultivate) with those of wildlife (to migrate). The primary rationales for using prints as a surrogate for animal observations were that; 1) animals were frequently present at densities too low to detect patterns through statistical analysis, and 2) I wanted to capture movements that may not be apparent in the daytime when total animal counts were conducted (see Chapters 4 and 5). It was commonly reported that wildlife enter the cultivated fields during the nighttime rather than the daytime, and this is why children guard the fields during the daytime, but warriors guard during the nighttime.

The two comparisons of interest to this study are internal versus external densities of prints, and densities along the gradient of distance from cultivation across the ten leg classes. Data revealed some interesting patterns (Table 3.14). There was no evidence of any species of interest responding to the gradient of distance to cultivation outside of the cultivated fields. All species demonstrated statistically equal distributions across this gradient. This suggests that cultivation presents little aversion to wildlife at the scale of the individual cultivated field. Animals, in general, are just as likely during a 24-hour period to walk adjacent to cultivation as to walk 500 m or 1 km away. The implications of this are important, since results suggest a much weaker response of wildlife to cultivation boundaries than is currently assumed by policy makers. These assumptions may be based on daytime observations of wildlife that likely would demonstrate avoidance of cultivated fields at the pasture scale, the scale visible to an observer on the ground (see Chapter 4). However, these data qualify this daytime pattern by indicating complete use of the grazing landscape outside of small-scale cultivated fields over the course of time. Having wildlife densities equal for all species and species groups across the entire 1km distance gradient hints that at the edge, wildlife habitat loss is restricted to the area that is cultivated and does not include an impact zone beyond that.

However, comparisons between the interior and exterior of cultivated plots varied among species. Wildebeest prints were rarely observed in fields. This combined with conversational information from local people that wildebeest do not actually *eat* maize, they just go inside and play (this does sometimes cause some damage), suggests that wildebeest are the species of interest with the least likelihood of causing actual damage. Zebra prints also occurred in lower densities inside of cultivated fields than outside, but this relationship is weaker than for wildebeest. The apparent tendency of zebra to concentrate slightly more in the proximal zone indicates that zebra may be attracted to cultivation but have a difficult time getting inside. Both wildebeest and zebra may also be wary of predators inside the fields, who use the maize as ambush cover just as they would tall grass.

Grant's gazelle did not display any difference in print density among any zones or legs across this study. Like the small resident herbivore group, these animals are small-bodied. They are also very good jumpers, giving them two effective ways of getting across the typical thornbrush fence. However, even though gazelle were inside the fields, this does not mean that they were causing severe damage; gazelle were the species with the lowest damage rank of all wildlife-cultivation conflict species. This reinforces the value of combining interview data with transect data, since observing high densities of gazelle may lead one to the conclusion that they are a large problem. Interview data suggest otherwise, and leave open the alternative explanation that gazelle use cultivation as a refuge.

Prints of small resident herbivores (porcupine, warthog, dik dik and steenbok combined) and predators (lion, hyena and leopard combined) were denser inside cultivation than outside. Predators appear to use cultivation as a screen for hunting, as well as for shade during the daytime. They do not damage crops other than potentially for small distances through which they might drag a killed animal or congregate to eat it. Porcupine and warthog are ranked as causing a medium level of damage to crops, but because a large number of informants reported them in their fields their PSI value is high relative to all other species other than zebra. While these species were not frequently encountered on transects, the concentration of prints inside cultivation is supportive of interview reports.

The print densities of cattle and goats were quite different, and this may be a function of both where these animals are herded, and who is herding them. Young adults or adults are usually in charge of herding cattle, and cattle are herded to pastures more distant from the household location. In contrast, goats are typically herded closer to the household location by children. The print density data of goats mirrors that of gazelle, showing no response to either cultivation boundaries or gradient. While the gradient response is of little interest here because like cattle goats are herded wherever people take them, but the fact that they are frequently entering the cultivated fields indicates that they likely contribute to crop damage. Cattle were effectively kept out of fields. Both goats and cattle eat maize, and I have observed both species eating all parts of the plant.

The use of print counts to conduct this edge effect study proved to be extremely important to measuring what wildlife are actually doing in the TME and how they are responding to cultivation. If data were restricted to counts of actual animals during daytime hours, results would have been skewed to avoidance. In reality, no species appears to be avoiding cultivation, and several species are entering fields. The use of this method combined with the analysis in Chapter 4 (wildlife responses to cultivation at the pasture scale) supports the daytime to nighttime fluctuation in wildlife locations relative to cultivation.

Fragmentation of the pastoral landscape in Simanjiro is occurring as a result of cultivation by pastoralists as well as outsiders who lease land from pastoralists for cultivation. The repercussions of this fragmentation for wildlife have been the subject of debate for at least two decades, with much of the discussion focusing on negative impacts. This research suggests, however, that at the boundaries of individual cultivated plots the implications of cultivation for wildlife may not be as great as managers sometimes assume they are; for some species cultivation may actually facilitate wildlife use of the landscape, at least at the scale of this study. Cultivation at the small-scale household level acts as another element of heterogeneity and patchiness that some species, primarily predators and small-bodied resident and migratory herbivores, appear to perceive positively for hiding, hunting and/or foraging. Larger-bodied zebra and wildebeest do appear to avoid areas of high cultivation intensity in particular (see Chapters 4 and 5), so this suggestion of facilitation does not hold at larger landscape scales. But the data presented here suggest that they do not demonstrate any response to cultivation along the external distance gradient at the small scale of 100m intervals over the course of both day and night, other than a slight and non-significant lower density of wildebeest in the 100m directly outside of fields.

The implications of these results for conservation are important. While Hobbs et al (2008) make the point that spatial isolation in grazing ecosystems can limit the ability of people and both wild and domestic animals to exploit heterogeneity in vegetation, this study suggests that some species benefit from, or at least utilize, cultivation to promote their survival. It presents a counter-argument that for some species, cultivation acts as an agent of increasing heterogeneity (small resident herbivores, gazelle and predators), and that for other species of interest (zebra and wildebeest), a barrier to movement and landscape access occurs at the boundary of cultivation rather than at some buffer distance of avoidance. The importance of explicitly studying and assessing impacts of land use change for wildlife on a species-by-species basis and at a small spatial scale (in addition to larger scales) is paramount to making objective and constructive management decisions that have implications for both wildlife and land users.

The results of this study indicate that wildlife habitat loss is restricted to the area that is cultivated and does not include an impact zone beyond that. This, combined with results from the landscape scale analysis (conducted in Chapter 5) that indicate a large-scale negative response by some species to dense cultivation, lead me to conclude that there is a possibly optimal arrangement for cultivation. Concentrating cultivated plots in large clusters on the landscape will allow subsistence farming to continue with potentially minimal impact on wildlife beyond the edge of the clusters. Concentrated plots would also mean less edge, and therefore lower probability of wildlife intrusions with effective guarding. While cultivation is commonly clustered in small groups, what I suggest is to cluster all cultivation for entire subvillages in one location to concentrate the negative impacts of cultivation for wildlife, while maintaining access to this important food source (see Chapter 2) for local people.

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Figures and Tables

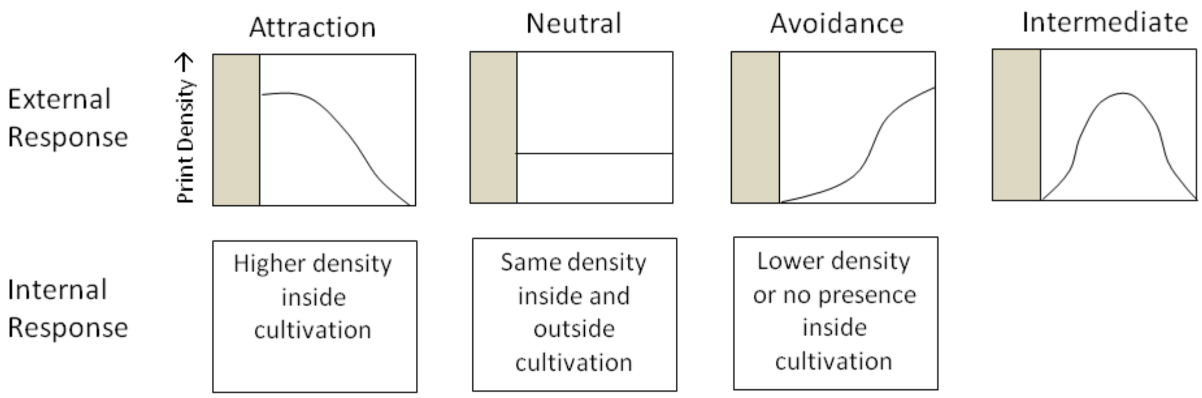

Figure 3.1. Hypothetical set of possible responses to cultivation by wildlife species. The Kruskal-Wallis null hypothesis is that there are no differences in means across the cultivation gradient, or that the response to cultivation is neutral. Significant differences in means (critical $p<0.1$) across the gradient of either legs or zones will indicate the species response is not neutral and that another of these graphs may be a truer representation of species responses to cultivation. The shape of the curve inside cultivation (gray) cannot be predicted with this dataset because there is only one leg of data available, but the shape of the curve outside cultivation is measurable across 1 km. Internal responses are measured through a comparison of internal and external print densities.

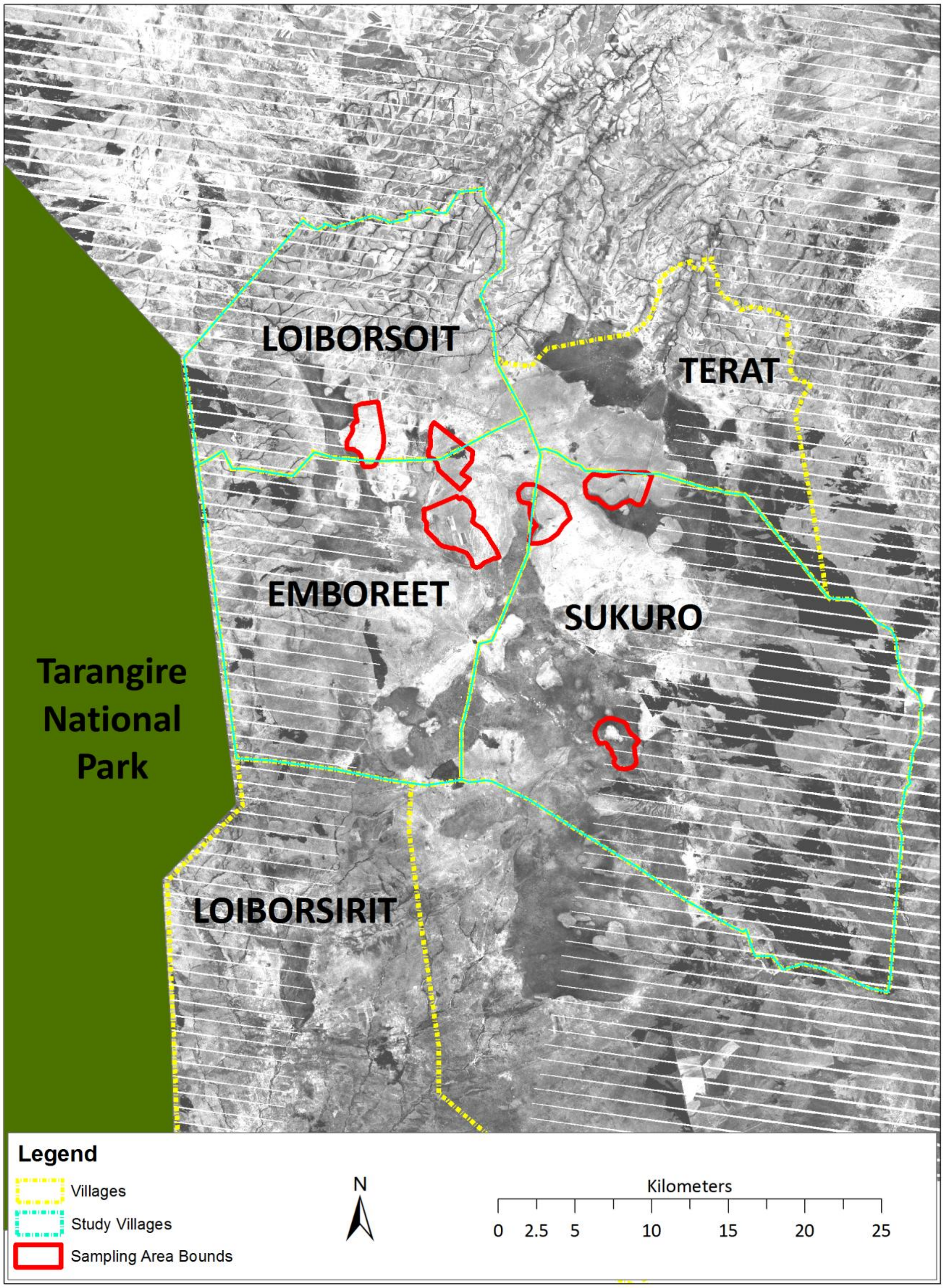

Figure 3.2. Map of the study area and surrounding Villages.

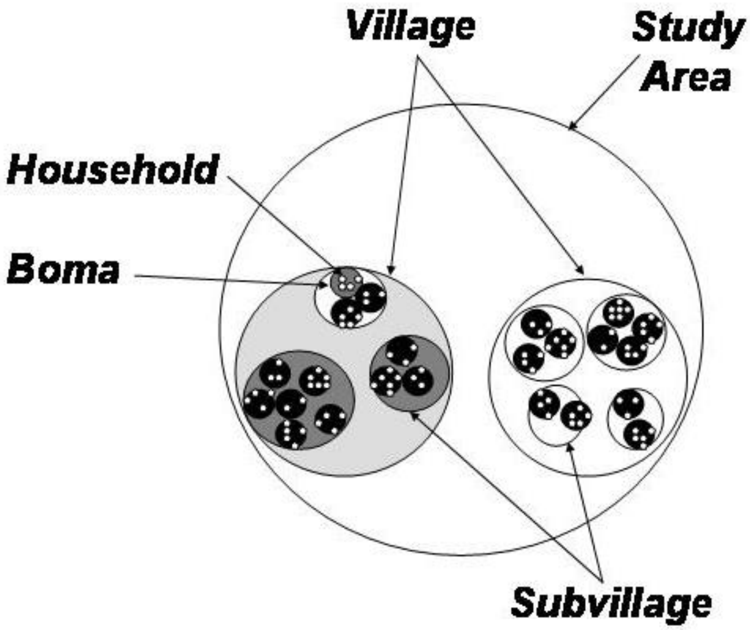

Figure 3.3. Schematic of the clustered and stratified interview design developed to allow analysis at the household, boma, subvillage, and village levels. Bomas were randomly selected from a boma census to represent each subvillage and village of the study area. Every available household head was interviewed.

Figure 3.4. Transect locations within the study area. Eight transects originated 50m inside of cultivation and continued for up to 1 km outside of cultivation. Observations were recorded for at alternating 50 m intervals, once inside and for ten intervals outside beginning with the boundary interval.

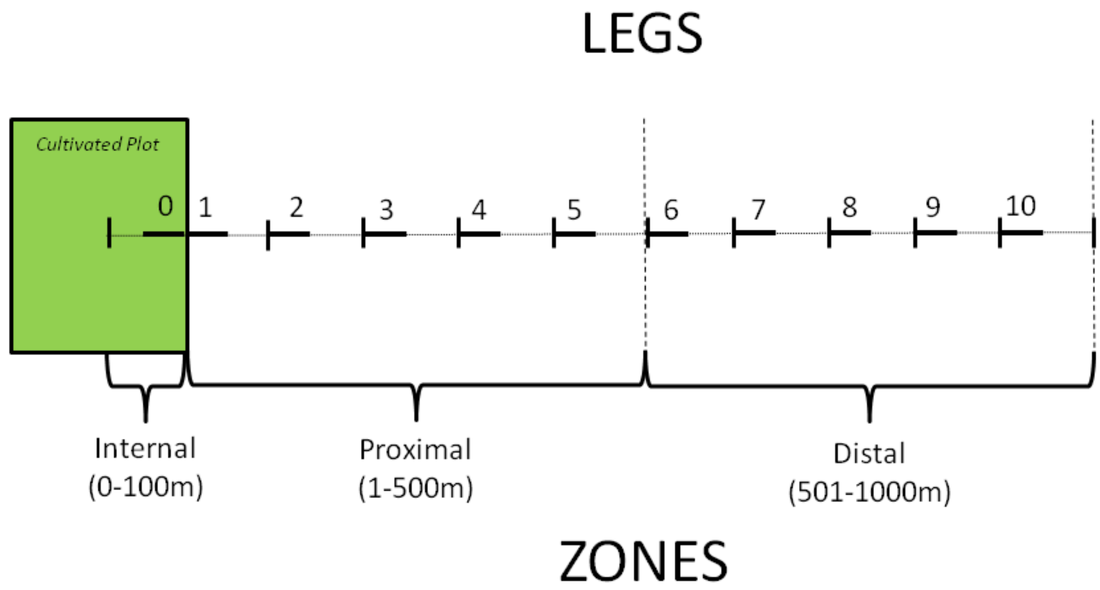

Figure 3.5. Observations were compiled across all transects and dates to calculate mean densities of print individuals and groups by leg class. These leg classes allowed a fine-scale assessment of wildlife responses to cultivation. Data were also analyzed by three zone classes that represented "inside", "proximal", and "distal" distance classes to test whether any patterns would manifest themselves at a coarser resolution.

Table 3.1. Dry season human-wildlife conflicts were reported in open-ended household-level interview questions. (Total n=105)

Dry Season Human-Wildlife Conflicts

Dry Season Conflicts Exist		Wildlife Leave (no conflict)		Wildlife Eat Crops		Predators are a Problem		Predators Kill Livestock		Wildlife Endanger People		Buffalo Endanger Livestock		Wildlife Bring Disease	
Count	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*
65	**61.9**	**40**	**38.1**	**0**	**0.0**	**13**	**12.4**	**15**	**14.3**	**43**	**41.0**	**6**	**5.7**	**1**	**3.8**

Wildebeest Bring MCF		Wildlife Eat Livestock Forage		Wildlife Destroy Wells		Wildlife Finish Livestock Water	
Count	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*
1	**3.8**	**4**	**3.8**	**39**	**37.1**	**2**	**1.9**

Table 3.2. Wet season human-wildlife conflicts were reported in open-ended household-level interview questions. (Total n=104)

Wet Season Human-Wildlife Conflicts

Wet Season Conflicts Exist		Wildlife Eat Crops		Predators are a problem		Predators Kill Livestock		Wildlife Endanger People		Buffalo Endanger Livestock		Wildlife Bring Disease		Wildebeest Bring MCF	
Count	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*
104	99.0	93	89.4	73	70.2	33	31.7	29	27.9	3	2.9	69	66.3	62	59.6

Wildlife Bring Ticks		Impala Bring Goat Disease		Warthog Bring Sheep Disease		Wildlife Eat Livestock Forage		Wildlife Destroy Wells		Wildlife Finish Livestock Water		Wildlife Destroy the Environment	
Count	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*	*Count*	*Percent*
6	5.8	3	2.9	1	1.0	42	40.4	5	4.8	3	2.9	2	1.9

Table 3.1. Human-wildlife conflicts in cultivated plots by species. Interviewees listed and ranked problem species (1=worst). Mean damage severity rank was calculated across all households reporting that species, and a Problem Severity Index (PSI) was calculated using the equation PSI = Percent Reporting * 1/Mean Rank.

Species reported to cause damage to cultivation and problem severity			
SPECIES REPORTED	**Percent of Households Reporting (PR)**	**Mean Rank by Reporting Households**	**Problem Severity Index: PR * 1/mean rank**
Zebra	59	2.10	28.10
Porcupine	57	3.04	18.75
Warthog	44	3.09	14.24
Eland	32	2.31	13.85
Buffalo	20	2.15	9.30
Gazelle	22	5.55	3.96
Wildebeest	17	5.06	3.36
Francolin Bird	13	5.06	2.57
Vervet Monkey	7	3.43	2.04
Elephant	2	1.00	2.00
Hornbill Bird	2	5.50	0.36

Table 3.2. Total counts of wildlife and livestock group observations (prints) were compiled by transect leg (above). Counts were divided by effort to calculate mean number of group observations per $50m^2$/leg. Grand means were then taken to calculate mean individuals/$50m^2$/zone (below).

	TOTAL COUNT OF GROUPS (#/800m2)											
SPP	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	*TOTAL*
Zebra	60	106	98	79	57	59	68	71	35	41	46	720
Wildebeest	7	28	57	69	66	67	50	60	43	49	51	547
Grants Gaz	19	7	20	20	20	14	10	21	7	11	14	163
Giraffe	0	2	0	0	2	0	1	2	0	0	0	7
Ostrich	1	0	1	1	4	1	1	1	0	0	1	11
Cattle	0	17	15	10	4	9	10	4	1	2	3	75
Goats	3	3	0	3	6	3	4	1	2	0	0	25
LEG EFFORT:	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*15*	*12*	*12*	*12*	
ZONE EFFORT:	*16*	*80*					*67*					

	MEAN NUMBER OF GROUPS BY LEG (mean #/50m2)											MEANS BY ZONE (#/50m2)		
SPP	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**INSIDE**	**PROX**	**DIST**
Zebra	3.75	6.63	6.13	4.94	3.56	3.69	4.25	4.73	2.92	3.42	3.83	3.75	4.99	3.83
Wildebeest	0.44	1.75	3.56	4.31	4.13	4.19	3.13	4.00	3.58	4.08	4.25	0.44	3.59	3.81
Grants Gaz	1.19	0.44	1.25	1.25	1.25	0.88	0.63	1.40	0.58	0.92	1.17	1.19	1.01	0.94
Giraffe	0.00	0.13	0.00	0.00	0.13	0.00	0.06	0.13	0.00	0.00	0.00	0.00	0.05	0.04
Ostrich	0.06	0.00	0.06	0.06	0.25	0.06	0.06	0.07	0.00	0.00	0.08	0.06	0.09	0.04
Cattle	0.00	1.06	0.94	0.63	0.25	0.56	0.63	0.27	0.08	0.17	0.25	0.00	0.69	0.28
Goats	0.19	0.19	0.00	0.19	0.38	0.19	0.25	0.07	0.17	0.00	0.00	0.19	0.19	0.10

Table 3.3. Total counts of small resident herbivore individual observations (prints) were compiled by transect leg (above). Counts were divided by effort to calculate mean number of individual observations per 50m^2/leg. Grand means were then taken to calculate mean individuals/50m^2/zone (below).

	TOTAL SMALL RESIDENT HERBIVORE COUNTS (mean #/800m2)											
SPP	0	1	2	3	4	5	6	7	8	9	10	*TOTAL*
Dik dik	28	1	1	1	0	0	0	0	0	0	0	*31*
Warthog	4	0	0	0	0	0	0	0	0	0	0	*4*
Porcupine	11	0	0	0	0	0	0	0	0	1	0	*12*
Steinbok	3	0	0	0	0	0	0	0	0	0	0	*3*
TOTAL SMALL HERBIVORES	46	1	1	1	0	0	0	0	0	1	0	*50*
LEG EFFORT:	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*15*	*12*	*12*	*12*	
ZONE EFFORT:	*16*	*80*					*67*					

	SMALL RESIDENT HERBIVORE COUNT MEANS BY LEG (mean #/50m2)											MEANS BY ZONE (#/50m2)		
SPP	0	1	2	3	4	5	6	7	8	9	10	INSIDE	PROX	DIST
Dik dik	1.750	0.063	0.063	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.750	0.038	0.000
Warthog	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000
Porcupine	0.688	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.083	0.000	0.688	0.000	0.017
Steinbok	0.188	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.000	0.000
TOTAL SMALL HERBIVORES	2.875	0.063	0.063	0.063	0.000	0.000	0.000	0.000	0.000	0.083	0.000	2.875	0.038	0.017

Table 3.4. Total counts of predator individuals (print observations) were compiled by transect leg (above). Counts were divided by effort to calculate mean number of observations per $50m^2$/leg. Grand means were then taken to calculate mean individuals/$50m^2$/zone (below).

	TOTAL PREDATOR COUNTS (#/800m2)											
SPP	0	1	2	3	4	5	6	7	8	9	10	*TOTAL*
Lion	7	2	0	0	0	0	0	3	0	0	0	*12*
Hyena	11	0	0	0	1	0	1	0	0	0	0	*13*
Leopard	2	0	0	0	0	0	0	0	0	0	0	*2*
TOTAL PREDATORS	20	2	0	0	1	0	1	3	0	0	0	*27*
LEG EFFORT:	*16*	*16*	*16*	*16*	*16*	*16*	*16*	*15*	*12*	*12*	*12*	
ZONE EFFORT:	*16*	*80*					*67*					

	PREDATOR COUNT MEANS BY LEG (mean #/50m2)											MEANS BY ZONE (#/50m2)		
SPP	0	1	2	3	4	5	6	7	8	9	10	INSIDE	PROX	DIST
Lion	0.438	0.125	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.438	0.025	0.040
Hyena	0.688	0.000	0.000	0.000	0.063	0.000	0.063	0.000	0.000	0.000	0.000	0.688	0.013	0.013
Leopard	0.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.125	0.000	0.000
TOTAL PREDATORS	1.250	0.125	0.000	0.000	0.063	0.000	0.063	0.200	0.000	0.000	0.000	1.250	0.038	0.053

Table 3.5. Zebra group print density by zone and leg (Kruskal-Wallis tests and Conover-Inmann pairwise comparisons, criteria p-value < 0.1)

Zebra by Zone

Zone(i)	Zone(j)	Statistic	p-Value
Internal	Proximal	1.83	0.07
Internal	Distal	1.36	0.18
Proximal	Distal	0.73	0.47

Kruskal-Wallis Test Statistic: 3.363

The p-value is 0.186 assuming chi-square distribution with 2 df.

Zebra by Leg

Leg(i)	Leg(j)	Statistic	p-Value
0	1	2.05	0.04
0	2	1.53	0.13
0	3	1.81	0.07
0	4	0.82	0.41
0	5	0.80	0.42
0	6	1.54	0.13
0	7	1.63	0.11
0	8	0.41	0.69
0	9	0.61	0.54
0	10	0.66	0.51

Kruskal-Wallis Test Statistic: 8.137

The p-value is 0.615 assuming chi-square distribution with 10 df.

Table 3.6. Wildebeest group print density by zone and leg (Kruskal-Wallis tests and Conover-Inmann pairwise comparisons, criteria p-value < 0.1)

Wildebeest by Zone

Zone(i)	Zone(j)	Statistic	p-Value
Internal	Proximal	3.74	0.00
Internal	Distal	4.12	0.00
Proximal	Distal	0.74	0.46

Kruskal-Wallis Test Statistic: 15.889

The p-value is 0.000 assuming chi-square distribution with 2 df.

Wildebeest by Leg

Zone(i)	Zone(j)	Statistic	p-Value
0	1	1.89	0.06
0	2	2.88	0.01
0	3	3.04	0.00
0	4	3.38	0.00
0	5	3.09	0.00
0	6	2.76	0.01
0	7	3.49	0.00
0	8	2.72	0.01
0	9	3.30	0.00
0	10	3.00	0.00

Kruskal-Wallis Test Statistic: 19.185

The p-value is 0.038 assuming chi-square distribution with 10 df.

Table 3.7. Grant's gazelle group print density by zone and leg (Kruskal-Wallis tests and Conover-Inmann pairwise comparisons, criteria p-value < 0.1)

Gazelle by Zone

Zone(i)	Zone(j)	Statistic	p-Value
Internal	Proximal	0.74	0.46
Internal	Distal	0.59	0.56
Proximal	Distal	0.23	0.82

Kruskal-Wallis Test Statistic: 0.553

The p-value is 0.758 assuming chi-square distribution with 2 df.

Gazelle by Leg

Leg(i)	Leg(j)	Statistic	p-Value
0	1	0.38	0.71
0	2	1.02	0.31
0	3	0.75	0.46
0	4	0.98	0.33
0	5	0.47	0.64
0	6	0.04	0.97
0	7	1.47	0.15
0	8	0.11	0.91
0	9	0.11	0.91
0	10	0.48	0.63
1	7	1.84	0.07

Kruskal-Wallis Test Statistic: 6.141

The p-value is 0.803 assuming chi-square distribution with 10 df.

Table 3.8. Small resident herbivore (porcupine, dik dik, warthog, and steenbok) individual print density by zone and leg (Kruskal-Wallis tests and Conover-Inmann pairwise comparisons, criteria p-value < 0.1)

Small Resident Herbivores by Zone

Zone(i)	Zone(j)	Statistic	p-Value
Internal	Proximal	11.25	0.00
Internal	Distal	11.32	0.00
Proximal	Distal	0.43	0.67

Kruskal-Wallis Test Statistic: 115.461

The p-value is 0.000 assuming chi-square distribution with 2 df.

Small Resident Herbivores by Leg

Leg(i)	Leg(j)	Statistic	p-Value
0	1	8.44	0.00
0	2	8.44	0.00
0	3	8.44	0.00
0	4	9.00	0.00
0	5	9.00	0.00
0	6	9.00	0.00
0	7	8.85	0.00
0	8	8.33	0.00
0	9	7.65	0.00
0	10	8.33	0.00

Kruskal-Wallis Test Statistic: 116.639

The p-value is 0.000 assuming chi-square distribution with 10 df.

Table 3.9. Predator (lion, hyena and leopard) individual print density by zone and leg (Kruskal-Wallis tests and Conover-Inmann pairwise comparisons, criteria p-value < 0.1).

Predators by Zone

Zone(i)	Zone(j)	Statistic	p-Value
Internal	Proximal	8.89	0.00
Internal	Distal	8.83	0.00
Proximal	Distal	0.15	0.89

Kruskal-Wallis Test Statistic: 73.530

The p-value is 0.000 assuming chi-square distribution with 2 df.

Predators by Leg

Leg(i)	Leg(j)	Statistic	p-Value
0	1	6.02	0.00
0	2	7.20	0.00
0	3	7.20	0.00
0	4	6.61	0.00
0	5	7.20	0.00
0	6	6.61	0.00
0	7	6.44	0.00
0	8	6.67	0.00
0	9	6.67	0.00
0	10	6.67	0.00

Kruskal-Wallis Test Statistic: 76.174

The p-value is 0.000 assuming chi-square distribution with 10 df.

Table 3.10. Cattle group print density by zone and leg (Kruskal-Wallis tests and Conover-Inmann pairwise comparisons, criteria p-value < 0.1)

Cattle by Zone

Zone(i)	Zone(j)	Statistic	p-Value
Internal	Proximal	2.29	0.02
Internal	Distal	1.47	0.14
Proximal	Distal	1.32	0.19

Kruskal-Wallis Test Statistic: 5.625

The p-value is 0.060 assuming chi-square distribution with 2 df.

Cattle by Leg

Leg(i)	Leg(j)	Statistic	p-Value
0	1	2.34	0.02
0	2	1.88	0.06
0	3	1.41	0.16
0	4	1.29	0.20
0	5	1.80	0.07
0	6	1.40	0.16
0	7	0.94	0.35
0	8	0.51	0.61
0	9	1.01	0.31
0	10	1.52	0.13

Kruskal-Wallis Test Statistic: 8.153

The p-value is 0.614 assuming chi-square distribution with 10 df.

Table 3.11. Goat group print density by zone and leg (Kruskal-Wallis tests and Conover-Inmann pairwise comparisons, criteria p-value < 0.1)

Goats by Zone

Zone(i)	Zone(j)	Statistic	p-Value
Internal	Proximal	0.31	0.76
Internal	Distal	0.10	0.92
Proximal	Distal	0.35	0.73

Kruskal-Wallis Test Statistic: 0.169

The p-value is 0.919 assuming chi-square distribution with 2 df.

Goats by Leg

Leg(i)	Leg(j)	Statistic	p-Value
0	1	0.59	0.56
0	2	0.68	0.50
0	3	0.00	1.00
0	4	1.27	0.21
0	5	0.00	1.00
0	6	0.62	0.54
0	7	0.02	0.99
0	8	0.90	0.37
0	9	0.63	0.53
0	10	0.63	0.53

Kruskal-Wallis Test Statistic: 8.048

The p-value is 0.624 assuming chi-square distribution with 10 df.

Table 3.12. Summary response table representing species responses to cultivation via: 1. Concentration in the interior versus exterior of cultivation, and 2. Concentrations along the 1km gradient of distance to cultivation boundary represented by both legs (fine scale) and zones (coarse scale).

SPECIES	Interior Concentration	Gradient Response
Zebra	-	0
Wildebeest	-	0
Grant's Gazelle	0	0
Small Resident Herbivores	+	0
Predators	+	0
Cattle	-	0
Goats	0	0

APPENDIX 3.1: ABSENCE DATA INSERTION VBA (VISUAL BASIC FOR APPLICATIONS) PROGRAM FOR MICROSOFT EXCEL DATABASE OF WILDLIFE TRANSECT PRINT COUNTS

```
'Transect data
Option Explicit

Dim Rand_ID As Integer 'ID number
Dim SPP As Integer 'SPP Index
Dim SPP_ID As Integer ' Spp ID
Dim SPP_CHECK As Integer
Dim transect_code As Integer 'transect index
Dim Leg As Integer 'transect segment
Dim Datecode As Integer 'sample date code
Dim Groups As Integer 'number of group prints in leg
Dim Individuals As Integer 'Number of Individual prints in leg
Dim Record As Integer 'index for records

Sub Enter_Null_Records()

Worksheets("transect_new").Activate

Rand_ID = 0
SPP = 1
transect_code = 1
Leg = 0
Datecode = 1
Groups = 0
Individuals = 0
Record = 1

    SPP = 1
    For SPP = SPP To 14
        Call ID_SPP
        SPP_CHECK = 1
        For SPP_CHECK = 1 To 14
            If Cells(Record + 1, 1) <> SPP_ID Then
              SPP = SPP + 1
              Call ID_SPP
            End If
        Next SPP_CHECK
      For transect_code = 1 To 8
        For Leg = 0 To 10
            For Datecode = 1 To 2
              If Cells(Record + 1, 5) <> Datecode Then
                Call Insert
              ElseIf Cells(Record + 1, 4) <> Leg Then
                Call Insert
              ElseIf Cells(Record + 1, 2) <> transect_code Then
                Call Insert
              End If
              Record = Record + 1
```

```
            Next Datecode
        Next Leg
      Next transect_code
    Next SPP


End Sub
Sub ID_SPP()
        Select Case SPP
            Case 1
                SPP_ID = 101
            Case 2
                SPP_ID = 102
            Case 3
                SPP_ID = 103
            Case 4
                SPP_ID = 105
            Case 5
                SPP_ID = 107
            Case 6
                SPP_ID = 108
            Case 7
                SPP_ID = 110
            Case 8
                SPP_ID = 112
            Case 9
                SPP_ID = 113
            Case 10
                SPP_ID = 121
            Case 11
                SPP_ID = 122
            Case 12
                SPP_ID = 123
            Case 13
                SPP_ID = 201
            Case 14
                SPP_ID = 202
        End Select
End Sub
Sub Insert()
                Rows(Record + 1).Select
                Selection.Insert Shift:=xlDown
                Cells(Record + 1, 1) = SPP_ID
                Cells(Record + 1, 2) = transect_code
                Cells(Record + 1, 4) = Leg
                Cells(Record + 1, 5) = Datecode
                Cells(Record + 1, 6) = Groups
                Cells(Record + 1, 7) = Individuals
                Rows(Record + 1).Select
                    With Selection.Interior
                        .ColorIndex = 6
                        .Pattern = xlSolid
                    End With
End Sub
```

CHAPTER 4

PASTURE AND LANDSCAPE-LEVEL RESPONSES OF WILDLIFE TO CULTIVATION IN AN EAST AFRICAN PASTORAL SYSTEM

INTRODUCTION

Arid to semi-arid rangelands cover approximately one-third of the Earth's land surface (Galaty and Johnson 1990). People and animals have co-evolved with intact, unfragmented landscapes in most of these drylands of the world, where pastoral economies have existed for thousands of years (Hobbs, Galvin et al. 2008). Traditional pastoral land uses reflect intimate knowledge of these landscapes, and the spatial and temporal complexity of pattern, process and the interactions between them that are inherent in these ecosystems (Coughenour 1991; Scoones 1995; Goldman 2003). Spatial heterogeneity and movement play an important role in the maintenance of rangeland plant-herbivore systems (Coughenour 1991).

A combination of spatially and temporally variable rainfall, fire, grazing and browsing, and other spatially heterogeneous disturbances and land uses creates a dynamic and patchy rangeland landscape (Ellis and Swift 1988; Ellis et al. 1991; Behnke and Scoones 1993; Ellis and Galvin 1995; Swift et al. 1996). Indeed, rangelands are dynamic and depend upon disturbance to maintain their mosaic of resource patterns. The diversity of wildlife in African landscapes may, in fact, be an emergent outcome of this heterogeneity. Thus, biodiversity in arid and semi-arid landscapes may fare better under management regimes that allow for flexibility of animal movements amongst a matrix of conservation-compatible land uses rather than under protectionist management regimes that draw hard boundaries around protected areas of limited size and heterogeneity (Homewood 2004).

Land use and consequent land cover changes have become so pervasive that the compilation of these changes has had a great effect on Earth system function at all levels from the local, to the regional, and to the global (Lambin et al. 2001). But over-simplifications of cause and effect relationships are rampant, and unsubstantiated myths have at times actually gained enough public support to influence policies on environment and development (ibid). For instance, it is often assumed that all agricultural conversion is incompatible with conservation of large mammalian wildlife in the rangelands of Africa (see Sachedina 2006) yet the actual spatial responses of large-bodied wild species to cultivation have not yet been thoroughly investigated. It must be assumed that for these species there exists some threshold at which a combination of habitat loss, the actual loss of pasture area available to grazers, and fragmentation, the physical loss of access to still-existing grazing pastures due to movement barriers, will have a negative impact on wildlife. But where is this threshold, and are migratory wildlife necessarily negatively impacted by less widespread cultivation as many wildlife advocates believe?

African protected areas have expanded significantly in the past 30 years, but their capacity to support viable populations depends on human influences both inside and outside of reserves that can lead to reserve degradation and isolation (Newmark 2008).

Newmark (2008) identifies the most important mechanistic contributors to reserve isolation as habitat loss, fences and roads, overhunting and disease. The drivers of many of these changes are ultimately population growth, economic expansion, social and environmental human displacement, and poverty. Land use history, current activities, and likely future land use trajectories have important effects on the functional linkages that facilitate animal movement, and thereby impact functional landscape size (Wiens 2009). Human land-use strategies simultaneously shape and are shaped by ecological patterns and processes, with wider linkages to political and economic drivers (Burnsilver et al. 2003). For instance, the process of land fragmentation in East Africa is an outcome of socio-political and economic drivers, and this land fragmentation in turn impacts both social and ecological function and sustainability.

Hobbs et al (2008) make it clear that the state of the Earth's ecosystems cannot be fully understood without carefully considering the coupling between human societies and biological and physical processes. In addition, recognition of the fact that changes occurring for any component of an ecosystem, be it land tenure change, land use change, climate change, disease, system shocks such as droughts floods and fire, or any other short or long-term change, is likely to have impacts on other system components. Because of land-use's impacts on landscapes and the processes that occur within them, it is necessary to include areas outside of protected areas as part of the conservation landscape. The complex context of the patterns and processes under scrutiny must be thoroughly considered, otherwise, implications and causes and effects may be misinterpreted.

Across East Africa at the interface of wildlife, pastoralism and cultivation, there is increasing competition for space and resources. When landscapes get "used up" by one land use, they may become less available, or no longer available, to the others. This is particularly evident in The Tarangire-Manyara Ecosystem (TME) of northern Tanzania, the area that forms the focus of this study. The trade-offs between environment and development outcomes are difficult to integrate into a consistent approach and set of priorities for management (Homewood 2004). It is important both to ask the right questions, and to integrate a wide variety of multidisciplinary data to encompass both environmental and development dimensions (ibid).

The question still remains as to what land uses are compatible with conservation, and agreement on this question between diverse stakeholders is difficult to find. Some degree of hunting (Homewood 2004), cultivation, grazing, tree harvest and other land uses may not necessarily be detrimental to conservation objectives, and in fact may have a positive conservation influence either through landscape mosaic maintenance and other disturbance effects, or by reducing direct conflict between conservation and livelihood agendas. In recent years it has become more widely recognized that the need of pastoralists for large grazing areas is complementary with the needs of many of the wild ungulates that share the pastures (Nelson 2000). The idea of livestock's compatibility with wildlife has, as a result, become more acceptable. However, cultivation in these systems is still believed to be inconsistent with wildlife conservation goals (McCabe 2003).

Important wildlife corridors and other important wildlife resources that are located outside of national parks in Tanzania are not protected by law (Gamassa 1995).

The combination of a lack of wildlife protections and a lack of human land tenure security creates a condition of juxtaposed vulnerabilities that is very difficult to address. This is particularly true because the value of cultivation for Maasai pastoralists and the cost of cultivation to wildlife have not been measured. Rather, land use regulations are largely founded on the belief that wildlife are negatively affected by cultivation, and that people can find alternate means of subsistence. While either or both of these assumptions may be true at times, they are not necessarily both true all of the time.

In the Serengeti-Mara Ecosystem that straddles the Kenyan-Tanzanian border, 60,000 hectares of rangelands were converted to mechanized agriculture in 20 years [1975-1995], and the total wildlife population declined by 58% during the same time period (Homewood et al. 2001). The study found that changes in land use were driven by markets and national land tenure policies, as well as by the location of cultivation in areas that provided resources critical to wildlife. Wildlife populations inside and around Tarangire National Park experienced serious documented declines from 1988-2001, with wildebeest declining by 88%, hartebeest declining by 90%, and oryx declining by a full 95% in just those thirteen years (TAWIRI 2001). Newmark (2008) surmises that this is related to the expansion of agriculture adjacent to Tarangire National Park, and many wildlife managers would concur. But the actual impact of cultivation on wildlife distribution has not been measured in the Tarangire Ecosystem.

A wealth of landscape metrics exists to study landscape composition but, in many situations, it is actually more meaningful to look at continuous gradients rather than discrete patches on the landscape (McGarigal et al. 2009). In the Simanjiro Plains east of TNP, cultivation forms unmistakably discrete landscape patches, but the perception of cultivation by wildlife may not be so black and white. Rather, the matrix around cultivation may actually contain gradients of suitability in relation to the patches of interest. Alternately, wildlife may demonstrate a threshold response to cultivation, where animal densities begin to fall at an unknown level of cultivation. Whatever the response, it will be species-specific, so every species or related species group should be investigated individually, and the metrics to be measured need to be relevant to both the organism and processes of interest (Neel et al. 2004). This study specifically utilizes the landscape metrics of Euclidian distance and cultivation intensity to test responses of wildlife to cultivation. Euclidian distance (ED) measures straight-line distance to the nearest cultivated plot. Cultivation intensity (CI) a distance-weighted metric of cultivation density.

Of particular interest to contemporary ecological study is how well species can move through landscapes (Malanson 2003). The effectiveness of links through landscapes need to be quantified and examined (ibid). The propagation of material, information, organisms, or disturbance across landscapes in response to ecosystem pattern and resource availability is the subject of "percolation theory" (Stauffer 1985; Malanson and Cramer 1999). Percolation theory addresses ways in which habitat changes impact animal movements across landscapes (Malanson 2003). It predicts that there are thresholds of connectivity between landscapes that support versus do not support movement. Such non-linear thresholds are the outcomes of the combination of the spatial pattern of the landscape and species population dynamics (ibid) and, as such, will be species-specific. Unfortunately, because of their non-linear characteristics, thresholds often cannot be identified until they are crossed (Malanson 2003; Groffman et al. 2006; Hunter et al. 2009). This makes it difficult for regulatory thresholds (such as land use regulations) to correspond to clear ecological thresholds; ecosystems are too highly variable (Hunter et al. 2009).

Landscape ecology is the broadly interdisciplinary study of spatial variation in landscape patterns and processes at a variety of scales (Turner 1989; IALE 1998; Turner et al. 2001; Tress et al. 2005). The goal of landscape ecology is to design and manage land use to promote the well-being of both people and nature, as well as the overall sustainability of the landscape (Wiens 2009). Wiens (2009) outlined four areas in which landscape ecology can contribute to conservation: 1) identification of conservation-oriented protected areas that exist in a landscape context that may influence movement into and out of the PA; 2) assessment of how the contents of the landscape outside of PAs may impact biodiversity within them, often as a result of human activities; 3) determination of why the scale of management may not coincide with the scale of patterns and processes of interest, presenting challenges to both landscape ecology and conservation, and; 4) identification of how the sustainability of conservation depends on the consideration of tradeoffs between human use and biodiversity values of the landscape.

Levin (1992) explains that the concept of scale, and the inter-related processes and patterns that occur at different spatial, temporal, and organizational scales is fundamental to the development of proper principles of management. He emphasizes that not only is environmental heterogeneity fundamental to the coexistence of species, but that the description of the distributions of species across space and time is by definition a description of pattern. As forage or water become limiting in local spaces of utilization, over the course of weeks animals will re-locate to new spaces with more abundant resources. How they choose to move both within and between pastures depends on both the availability of necessary resources and their spatial arrangement. But it also depends on working around hard and soft barriers to movement that fragment and consume portions of the landscape, making those areas unusable, inaccessible or less appealing sources of resources.

Natural restrictions on wild ungulate distributions may include factors such as forage abundance and quality, water availability, competitive or facilitative interactions with other wildlife or livestock, and risks of predation (Sinclair and Norton-Griffiths 1982; Sinclair et al. 1985; Fryxell 1995). But in addition to natural restrictions on distributions, since most large-bodied wildlife species range widely over diverse landscapes, human land use within those landscapes may affect their access to resources (Sundaresan et al. 2008; Groom and Harris 2010).

More recently, land tenure and land use changes have precipitated fragmentation in these extensive pastoral rangeland systems (Galvin 2009). Fragmentation of once contiguously intact rangelands spatially isolates portions of the landscape, leading to compartmentalization of important components of the environment (Boone and Krohn 2000; Coughenour 2004; Hobbs et al. 2008; Galvin 2009). The actual physical arrangements of landscapes and the manifestations of change (such as fences, cultivation, or political boundaries) that are occurring within them are highly variable from place to place. Many of the actions that result in fragmented landscapes are taken to enhance human welfare, and often measurable enhancements in people's livelihoods and well-being are realized (Hobbs et al. 2008). However, there are also many cases of landscape fragmentation that have resulted from the placement of political boundaries, land tenure arrangements, or the creation of protected areas to protect wildlife and natural resources that have not served to benefit local livelihoods. The reduction in landscape scale and heterogeneity that results from fragmentation presents a real challenge to both pastoral livestock and resident and migratory wildlife to access all ecosystem components necessary for individual survival and maintenance of populations. Spatial isolation in grazing ecosystems limits the ability of people and both wild and domestic animals to exploit heterogeneity in vegetation (Hobbs et al. 2008), as well as spatially- and temporally-variable water resources.

Learning more about how multi-scaled interactions with the environment influence the movement patterns of multiple migratory species will enhance our understanding of the effects that habitat fragmentation and habitat loss may have on population size and structure (Schick et al. 2008). Research has shown that patterns of diversity-heterogeneity relationships vary by scale, and the responses are taxon-specific (Gonzalez-Megias et al. 2007). The need to investigate the relationships between process and pattern at multiple scales is more of a rule than an exception (ibid). Doing so will help to elucidate the scale at which species respond to landscape patterns, and this may have important implications for conservation ecology and community management (ibid). This study focuses on population distributions (rather than estimating population sizes) as a response to the influence of environmental structure presented by cultivation on the landscape.

Out of necessity, areas outside of protected areas must be considered part of the conservation landscape. Protected areas cannot by themselves stem the tide of global biodiversity loss - context matters. Yet little consideration is given to land use history in surrounding areas, or to the likely trajectories of future use (Wiens 2009). Land managers who focus solely on protected areas without considering the surrounding landscape's functional linkages to a protected area may miss management targets, because animal movements make the functional landscape larger than the protected area itself (ibid). Conversely, threats can impinge on the protected area from the surrounding landscape as a result of human activity and land conversion, so measuring these impacts on conservation targets is important (ibid). Whatever the rationale behind the change in landscape arrangement and access in multi-sector socio-ecological systems, multiple users may be impacted differentially, and the implementation of mechanisms to improve resilience in one sector may actually increase vulnerability in another (Lynn *In Press*).

The goal of this study is to investigate species-specific responses of wildlife to cultivation to determine whether there are attractive or repellant forces that may impact wildlife species' use of the grazing landscape at two scales: at the scale of individual pastures that range in size from 5-10 km^2, and at the landscape scale encompassing all six study pastures across a 500 km^2 wildlife study area located at the nexus of the three study villages. I apply the landscape metrics of Euclidian distance (ED) to nearest cultivation, and cultivation intensity (CI), to test responses of wildlife to cultivation. ED measures straight-line distance to the nearest cultivated plot. Cultivation intensity (CI) is an inverse distance-weighted (IDW) measure of cultivation density for which proximal cultivation receives a higher weight assuming it has more influence, more distant cultivation a lower weight assuming it has lower influence (for other applications of IDW see (French et al. 2004; Roberts et al. 2004; Woodcock et al. 2008)). I examine the relationship between ED, CI and three wildlife species groups (zebra, wildebeest, and combined Grant's and Thompson's gazelle), with some discussion of livestock (combined cattle, goats and sheep) and people.

Models can incorporate multiple spatial and temporal scales (Schick et al. 2008), but for this study I focused on varying the spatial scale of analysis, while recognizing the fact that in Simanjiro temporal changes in resource availability play an important role in overall movement patterns. Both seasonal and year-to-year differences in large-scale movements are quite important. The design of this study is based upon existing knowledge/assumptions that: 1) migratory species move seasonally at a large scale, migrating out of TNP and into the village areas during the wet season, and out of the village lands back to TNP (to access the permanent water source of the Tarangire river) in the dry season; 2) within a particular season animals move within and among grazing pastures as forage quality and quantity change over time and they attempt to meet their daily nutritional requirements.

Most research on the effects of habitat loss and fragmentation on ecosystems has been based on observational studies (August et al. 2002). Results from this type of research should be categorized by organism so that it is most useful (August et al. 2002) (also see Reid et al. 2004; Worden 2007; Galvin et al. 2008; Ogutu et al. 2009). If native species will tolerate levels of fragmentation that were previously thought to be detrimental to these species, then land planners and managers will have more flexibility with developing plans and policies that do not have a negative impact on landscape integrity and sustainability (August et al. 2002).

The study specifically addresses two questions. First, do different wildlife species groups respond (neutral, attracted, repulsed, or intermediate) to cultivation at the scale of the individual grazing pasture (Figure 4.1a)? Second, do different wildlife species groups respond (neutral, attracted, repulsed, or intermediate) to cultivation at the larger landscape scale (Figure 4.1b)? A positive response to either CI or ED would indicate that cultivation was attractive, evidenced by observed densities being higher than would be expected (with no cultivation effect) in areas of the pastures with lower ED and/or higher CI. A negative response would suggest that cultivation was repellent, evidenced by observed densities being higher than would be expected (with no cultivation effect) in areas of the pastures with higher ED and/or lower CI. An intermediate response would indicate that areas of higher ED or CI were attractive, but that some characteristic of cultivation was simultaneously repellant. This response is demonstrated by a hump-shaped population distribution with the highest densities in areas of intermediate ED or CI value. A neutral response would essentially indicate no response at all, with populations evenly distributed across both ED and CI gradients, similar to what would be expected with no cultivation effect. Finally, I examine implications of species-specific response patterns by asking: what are the potential consequences of detected pasture-level and landscape-level wildlife responses to cultivation for both cultivators and wildlife, and what are the implications for conservation and land use policies in Simanjiro?

While research has been conducted to investigate the impacts of water and settlement locations on wildlife distributions (Ogutu et al. 2009; Ogutu et al. 2010) and populations (Lamprey and Reid 2004) in East Africa, no study has explicitly looked at the impact of cultivation on wildlife distributions. Ogutu et al (2010) found that wildlife generally concentrated at intermediate distances from both water sources and settlements. They conclude that this is due to overlapping gradients of forage quantity (increasing with distance from water and settlements due to livestock offtake closer to settlements and water) and quality (decreasing with distance from water and settlements), combined with a disturbance effect close to settlements due to the activities of people and dogs. The forage quality improves closer to settlement, pulling the wildlife in, but settlement activities and daytime livestock watering provide a push that keeps wildlife away.

Mworia et al (2008) found that cattle density was the most important factor after vegetation and water in determining combined wildlife species distribution in south-central Kenya. While Mworia et al. also included a measurement of "cultivation intensity" as a driver of wildlife densities, their measurement of this indicator consisted of farms/km^2, regardless of farm size and over all of the landscape area covered. This metric is insufficient for determining a relationship between cultivation and wildlife densities and distributions. Furthermore, since all wild species in the Mworia et al. study were combined into a single analysis, the subtle to sometimes extreme differences in species-specific responses would have been obscure. Both of these study design-related factors could have affected their conclusion that small-scale cultivation in pastoral areas was not as important as cattle density and boma density in influencing wildlife distributions.

Cultivation may attract some wildlife species as forage or other benefit, but repel other wildlife species as a landscape disturbance. I expect that animals that actually eat maize and beans are the ones that will be found closer to cultivated fields, while those who do not will either not react at all, or those who are sensitive will be repelled by cultivation and activities associated with the fields. But there is no forage quality or quantity gradient that would result directly from the cultivated fields as from a settlement or water point, so any response is likely to be a response to the cultivation fields and associated activities.

METHODS

The analyses that I undertook for this study form part of a larger investigation into pastoral livelihood and multi-scaled wildlife responses to cultivation. In order to accomplish this, I integrated multiple methodological techniques that were coordinated over space and time. I collected livelihood data through household interviews, discussed in Chapter 2. I developed complementary methodologies to best coordinate nested studies of wildlife responses to cultivation at three different scales. Wildlife responses to cultivation boundaries are discussed in Chapter 3. This chapter investigates wildlife responses to cultivation at the scales of both the individual pasture and across the larger landscape.

Study Area

The 20,000 km^2 Tarangire-Manyara Ecosystem (TME) includes two national parks: Tarangire National Park (TNP) and nearby Lake Manyara National Park (320 km^2). Together these parks make up only 15% of the TME. The balance of the ecosystem falls outside the National Parks and in the village lands of the Maasai Steppe's Simanjiro Plains (TMCP 2002). The boundaries of the ecosystem are based upon the annual movements of migratory wildlife, particularly wildebeest. Land use outside park boundaries is relevant to conservation inside because during the rainy season animals leave the parks to disperse over much of the pastoral zone to take advantage of widespread water resources and high quality forage (Borner 1985).

The TME was selected as the focus of this study precisely because of concerns raised by TME wildlife managers and resident Maasai themselves. Wildlife managers expressed frustration with land use change outside of national park boundaries, areas largely outside of their administrative control but relevant to their wildlife conservation agenda. Simultaneously people living in villages outside of the national parks were feeling "squeezed" by national park restrictions to the west and their associated wildlife, and large-scale farms encroaching into the historically pastoral zone from the north and east.

Loss of migratory corridors and wet-season grazing areas outside of TNP would be detrimental to migratory ungulate populations, since the concentration of wild ungulates in TNP during both wet and dry seasons would result in forage of insufficient quantity and quality to satisfy the population's nutritional requirements (Voeten 1999; Voeten and Prins 1999). TNP authorities are concerned that wildlife may lose access to these critical grazing grounds through a number of land use changes, particularly increased cultivation. In fact, a key objective of the TNP Management Zone Plan is to "maintain natural ecological processes that perpetuate the greatest degree of biological diversity and ecosystem integrity within the park and where possible within the larger Tarangire Ecosystem" (TANAPA 1994). This language that explicitly states a national interest in the expansive areas outside park bounds worries village residents that their land could be requisitioned by the government in order to expand the parks.

Study Design

The wildlife study area is an approximately 500 km^2 area located at the center of the Simanjiro Plain's 20,000 km^2, and at the nexus of the three study area villages – Sukuro, Loiborsoit 'A' and Emboreet. This area covers six distinct grazing pasture Sampling Areas (SAs) and the matrix area between them (Figure 4.2). Each of the pastures selected has a Maasai name given to the pasture by local residents. SA1 was located in *Loipolos* (Loiborsoit Village), SA2 in *Osilale* (Loiborsoit and Emboreet Villages), SA3 in *Alarramatihoreki* (Loiborsoit Village), SA4 in *Loltepesi* (Sukuro Village), SA5 in *Ndumo* (Sukuro Village), and SA6 in *Ilturuut Ooibor* (Sukuro Village). For the sake of simplicity I refer only to the code names throughout this dissertation.

This strategically-defined location incorporates a range of cultivation intensities. It also allows integration of results from the wildlife studies with those of the livelihood study that was conducted in the same villages (see Chapter 2). The spatial scale of both human and wildlife studies considers the scale of land use decisions by people (with respect to their livestock herding and cultivation decisions) and wildlife across time and space in this area. Since the socially and ecologically-defined boundaries of Maasai pastoralists often transcend the official village boundaries within which bureaucratic land use decisions are made (Goldman 2003). Consequently collecting data across three villages was important for recognizing the fact that as cultivation alters landscape patterns at the local level there may be implications for ecosystem processes at the landscape and ecosystem levels due to the spatial fluidity of movement responses.

Potential SA locations were identified along a CI gradient using a combination of: 1) existing data on seasonal wildlife movements and cultivation, 2) a February 2000 Landsat Thematic Mapper (TM) image of the study area (USGS 2000), 3) guidance from local villagers, and 4) observations in the field. Six final SAs were selected to cover a range of cultivation densities in and immediately around the SAs: two with visibly high levels of cultivation but open area sufficient for conducting wildlife counts (SA1 and SA2), two with existing but visibly lower levels of cultivation (SA3 and SA4), and two with no cultivation visible nearby (SA5 and SA6) (Figure 4.2). These final sites were selected based upon the refined criteria of: 1) vegetation physiognomy (primarily grassland/low vegetation with high visibility for counts), 2) a patch size of $5km^2$ to $10km^2$, 3) no cultivation visible in and around sites designated as *no cultivation,* 4) permission from two individuals per SA *with cultivation* to enter cultivated plots for walking transects (described in Chapter 3), 5) mixed edge types including vegetation shifts, roads, soils, village boundary, or random line, and 6) accessibility. Several potential SAs that would have been suitable according to selection criteria 1-5 were completely inaccessible for data collection in the rainy season and had to be discarded from the study.

Data Collection

Sampling Area Animal Counts

Wildlife data were collected during the wet season of 2004, during the months March - June when large numbers of wildlife had dispersed from Tarangire National Park eastward into the villages. Driving pathways were established for each SA based upon a 1 kilometer wide driving belt transect for counting 500m on each side of the vehicle, and occasional driving obstacles. SAs were driven four times each during a single rainy season, March through May 2004. Each was driven once every two to three weeks from approximately 9:00am to 12:00pm.[6] Limited resources were available that consisted of a single vehicle and a field team of four individuals, so data could be collected only in the daytime. While the focus of the study is wildlife, data were collected on livestock and people as well to investigate potential interactions with cultivation as drivers of wildlife distributions, facilitating response interpretation. When animal groups were sighted, a global positioning system (GPS) determined vehicle location, a compass determined direction to observed groups, and rangefinder binoculars accurate for distances within 1000 meters of the vehicle. These data were used to triangulate a pinpoint location for the center of each group encountered.

Two counters worked on each side of the vehicle. The front seat counters were primarily responsible for navigating, driving, and recording in addition to counting. When a large group of more than 50 animals was encountered, all four counters counted the group and the mean value was recorded. Large groups were counted and located at

[6] The dates of animal counts were as follows: SA1: 3/26/04, 4/22/04, 5/4/04, and 5/22/04; SA2: 4/3/04, 4/28/04, 5/9/04, and 5/31/04; SA3: 3/29/04, 4/24/04, 5/6/04, and 5/28/04; SA4: 3/23/04, 4/20/04, 5/3/04, and 5/18/04; SA5: 4/2/04, 4/26/04, 5/8/04, and 5/30/04; SA6: 3/22/04, 4/19/04, 5/02/04, and 5/20/04.

the earliest opportunity, and re-located continuously during approach to insure the most accurate count and most precise location before evasive movement of the group could occur in response to vehicle approach. This was a particularly important strategy once poaching commenced and wild species demonstrated an increased fear of vehicles. In Simanjiro, poaching begins soon after wildlife migrate into the villages. Later in the season (June 1 – Dec 1) legal hunting concessions in the area experience an influx of foreign hunters. Nyahongo (2008) found that mean flight initiation distances for five herbivore species were significantly different between central Serengeti and the western corridor of Serengeti, which was surmised to be a factor of both greater vehicle habituation inside the Park, and lack of both poaching and legal hunting there.

Visibility and weather were recorded on each day. Rainy weather was occasionally encountered and affected sightability, but this impact could not be measured. Visibility due to weather is not correlated with any measure of cultivation, and was therefore assumed to not have a significant bearing on overall results.

Transect Print Counts

Two print count transects were established in each of the four SAs that contained or were bounded by cultivation. Transects were only conducted in areas with cultivation (SA1 to SA4). Permission was gained from two individual cultivators per SAs 1-4, to enter their plots and walk transects five times, approximately once every two to three weeks. A 1-meter wide belt transect (0.5 m on either side of the measuring tape) originating 50 meters within the cultivated plot and extending outward into the grazing pasture for 1-2 km was located with a GPS, and the direction of the transect was determined using a GPS compass and visual guides on the horizon. Transects were labeled 1A, 1B, 2A, 2B, 3A, 3B, 4A and 4B to coincide with the SAs in which they were located (Figure 4.3).

The transect data collection team consisted of a core team of 4 individuals, plus two individuals from each village to assist with data collection in their home village. This kept two-thirds of each walking team of three constant, while allowing me to spread the benefit of employment across all three villages. The two transects for each SA were walked simultaneously by teams of three people between approximately 9:00am and early afternoon on the day following the driving count for that SA. Three walkers walked shoulder-to-shoulder, with the outer walkers locating, identifying and counting tracks, and the middle person navigating, recording observations, and helping with print identification as needed. A field guide (Stuart and Stuart 2000) was used to differentiate between similar prints as necessary during data collection. Occasional unidentifiable prints were recorded but with species listed as “unknown”.

Print observations were combined into groups (by species) when less than 1 meter apart, and recorded separately when more than 1 meter apart. When print groups were not countable, the group was coded as a “large group”. Observations were taken for 50 m inside the cultivated plot, then on alternating 50-m intervals outside the cultivated plot beginning at the edge (Figure 4.4). A GPS location was taken for each observation, to identify its location along the transect, but for this study the important characteristic of record is whether the observation occurred inside or outside cultivation.

Data Processing

Cultivation

CULTIVATION LAYER

An adequate map of cultivation for the study area that coincided with the timing of data collection did not exist prior to this study. I produced one by manually digitizing all cultivation visible in an August 2004 Thematic Mapper (TM) image of the region (USGS 2004) using ArcMap 9.3 (ESRI 2008)[7] (Figure 4.5). Hand digitization is actually preferred to automated classification at this scale of analysis, because the spectral signatures of crops and native vegetation can be confused, but edges are easy to demarcate visually (M. Binford, personal communication). The August 2004 image was taken just two months after the conclusion of data collection, so the visible cultivation is concordant with that observed on the ground during data collection. Multiple bandwidths of the image were used to distinguish cultivation boundaries from the surrounding matrix and hand-digitize visible plots, similar to Boone et al. (Boone et al. 2006).

TM Bands 1-7 have a resolution of 30 m; panchromatic Band 8 has a resolution of 15 m. Very small plots of cultivation (less than approximately 30 m per side or slightly larger) would not have been visibly distinguishable from the background signature, but many people cultivated collectively near settlements or in cultivation clusters, and most large, collective plots were highly visible due to their straight edges. Ground data on the location of cultivated plots were limited to plots used to study wildlife responses to

[7] On May 31, 2003, an equipment failure occurred on Landsat 7 that affects Thematic Mapper (TM) image quality. The effects are most pronounced toward the edges of each TM scene, with very little data loss in the central vertical strip of the scene. Fortunately, the core wildlife study area investigated here fell entirely within the center of the TM scene, so the images remained useful for the study. More information on the equipment failure can be obtained online at the United States Geological Survey (USGS) website.

cultivation edge in another related study. The area digitized included all sampling areas, and the matrix area between and around the SAs to a 5 km buffer. This buffer distance was determined by finding the maximum straight-line Euclidian distance to cultivation from any cell within the bounds of the sampling areas (5087 m, located in SA6), the greatest distance for which impact on wildlife distributions could be measured within any SA. For this model, cultivation at distances greater than 5 km is assumed to have no impact on distributions.

EUCLIDIAN DISTANCE

I created a surface map of Euclidian distance (ED) to cultivation in ArcMap (ESRI 2008) using the Spatial Analyst Euclidian Distance tool (Figure 4.6). ED measures the straight-line distance to the nearest patch of cultivation at a 5 m^2 resolution for every cell in the study area landscape[8]. To determine the mean ED for each SA, this surface was clipped to the bounds of the six SAs, and the mean ED value calculated for each. This value contributed to a ranking of SAs by a cultivation intensity factor (CIF), to be discussed. The continuous surface ED map was then classified into an 11-class ED map, with equal intervals of 500 m for each class (Figure 4.7) [Appendix 4.3].

CULTIVATION INTENSITY

I created a surface map of cultivation intensity (CI) in ArcMap 9.3 (ESRI 2008) using the *Focalmean* process in Spatial Analyst. *Focalmean* finds the mean of the values for every cell of an input raster map (in this case the input surface of the study area, with cultivation = 1, no cultivation = 0) within a specified neighborhood of a cell of interest,

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[8] Note that Euclidian distance calculations are valid only for the areas inside the sampling areas, and not for the matrix areas. The cultivation data that were digitized to a 5 km buffer of the SAs was used to: 1) create a map of cultivation in the areas inside and within 5 km of each SA, and 2) to calculate Euclidian distance for the areas inside the SAs.

This essentially calculates the proportion of the annulus' area that is under cultivation, with the extremes of 0 = 0%, and 1 = 100%. The corresponding *Focalmean* value is then assigned to that cell in an output raster map. In this case, the goal was to measure mean cultivation value for each of 11 concentric rings, or annuli (each 500m–wide), around each landscape cell, with the value of each annulus's contribution to the final CI calculation weighted by annulus proximity to the cell so that closer annuli received a greater weight (inverse distance weighted (IDW)) (Table 4.1). CI was calculated independently for every 25 m^2 grid cell on the landscape.

Focalmean scales the output value to the number of cells in the annulus, so that the final value does not get erroneously weighted by the number of cells in the annulus; the area of each annulus increases with distance class. While it is possible to run the analysis at as fine a scale as 5 m, 25 m was chosen as the scale of analysis both to save processing time, and because the 500 m annulus width is evenly divisible by 25m. I calculated a *Focalmean* surface for each annulus neighborhood range (Figure 4.8), then inversely weighted and summed the eleven resulting surfaces to create a single CI surface reflecting these additive values. The equation for this process is:

$$
\begin{aligned}
CI = [&\mu(Cult500 * 10) + \mu(Cult1000 * 9) + \mu(Cult1500 * 8) \\
&+ \mu(Cult2000 * 7) + \mu(Cult2500 * 6) + \mu(Cult3000 * 5) \\
&+ \mu(Cult3500 * 4) + \mu(Cult4000 * 3) + \mu(Cult4500 * 2) \\
&+ \mu(Cult5000 * 1) + \mu(Cult5500 * 0)]
\end{aligned}
$$

where $Cult_X$ is cultivation area in the band between distance X-500 m and X from a grid-cell. This equation, an application of IDW, gives cultivation within the 0-500 m annulus a weight of 10, assuming that cultivation in this proximal zone has the highest impact. The weight of cultivation decreased with each distance class until cultivation at a distance of 4500-5000 m was assigned a weight of '1'. Cultivation at >5000 m distance is assumed to have no impact, and is therefore weighted a '0'.[9] The continuous surface CI map reflects an index of the CI for every cell in the study area landscape (Figure 4.9). This map was clipped to SA boundaries. The continuous surface CI map was then classified into an equal-interval 11-class CI map that would be used for SA-scaled wildlife distribution analysis (Figure 4.10) [Appendix 4.3].

Cultivation Intensity Factor Sampling Area (SA) Ranks

In order to rank the SAs by overall impact of cultivation, I combined ED and CI into a single measure to create a relative Cultivation Intensity Factor (CIF)[10]. I scaled both the ED and CI values to a 0-1 scale, and reversed the ED scale by subtracting the real values from one since ED and CI run counter to each other; ED impact (on wildlife) is hypothesized to increase with decreasing values (closer proximity to cultivation), whereas CI impact is hypothesized to decrease with decreasing values. This adjustment corrects for that idiosyncrasy of the two measures. I then calculated the mean CIF value for each SA by adding the scaled ED and CI values and dividing by two to give equal weights to CI and ED. I ranked and labeled SAs according to the final value so that SA1 is the patch with the highest CIF, SA6 the patch with the lowest CIF. While SAs are not located at equal value intervals across the CIF continuum, CIF does represent an

[9] One known restriction of calculating CI in this manner is that it is not known where concentration of cultivation is because values are combined. All that is known is the additive value in the region under analysis.

[10] The resulting CI scale is relative to the SAs alone, and does not stretch to include the full potential range of values from 0% to 100% cultivated in a 5 km radius. The decision to limit the CI scale to observed values was a strategic one made because the observed range is small in comparison to the potential range, and this study is interested in relative rankings. Using the full potential scale would have deflated the contribution of CI to the final CIF scale.

objective single-measure relative ranking of the impact of cultivation on SAs through a combination of proximity (ED) and density (CI) measures[11] (Table 4.2).

Animal Data

OBSERVED ANIMAL DATA PROCESSING

All animal observations were recorded during data collection, but not all species provided data of sufficient quantity to use for analysis. Species groups that I included in analyses include zebra, wildebeest, gazelle, livestock, and people. Thompson's gazelle and Grant's gazelle were combined into a single "gazelle" category for analysis. These gazelle species had similar distributions, and combining them increased sample size for the gazelle analysis. Wildlife species that were encountered infrequently and left out of this analysis due to inadequate sample size include giraffe, eland, dik dik, ostrich, impala, warthog, oryx, porcupine, steenbok, hare, aardvark, lion and hyena. Livestock species (cattle, calves, goats and sheep) also had comparable distributions, and I combined them into a single category of "livestock". Data were collected for donkeys and dogs, but these animals were not frequently encountered and always associated with people so I left them out of the analysis.

Because I was interested in density differences across space and not changes over time, I collapsed the wildlife data from each SA's four sampling dates (the effort for each SA = 4) into a single file that contained information on date, species, group size, and group density. In addition, I transformed wildlife location data that was collected in the

[11] One possible limitation to the approach taken is that the relative impact of proximity and density is not distinguished, so that an SA with high ED and low CI will be given a similar ranking to an SA with low ED and high CI. Also, the arrangement of cultivation is unknown.

form of vehicle location, direction to group, and distance to group into a set of geographic coordinates for the location of the group's approximate centerpoint (see Rannestad, Danielsen et al. 2006). To do this I used the equations:

$$x = \text{vehicle } x + \mathit{Length}\ \text{COS}\ (\mathit{Angle})$$

$$y = \text{vehicle } y + \text{Sqrt}\ (\mathit{Length}\text{\^{}}2 - x\text{\^{}}2)$$

where *Length* is the distance to the group from the vehicle, and *Angle* is the direction to the group from the vehicle location identified as the number of compass degrees from north. I then projected the resulting set of point coordinates into ArcMap 9.3 (ESRI 2008) (Figure 4.11) to overlay on the ED and CI surfaces.

Creation of Null Models

A null model is a pattern-generating model based on the randomization of ecological data, designed with respect to some ecological process of interest (or alternatively base on a random sample taken from a known or specified distribution) (Gotelli and Graves 1996; Gotelli 2001; Gotelli and McGill 2006). While some elements of the data are held constant, others are allowed to vary randomly to create new grouping patterns. This design is intended to produce a pattern that would be expected in the absence of the ecological condition of interest (Gotelli and Graves 1996).

An assumption of null models is that species occurrences are random and independent (Gotelli and McGill 2006). While I recognize that some species may be positively or negatively correlated with each other, of primary interest to this study is the relationship of animal distributions to cultivation regardless of inter- and intra-specific spatial arrangements. I also recognize that all three primary wildlife species groups of interest occur in clustered populations[12], however it is not the intra-specific spatial pattern of the populations that I was interested in, but again the spatial arrangement of these populations with respect to cultivation.

I randomized wildlife group occurrences spatially across the Simanjiro landscape to test the effect of cultivation on distributions by comparing the observed distributions with the randomized null model distributions. I created two null models using this database. The first one I designed to test distributions *within* individual pastures (sampling areas), the second to test distributions *across* the six sampling areas. Two Arc Macro Language (AML) scripts (Appendix 4.1a and 4.1b) were written to generate a paired random point location for each of the 937 observed points in ArcInfo 9.3 (ESRI 2008). Each script was run 30 times, resulting in 30 sets of 937 random locations across the six sampling areas for each null model. These 30 sets of locations would allow me to calculate a 95% confidence interval of expected densities for each species given no influence of cultivation on distribution.

Pasture Scale Null Model

The first null model was created to test animal distributions across individual pastures in relation to ED and CI. A random number generator was used to generate random X and Y coordinates anywhere in the 500km2 study area. Points falling outside the bounds of the SA of origin were discarded and re-generated until a point fell within

[12] The study of autocorrelations between observations resulting from clustering patterns of particular species is quite computation intensive, and would present a significant digression if pursued as part of this study. For one method of analyzing resource selection data with latent autocorrelation, see: Okamura, H., M. Kiyota and T. Kitakado (2008). "A resource selection model for analyzing pseudoreplicated data due to grouping behaviour of animals." Journal of Agricultural, Biological, and Environmental Statistics **13**(3): 294-312.

the SA. This process was followed for each of the 937 observed wildlife points to create a complete set of random wildlife points, then the entire procedure was repeated 30 times to create the pasture scale null model. Each of the paired random points carried the same attributes as the original observation (original location coordinates, original SA, group size, species, and animal density), as well as the new attribute of random geographic location within the SA of origin.

Landcape Scale Null Model

The second null model was created to test animal distributions across the landscape-scale cultivation intensity factor (CIF) gradient represented by the six SAs. A random number generator was used to generate random X and Y coordinates anywhere in the 500km2 study area. Points falling outside the bounds of any of the SAs (in the matrix) were discarded and re-generated until a point fell within any of the SAs in the study area. This process was followed for each of the 937 observed wildlife points to create a complete set of random wildlife points, then the entire procedure was repeated 30 times to create the landscape scale null model. Each of the paired random points carried the same attributes as the original observation, as well as the new attributes of random geographic location coordinates and new SA location. While each original and random point is associated with geographic landscape coordinates that were important methodologically, the exact location is irrelevant to this study. I was primarily interested in the SA location as I compared density distributions of each species across the six SAs along the CIF gradient.

TRANSECT DATA

I integrated absence data for each species into the data on presence (Tsoar et al. 2007) using a script written to fill in zeroes for all transect legs with no occurrence of the species [Appendix 4.2]. To minimize the error that would be introduced through re-counts of the same print(s), I processed only the second (April 2004) and fourth (May 2004) sets of data for analysis.[13] These two dates were chosen because: 1) The first date's data were the least reliable because it was the first time to implement the method across all transects outside of the training period, and 2) because lions in the cultivated plots created a safety issue during the last month of data collection. Data for all transects exceeding 1 km in length were then truncated to 1 km outside of the cultivated plots, or one leg inside and ten legs outside.

Since the goal of the study was to assess relative density of species using prints as a proxy for animals, obtaining true densities was not the objective. I used simple comparisons of observed mean print densities/50 m^2 across the cultivation gradient to test print densities across this gradient, and to see if crop ingress was different in SAs of high versus low CI. I analyzed print data by group, rather than by individual since groups larger than 7-10 individuals were uncountable.

Data Analysis

Pasture Scale Calculation of Observed and Null Model Densities by ED and CI Zones

I used ArcMap (ESRI 2008) to overlay observed and random datasets with ED and CI zones, and attached the ED and CI zone values of the point locations to each

[13] Dates of transect print counts used in analysis include: 1A/1B: 4/23/2004 and 5/23/2004; 2A/2B: 4/29/2010 and 5/31/2010; 3A/3B: 4/25/2010 and 5/24/2010; 4A/4B: 4/21/2010 and 5/19/2010.

observed and random point. I also calculated the area of each SA in square kilometers (km^2). This information was imported into a Microsoft Access 2007 database to calculate the group and individual densities as number per km^2, per zone, per SA.[14] Densities were calculated for each species' observed distribution, and for each of the 30 random spatial redistributions of the null model, across the ED and CI gradients of each SA. Zone densities were also calculated independently for each SA rather than pooled, because the zone composition varied by patch. Not all patches contain all ED and CI zones, and responses are clearer and more interpretable when analyzed separately. All observed and random densities were corrected for sampling effort by dividing the total by four (number of sampling dates). The result represents an *observed density* per SA per species as opposed to a *true* or *corrected density* because observed numbers were not corrected for detection functions (Buckland et al. 2001).

"Random" densities represent the distribution of each species (across the ED and CI zones present for each SA) that would be expected if there were no effect of cultivation on animal distributions, essentially an even distribution of animal groups and individuals across zones. Zones were numbered in order of decreasing cultivation pressure, so that EDs are displayed lowest to highest, and CIs are displayed highest to lowest. I then compared observed density pattern across the gradients of ED and CI to the 95% confidence interval of the 30 random spatial redistributions that comprise the pasture scale null model.

[14] Access has a batching function (Query) that can calculate densities of both groups and individuals for animals recorded by group with a number of individuals per group. Access automates these calculations. Data were batched by: 1) Random Run (30 random runs, plus observed coded as '0'), 2) Species, 3) Sampling Area, and 4) Count. The order of this batching system ensured that groups were properly defined for analysis.

Landscape Scale Calculation of Observed and Null Model Densities by CIF

Following the generation of the 30 random spatial redistributions that form the landscape scale null model, densities were calculated for each species' observed distribution, as well as for each of the 30 random spatial redistributions by SA. Densities were corrected for sampling effort by dividing the total by four (number of sampling dates), resulting in an an *observed density* per SA per species.

I used ArcMap (ESRI 2008) to calculate the number of observed and random animal groups for each species per SA, and to calculate the area of each SA in square kilometers (km^2). This information was imported into a Microsoft Access 2007 database to calculate the density of both groups and individuals as number per km^2, per SA. These calculations resulted in a single observed density for each species per SA, and thirty "random" SA densities for comparison. These "random" densities represent the distribution across SAs that would be expected if there were no effect of cultivation (CIF) on animal distributions. SAs were numbered in order of decreasing CIF rank (SA1 = highest CIF, SA6 = lowest CIF), so that SA placements along the x-axis would be a suitable proxy for decreasing CIF. I then compared each species' observed density pattern across the CIF gradient to the 95% confidence interval of the 30 random spatial redistributions that comprise the landscape null model.

Calculation of Transect Print Densities

The goal of the transect study was to assess relative density of species' prints across the CIF gradient (represented by SAs) using prints as a proxy for animals. Three individuals walked a narrow (1m) transect, so 100% accuracy in sighting of visible prints is assumed. We recognized that subsequent tracks usually erase the tracks of those that passed before, and this was an uncontrollable situation. Also, there is always some associated uncertainty regarding absence data since evidence for total absence is very difficult to obtain (Lobo et al. 2010). However, absences for this study indicate lack of presence at the time of the respective survey relative to other times and locations, not an absolute lack of potential presence in the study area or even the sub-location. I recognize that there is error in sampling through print counts in counting all of the presence data and introduction of false absences. However we did our best to minimize this error. Error should be relatively consistent across transects, so while an attempt to estimate true species densities would be fraught with error, comparative assessments of relative print densities should not be unduly affected.

Similar to observed animal data, I integrated absence data for each species nto the data on presence (Tsoar et al. 2007) using a script written to fill in zeroes for all transect legs with no occurrences. To minimize the error that would be introduced through inadvertent re-counts of the same print(s), only the second (April 2004) and fourth (May 2004) sets of data were processed for analysis. These two dates were chosen because: 1) The first date's data were the least reliable because it was the first time to implement the method across all transects outside of the training period, and 2) lions in the cultivated plots created a safety issue during the last date of data collection. Data for all transects exceeding 1 km in length were then truncated to 1 km.

I checked GPS coordinates of all observations for errors and then projected into ArcMap 9.3 (ESRI 2008) to check for points falling off of the transect lines. A few identifiable errors were corrected. I then imported the dataset into a Microsoft Access 2007 database to calculate the density of print groups by transect cultivation-distance intervals.[15] These compilations resulted in a single observed density per 50 m^2 for each species inside cultivation and outside of cultivation.

I analyzed species and species groups with sample sizes adequate to demonstrate patterns, including zebra, wildebeest, Grant's gazelle (prints of Thompson's gazelle were rare), livestock (combined cattle, goats and sheep), and people. Prints of wildlife species that were encountered infrequently were left out of this analysis due to inadequate sample size, including giraffe, eland, ostrich, hare, aardvark, jackal, mongoose, fox, buffalo, impala, Thompson's gazelle and various bird species (which were also difficult to identify). I was not interested in livestock and human densities in response to cultivation per se, rather I was interested in whether their densities were positively or negatively correlated with any of the wildlife species, since this could indicate factors of influence on distributions.

I analyzed data by groups to account for the fact that prints left by groups of greater than 7-10 animals were uncountable. As a result, groups ranging from 10 animals into the hundreds are indistinguishable in the dataset. This will lead to an underestimate of species that occur in large groups relative to species that occur in small groups, but because this problem exists across all SAs, it does not present a major problem in investigating relative print densities. Transect data were plotted using Systat 13

[15] Access has a batching function (Query) that can calculate densities of both groups and individuals for animals recorded by group with a number of individuals per group. Access automates these calculations. Data were batched by: 1) leg, 2) date, and 3) species. The order of this batching system ensured that groups were properly defined for analysis.

(Systat13 2009) to demonstrate the pattern of distribution across the four-SA CIF gradient**.**

RESULTS

Pasture Scale Analysis

Wildlife Species

I analyzed species density (#/km^2) by both number of individuals and number of groups. High variability in group sizes of zebra, wildebeest and livestock led to wider confidence intervals for individual analyses than for analysis by group, but in all cases the patterns are remarkably similar between group and individual analyses. Therefore group densities are displayed for interpretation. CI and ED values of SA2 and SA3 (henceforth SA2+SA3) were very similar, so their respective data were combined for analysis. SA1's low wildlife density led to sample sizes too low to discern any cultivation effect (this low wildlife density in SA1 represents a landscape-scale response to be discussed later in this chapter).

EUCLIDIAN DISTANCE (ED)

Wildlife

Zebra daytime distributions across SA2+SA3, SA4, and SA6 demonstrated a strong and consistent positive response to increasing ED, indicating a negative response to cultivation, even at distances of up to 5 km from cultivation as shown by distributions in SA6 (Figures 4.12, 4.13). Zebra group densities in the low-range ED zones were much lower than the lower bound of the 95% Confidence Interval of the null model. Observed densities of zebra across SA5, on the other hand, are difficult to interpret. This SA demonstrated density anomalies in the landscape-scale analysis as well. I cannot explain the pattern observed with this dataset, but hypothesize that vegetation differences may be a factor in these anomalies at both spatial scales.

Wildebeest were also not randomly distributed across the landscape during the daytime hours (Figures 4.14, 4.15). While distributions across SA2+SA3, SA4, and SA6 demonstrated positive responses to increasing ED, the relationship was not as clear as that of zebra when comparing observed groups with the 95% Confidence Interval of the null model. Again, SA5 presented difficulties for interpretation.

Gazelle distribution patterns varied by SA (Figures 4.16, 4.17). SA2+SA3 distributions were within the 95% Confidence Interval of the null model. Gazelles in SA4 appeared to demonstrate a positive response to increasing ED, but this may have been partially due to the density of livestock and people in SA4's proximal ED zones, with patterns inverse to those of livestock and people. Gazelle densities in SA5 and SA6 appeared to be negative in response to increasing ED. When the results of these SAs are looked at together, they indicate a possibly intermediate response to cultivation.

Livestock and People

Livestock and people followed similar daytime distributions to each other, but there was no discernable or interpretable pattern across ED zones (Livestock: Figures 4.18, 4.19, People: Figures 4.20, 4.21). In SA4, however, at this time of day both livestock and people were concentrated in the area around the cultivated plots, which were located in a ring around the settlements.

CULTIVATION INTENSITY

Wildlife

All of SA5 and SSA6 occur in CI zone 11, so CI wildlife distribution evaluations could only be made for SA2+SA3 and SA4.

Observed daytime zebra distributions demonstrated a strong negative response across SA2+SA3, and SA4to increasing cultivation CI (Figures 4.22, 4.23). High CI zone densities fell below the lower bound of the 95% Confidence Interval of the null model, middle-CI zone densities varied around the 95% Confidence Interval, and the lowest-CI zone density was much higher than the upper bound of the 95% Confidence Interval of the null model.

Observed wildebeest distributions demonstrated a clear negative response to cultivation CI in comparison to the null model's 95% Confidence Interval in both SA2+SA3, and SA4 (Figures 4.24, 4.25). Lowest densities occurred in the highest-CI zones, and highest densities in the lowest-CI zones.

Observed gazelle distributions demonstrated a negative response to cultivation CI in comparison to the null model's 95% Confidence Interval in both SA2+SA3, and SA4 (Figures 4.26, 4.27). Lowest densities occurring in the highest-CI zones, and highest densities in the lowest-CI zones.

Livestock and People

Observed livestock distributions did not demonstrate a strong response to cultivation CI in SA2+SA3 compared to the null model's 95% Confidence Interval in both SA2+SA3, and SA4 (Figures 4.28, 4.29). There was a clear positive response in SA4, however, with the highest density concentrated in the area of the highest CI.

Human densities matched livestock densities in SA4, but there was no clear pattern in distributions relative to the null model's 95% Confidence Interval (Figures 4.30, 4.31).

Landscape Scale Analysis

Wildlife Species

ANIMAL OBSERVATIONS

When densities were analyzed by number of individuals, the high variability in group sizes led to wider confidence intervals than for analysis by group, but in all cases the patterns are remarkably similar from group to individual analysis.

Zebra groups tended to avoid areas close to cultivation during the daytime hours (Figures 4.32, 4.33). Zebra group density in SA1, the sampling area with the highest CIF was much lower than the lower bound of the 95% CI of the null model. Observed densities of zebra in SA2, SA3 and SA4 fell within 95% upper and lower bounds of the 95% CI of the null model, indicating that moderate proximity to cultivation did not impact zebra densities. Observed zebra densities were above the 95% CI of the null model in SA5 and SA6, the two sampling areas most distant from cultivation. SA6, the area with the lowest CIF, had the highest zebra density of all SAs, but group size was smaller in SA6, resulting in a pattern difference between the group analysis and the individual analysis.

Wildebeest were not randomly distributed across the landscape during the daytime hours (Figure 4.34), but the relationship between wildebeest and cultivation was unclear (Figure 4.35). SA1 wildebeest densities were lowest, falling far below the lower bound of the 95% CI of the null model; SA6 wildebeest densities were highest, falling far above the upper bound of the 95% CI of the null model. Intermediate SAs followed a different pattern from zebra, however. Densities in SA2 and SA3 were much higher than random, and densities in SA4 and SA5 were much lower. While the densities in SA2 and SA3 were consistent with a random distribution, densities in SA4 and SA5 diverged from random.

Gazelles were not randomly distributed across the landscape (Figure 4.36). , Densities (number of groups and number of individuals per square kilometer) were negatively related to cultivation proximity and intensity (Figure 4.37). Densities rose with decreasing CIF from SA1 to SA4, peaking in SA4. Densities in SA5 and SA6 were far below the lower bounds of the 95% Confidence Interval of the null model, indicating avoidance of both cultivation and people/wildlife.

TRANSECT PRINT COUNTS

Histograms of observed print density distributions across SAs were created. These revealed fewer zebra outside cultivated plots in the SAs of high-CIF compared to the low-CIF SAs (Figure 4.38). Zebra also demonstrated fewer intrusions into cultivation in high-CIF SAs, revealed by fewer prints inside the cultivated plots (Figure 4.39).

Observed wildebeest prints also revealed fewer groups outside cultivated plots in the high-CIF SAs compared to the low-CIF SAs (Figure 4.38). Wildebeest similarly demonstrated fewer intrusions into cultivation in these high-CIF SAs (Figure 4.39).

Grant's gazelle print observations also revealed fewer groups outside cultivated plots in high-CIF SAs compared to the high-CIF SAs **(**Figure 4.38). Gazelle also demonstrate a lower number of intrusions into cultivation in these same zones **(**Figure 4.39).

Livestock and People

ANIMAL OBSERVATIONS

Livestock and people were not randomly distributed across the landscape (Figures 4.40 & 4.41). Densities of both were concentrated in SA4 (Figures 4.42, 4.43). It is reasonable to suspect that the high density of people and livestock may be influencing densities of other species, in particular those of wildebeest (show a decrease in SA4) and gazelle (show an increase in SA4).

TRANSECT PRINT COUNTS

Livestock analyses revealed a higher number of groups outside cultivated plots in the SAs of lower CIF compared to the higher CIF SAs **(**Figure 4.44**)**. Livestock also demonstrate a higher number of intrusions into cultivation in these same zones (Figure 4.45).

DISCUSSION

This study focused on wildlife distributions with respect to cultivation at two different scales. The scale of individual grazing pastures is a spatial scale at which migratory wildlife move on a more or less daily basis. The landscape scale is a spatial scale at which migratory wildlife tend to move across weeks rather than days. The pattern of observed animal distributions that I observed is reflective of daytime population patterns, since we counted animals during the morning and early afternoon hours. This does not present any concerns for the landscape-level analysis because animals tend to remain within individual pastures for several days or even weeks. At this scale of analysis, the pattern of distribution across sampling areas should be reflective of broad-scale population patterns that would not be affected by nighttime-daytime movements over the course of a single day. However, this does present a concern for the interpretation of pasture-level results, since animals can move across the pastures within a single day, and the locations observed may reflect a daytime effect. The transect print dataset analyzed in Chapter 3 incorporates all observed prints regardless of the time of day they were left, and this helps to qualify the pasture-level results presented here.

Pasture Scale

The pasture scale analysis suggests that wildebeest and zebra display a negative response to cultivation during the daytime hours, concentrating in areas of the pastures with low CI and high ED values. But Chapter 3 demonstrated no gradient response of any species to cultivation. The combination of these results points to nighttime movement *toward* cultivation. This suggests that these species demonstrate a pattern of movement over the course each 24-hour period, toward and away from cultivation at the scale of the 5-10 km^2 pasture (SA). Some of the avoidance of cultivated fields during the daytime may be due to human and livestock activity around these areas at that time (Ogutu et al. 2010). People and livestock density distributions do reveal a preference for areas close to cultivation in SA4, but they demonstrate no clear pattern with respect to cultivation in SA2+SA3.

Gazelle distributions at the pasture scale are more complicated to interpret, but it appears that in SA2+SA3 they responded more strongly to CI than to ED. In these two

SAs, the landscape patterns of ED and CI are quite different, so it is not surprising that response patterns were different between the two metrics. So gazelle may respond more strongly to the local intensity/density of cultivation than they do to the boundaries of the fields themselves.

Gazelle distributions in SA4 were the same across ED and CI gradients, but this was likely because the gradients themselves followed a similar pattern on the SA4 landscape. In this zone it was not possible to distinguish the effects of ED from those of CI. In this SA it was also difficult to determine whether observed distribution patterns were in response to cultivation, or were responses to high human and livestock densities proximal to cultivation itself and within the highest-CI zones. Interestingly, the landscape scale analysis revealed that SA4 contained the highest density of gazelle, which suggests a gazelle tolerance for, or even attraction to, areas with high densities of people and livestock. While the pasture-scale analysis demonstrated avoidance at this intermediate scale, integration of the results across scales suggests an intermediate response to cultivation by gazelle. This could indicate grazing facilitation between livestock and gazelle, that gazelle prefer areas grazed by livestock as greener grass closer to the ground is made more accessible after livestock remove the lower-quality taller forage (see Ogutu 2010 for a detailed discussion on this topic).

Landscape Scale

Based on comparisons of observed animal and null model distributions, as well as evaluation of observed print density distributions, all wildlife species of interest appeared to be responding in some way to cultivation in the Simanjiro landscape at the landscape scale. Zebra demonstrated the clearest negative response to cultivation, with group densities highest in the SA with the lowest CIF value (however, group sizes were smaller in this SA, so this spatial trend is not as clear for analysis of individual densities), and densities were clearly lowest in the SA with the highest CIF value. This is interesting, because in Chapter 3 it was evinced through both transect data and interview data that zebra were one of the wildlife species most present in and destructive to cultivation in Simanjiro. While zebra eat maize and will enter cultivated fields to do so, cultivation appears to repel them. This could be due at least in part to an avoidance of humans or impaired physical access into cultivated fields.

Wildebeest also demonstrated a negative response to cultivation, but low densities in SA4 and SA5 complicate interpretation. Similar to wildebeest, gazelle density was low in SA5, while zebra density was not. The low densities of wildebeest and gazelles in SA5 could have been due to SA5 being somewhat different vegetatively from the other areas, with a visibly higher proportion of small shrubs and forbs than the other zones. Data do not exist to thoroughly quantify these visually apparent differences, however low densities of wildlife in SA5 for these two species but *not* zebra would be consistent with lower forage quality in this area, and a greater tolerance of low quality forage by zebra. Zebra are hindgut digesters, and therefore can tolerate lower quality forage than ruminants such as wildebeest and gazelle.

I hypothesize that the low wildebeest density observed in SA4 was due to the high densities of people and livestock relative to the other SAs, that wildebeest are sensitive to high human and livestock densities. Converse to wildebeest, gazelle demonstrated peak density in SA4, which suggests a tolerance for, or even attraction to, areas with high densities of people and livestock. In fact, it appears as though gazelle respond positively to people and livestock, and in a possibly intermediate fashion to cultivation. This is precisely in line with what Ogutu et al. (2010) found with gazelle, that Grant's gazelle in particular concentrated close to settlements. In SA4 the settlements are located on the opposite side of the cultivated fields, supporting this conclusion. While Homewood et al could not statistically attribute changes in wildebeest numbers to increased competition with cattle (Homewood et al. 2001), in the case of this study I do believe that low densities of wildebeest in SA4 can be attributed, at least in part, to high human and livestock densities. While direct competition over forage may not be at play, a mechanism of avoidance may be. An alternative hypothesis is that herders are herding their livestock away from wildebeest to avoid the spread of malignant catarrhal fever[16] to their cattle during the calving (rainy) season. But if this were the case then cattle would not be found in any of the locations with wildebeest present.

Wildlife print density distributions outside cultivation across SAs, combined with observed animal densities, support the observed wildlife data conclusions that both zebra and wildebeest populations are responding to a threshold of cultivation intensity that lies between the levels of cultivation intensity that were present in SA1 and SA2. Grant's gazelle do not appear to demonstrate as strong of a response, though densities were lower in SA1 than in SA2. Lower wildebeest print density in SA4 is consistent with the observation of fewer wildebeest being detected in that area.

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[16] Malignant catarrhal fever is a disease that is fatal to cattle. It is cause by the alcelaphine herpes virus-1 (AHV-1), and is transmitted to cattle from wildebeest, which act as a wildlife reservoir but who are not themselves susceptible to the disease, acting as asymptomatic carriers. The disease is passed on to cattle from wildebeest calves of up to three months of age. Grootenhuis, J. (2000). Wildlife, livestock and animal disease reservoirs. Wildlife Conservation by Sustainable Use. H. Prins, J. Grootenhuis and T. Dolan. Boston, Kluwer Academic Publishers**:** 81-113.

Print densities inside cultivation demonstrate that the lowest wildlife invasion rates occur in SA1, the pasture with the lowest overall wildlife densities and the highest CIF value. This suggests that planning denser arrangements of cultivation may actually lead to a benefit of lower wildlife invasion rates. Not only does clustered cultivation have less edge (less opportunity for invasion and a smaller boundary to guard) but observed distributions indicate that wild animals simply are not in proximity due to avoidance of areas of dense cultivation despite availability of open areas to graze.

Summary

With all species of interest at detectably lower densities in the sampling area with the highest CIF value, and wildebeest and zebra numbers being at their highest levels in the area with the lowest CIF value, a migratory wildlife distribution pattern emerges. The CIF threshold lies between that of SA1 and SA2 (Table 4.2). Because there is little difference in CIF between these two areas, 0.607 and 0.560 respectively on a relative scale of 0-1, it is necessary to investigate the components of CIF individually to determine whether one or the other could be driving density differences between these two SAs.

Euclidian distance (ED) values were also similar between SA1 and SA2, at 0.799 and 0.851 respectively on a scale of 0-1. But cultivation intensities (CI) were much more different. The CI value for SA1 was 0.415, and for SA2 was 0.269 on a relative scale of 0-1. This suggests that the important driver of differences between the two SAs is, in fact, cultivation intensity alone. Rather than distance to the nearest cultivated plot being the primary determinant of animal distributions, in terms of landscape structure, it appears to be the broader-scale cultivation density, or the proportion of the surrounding landscape that animals view as being permeable or attractive, that drives their distributions. This is despite the availability of large grazing pastures such as SA1 among the patches of cultivation. While wildlife may over time equilibrate their use of patches that they choose to use, once a threshold of cultivation intensity is crossed in a landscape animals no longer choose to move through it. This suggests that when cultivation density reaches a threshold level perceptible by wildlife, wildlife habitat loss is *not* restricted only to the area that is cultivated, but rather it includes an impact zone beyond the cultivation boundary as animals avoid the entire area. It is unfortunate that thresholds are difficult to identify before they are crossed and a response seen (Walker and Meyers 2004; Groffman et al. 2006). In the case of Simanjiro it appears that this cultivation density threshold lies within the range between SA1 and SA2.

This inference is supported by the findings of Chapter 3, which demonstrated that wildlife are not avoiding the edge of cultivated plots along a gradient of 0-1 km of distance[17], so they are not avoiding SA1 in order to avoid the edge of the fields, but rather to avoid the broader-scale density of cultivation. Both SA1 and SA2 are proximal to settlements. SA1 is closer to the Loiborsoit 'A' village center, but in 2003 wildlife actually used SA1 as a migratory corridor, moving through and grazing along the way. Between 2002 and 2003, the density of cultivation increased significantly as people responded to threats of an expansion of Tarangire National Park. While I do not have numerical data to compare densities between years, my personal observation while conducting interviews in the area was that wildlife densities were higher in SA1 before

[17] Though a response may exist at distances beyond 1 km, it was not possible to study edge effects at that scale through this study due to lack of landscape patches in which long transects could be established that did not approach another cultivated plot and confound the results.

the additional fields were plowed than after. Wildlife migrations were not entirely stopped by this landscape development, rather they moved further to the south, shifting the corridor to a new location with less dense cultivation (personal observation, and multiple informant observations).

When science is used for predictive or diagnostic purposes, as it so often is in environmental policy making, its limitations may lead to overlooking some potential causes of problems, or to framing problems too narrowly (Jasanoff and Martello 2004). While limited site availability and limited personnel prohibited explicit incorporation of explicit human, livestock and settlement components into this study, data collected on human and livestock densities did assist with disentangling the effects of these factors from those of cultivation. In addition, if only the metric of Euclidian distance to cultivation (ED) had been investigated as a driving factor of wildlife distributions, the effect of cultivation intensity (CI) would have been missed as a strong driving factor of large-scale wildlife distributions, particularly for wildebeest and zebra. Finally, looking at print densities inside and outside of cultivated fields allowed me to investigate the impact of local cultivation intensity for wildlife ingress into cultivated fields, a key source of conflict between people and wildlife in this area (see Chapter 3).

Conservation policy and land use management will be most effective if they consider the spatial scales at which wildlife movement processes operate, as well as recognize sources of human wildlife conflict. Recognizing the needs of both by balancing the need of people to use the landscape for livestock and cultivation with the need to conserve wildlife access to grazing and water resources is will facilitate successful multiple stakeholder use. It will also minimize conflict among stakeholders if they believe that their needs are being taken into consideration in development of new policies.

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FIGURES AND TABLES

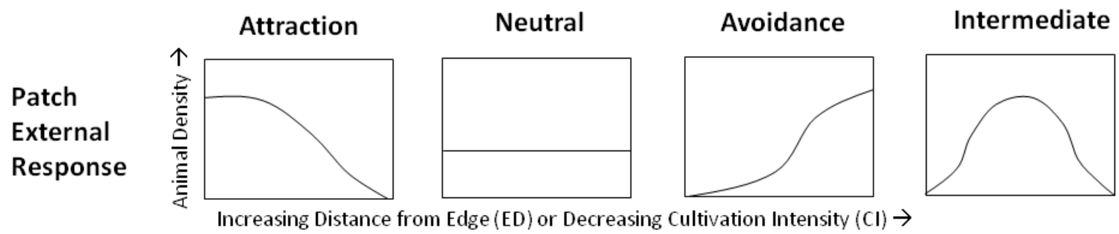


Figure 4.1a. Potential wildlife responses to cultivation at the pasture scale. The hypothesized responses pertain to both Euclidian distance (ED) or cultivation intensity (CI) patterns as drivers of wildlife distributions.

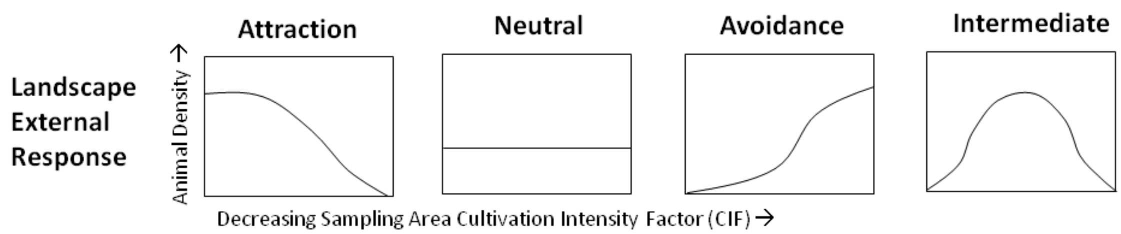


Figure 4.1b. Potential wildlife responses to cultivation at the landscape scale.

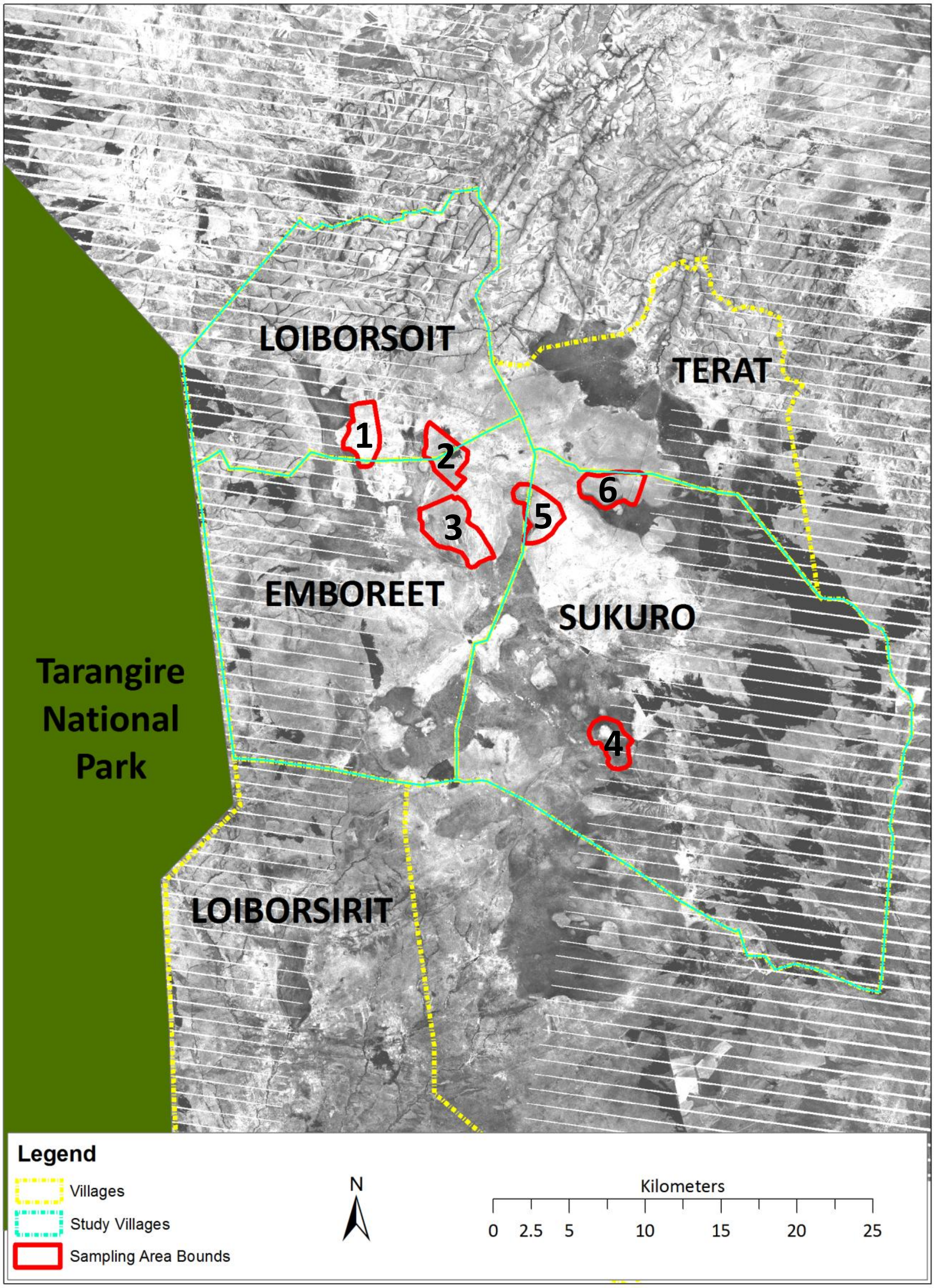


Figure 4.1. Map of sampling areas (SAs) within the study area and surrounding Villages.

Figure 4.3. Sampling area (SA) and transect locations within the study area. Eight transects originated 50m inside of cultivation and continued for up to 1 km outside of cultivation. Observations were recorded for at alternating 50 m intervals, once inside and for ten intervals outside beginning with the edge interval.

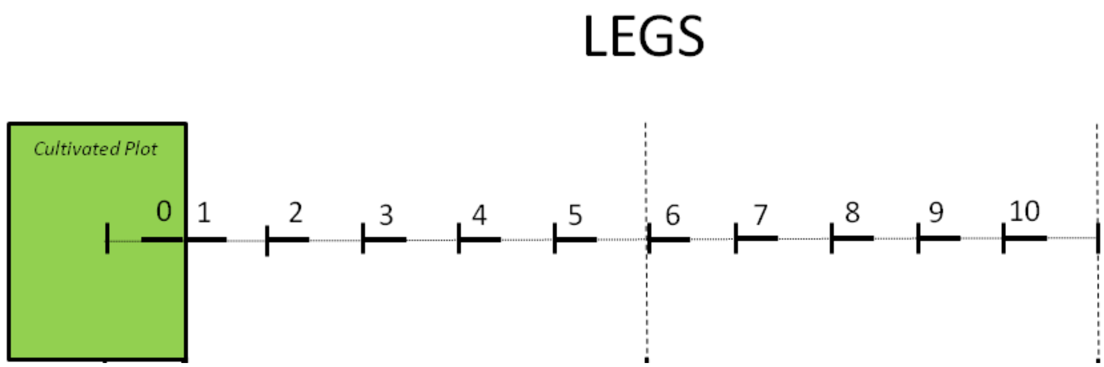


Figure 4.2. Observations of print individuals and groups were collected in alternating 50 meter segments. Leg 0 = Interior, Legs 1-10 = Exterior.

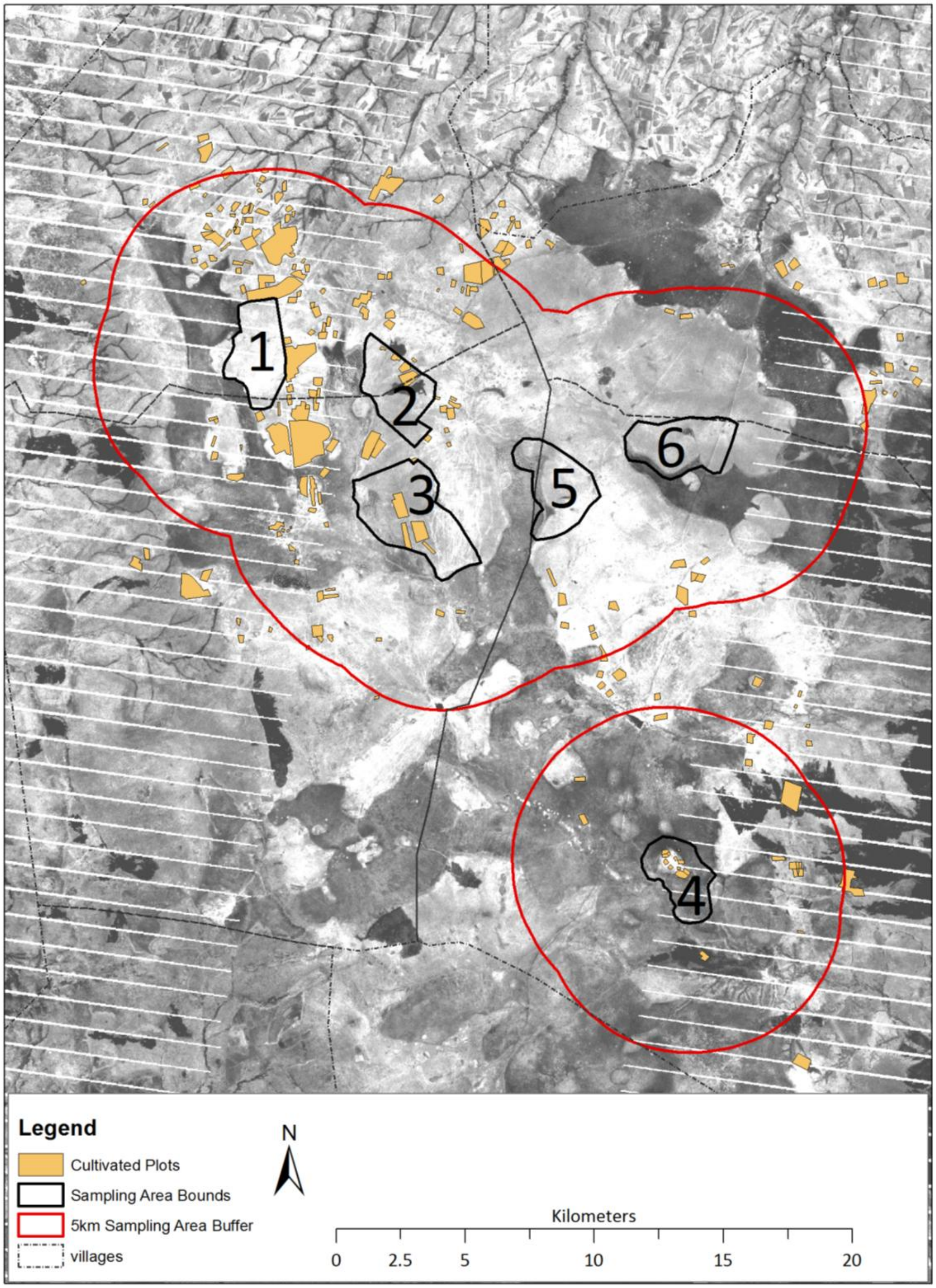


Figure 4.5. Cultivation was digitized by hand to a 5km buffer of the sampling areas in ArcMap using a 2004 TM image of the study area. Cultivation beyond the 5km buffer is not complete, and has no bearing on the sampling area analysis or calculation of cultivation intensity.

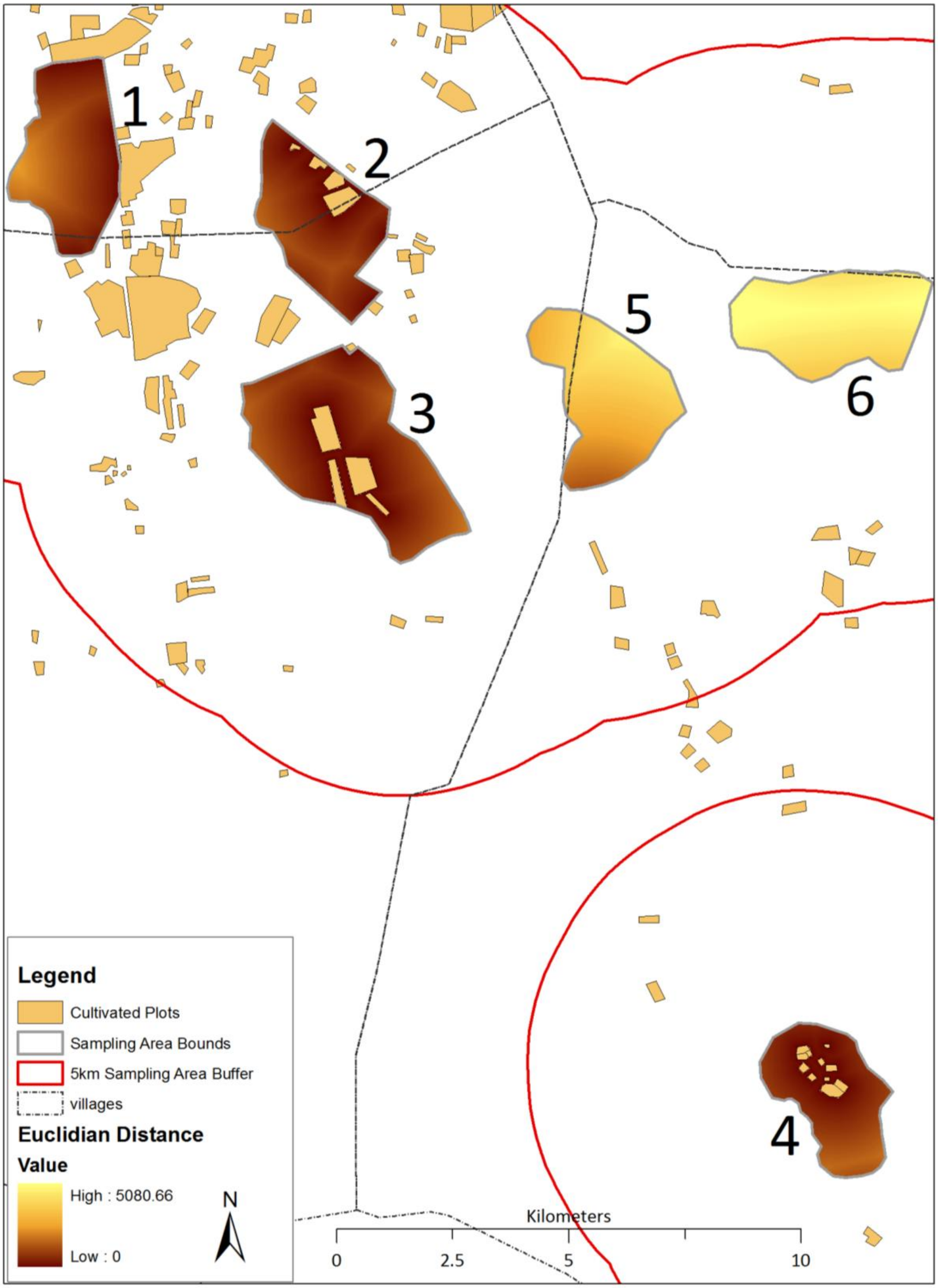


Figure 4.6. Continuous surface map of Euclidian distance (ED) for each of the six sampling areas. Areas closer to cultivation (lower ED value) are shaded darker, more distant areas are shaded lighter.

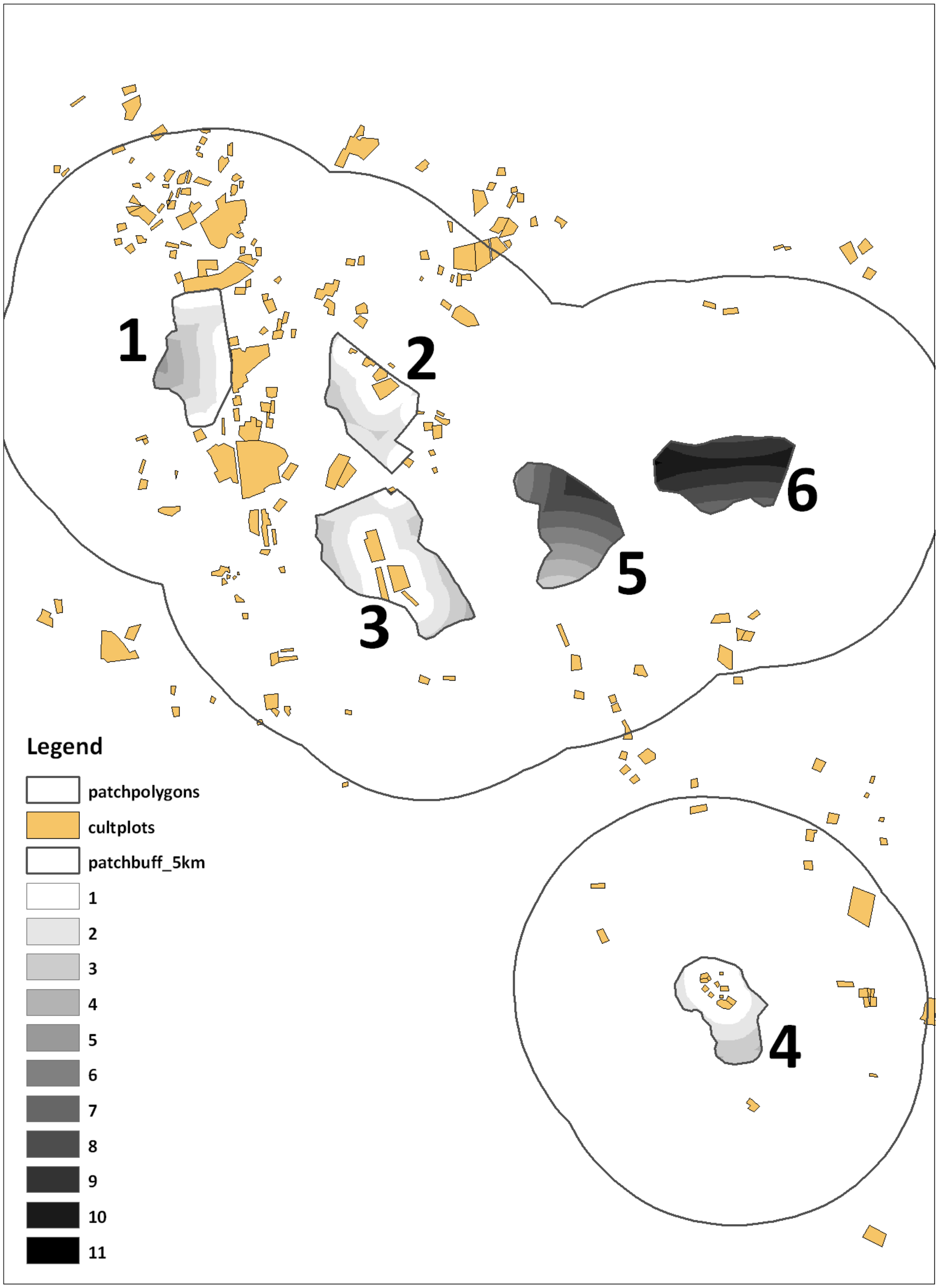
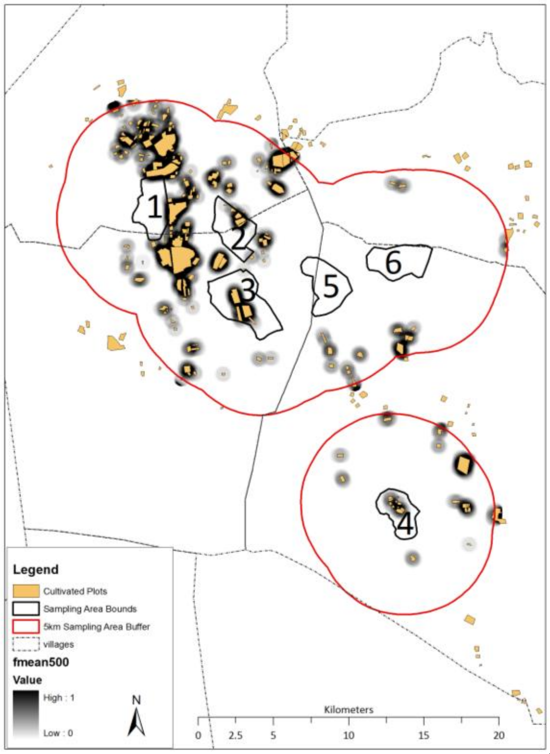


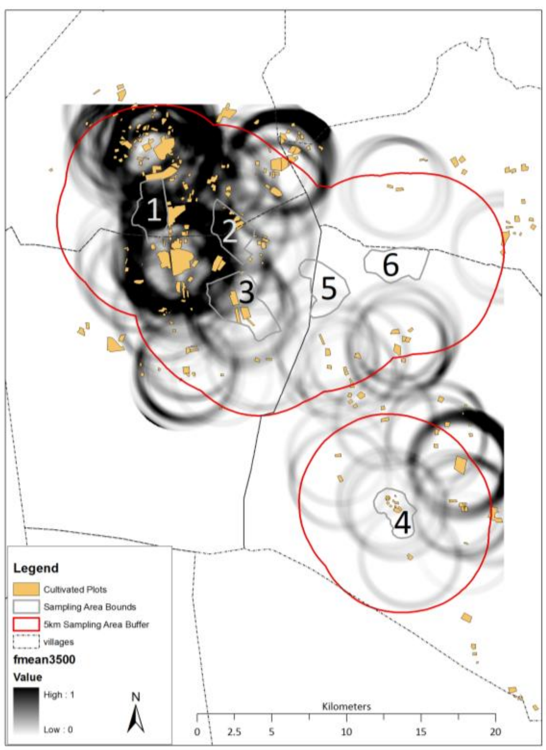
Figure 4.7. 11-class map of Euclidian distance (ED) for each of the six sampling areas. Areas closer to cultivation (lower ED value) are shaded lighter, more distant areas are shaded darker.

Table 4.1. Cultivation intensity was calculated for each $25m^2$ landscape gridcell by summing the FocalMeans for multiple fixed-width concentric annuli around the cell. Annuli were 500m wide (20 x $25m^2$ cells wide). The closest annulus was given a weight of 10, and all cultivation beyond 5km was weighted zero.

Annulus Width	Annulus Cell Range	Annulus Weight Value
1-500m	1-20	10
501-1000m	21-40	9
1001-1500m	41-60	8
1501-2000m	61-80	7
2001-2500m	81-100	6
2501-3000m	101-120	5
3001-3500m	121-140	4
3501-4000m	141-160	3
4001-4500m	161-180	2
4501-5000m	181-200	1
5001-5500m	201-220	0



A



B

Figure 4.8. Results of the *FocalMean* calculation process steps for grid cells: A) 0-500m from each 25m^2 landscape cell, and B) 3000-3500m from each 25m^2 landscape cell.

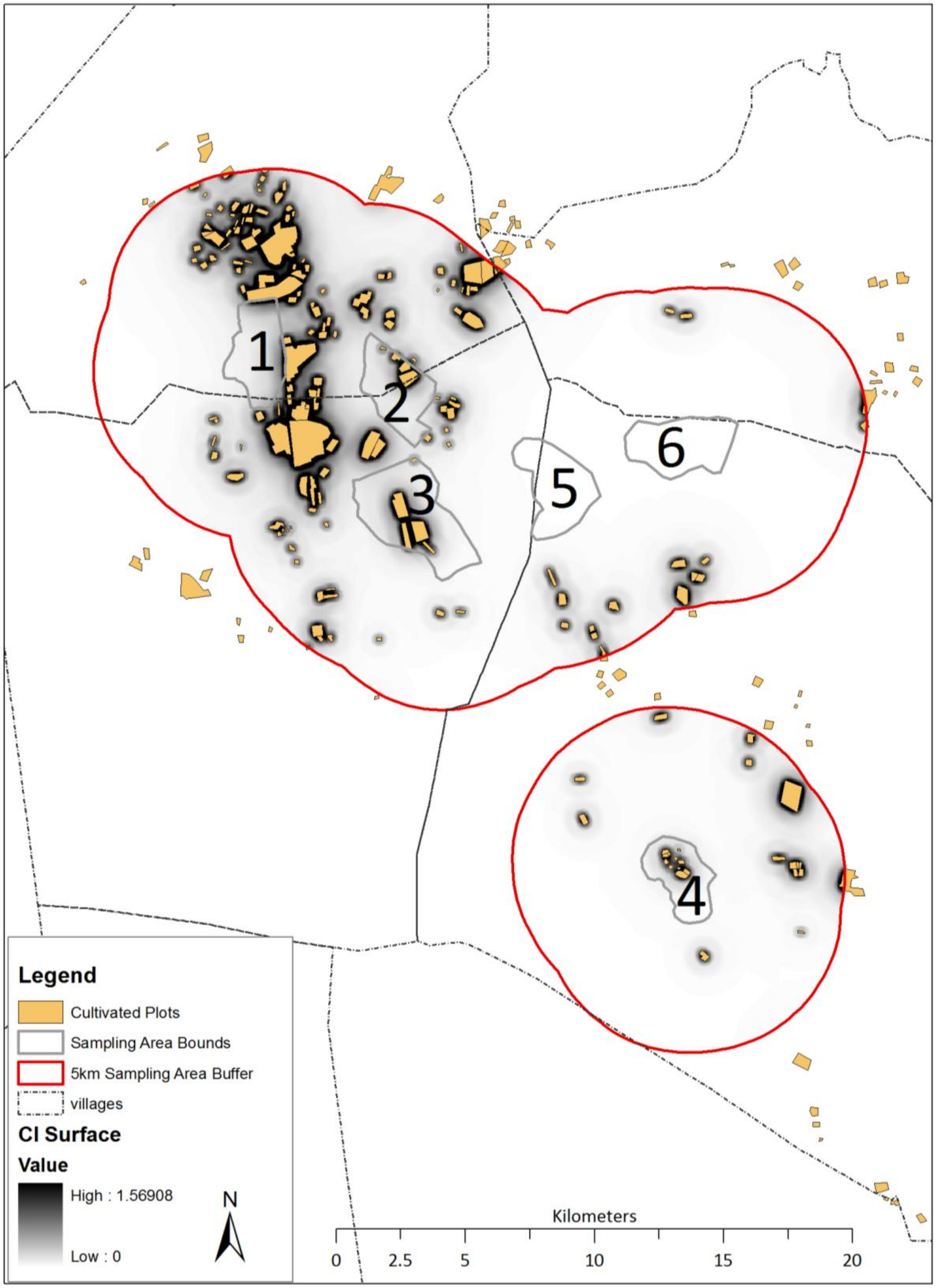


Figure 4.9. Final Cultivation Intensity (CI) continuous surface map. Higher cultivation intensity values are shaded darker, lower values shaded lighter.

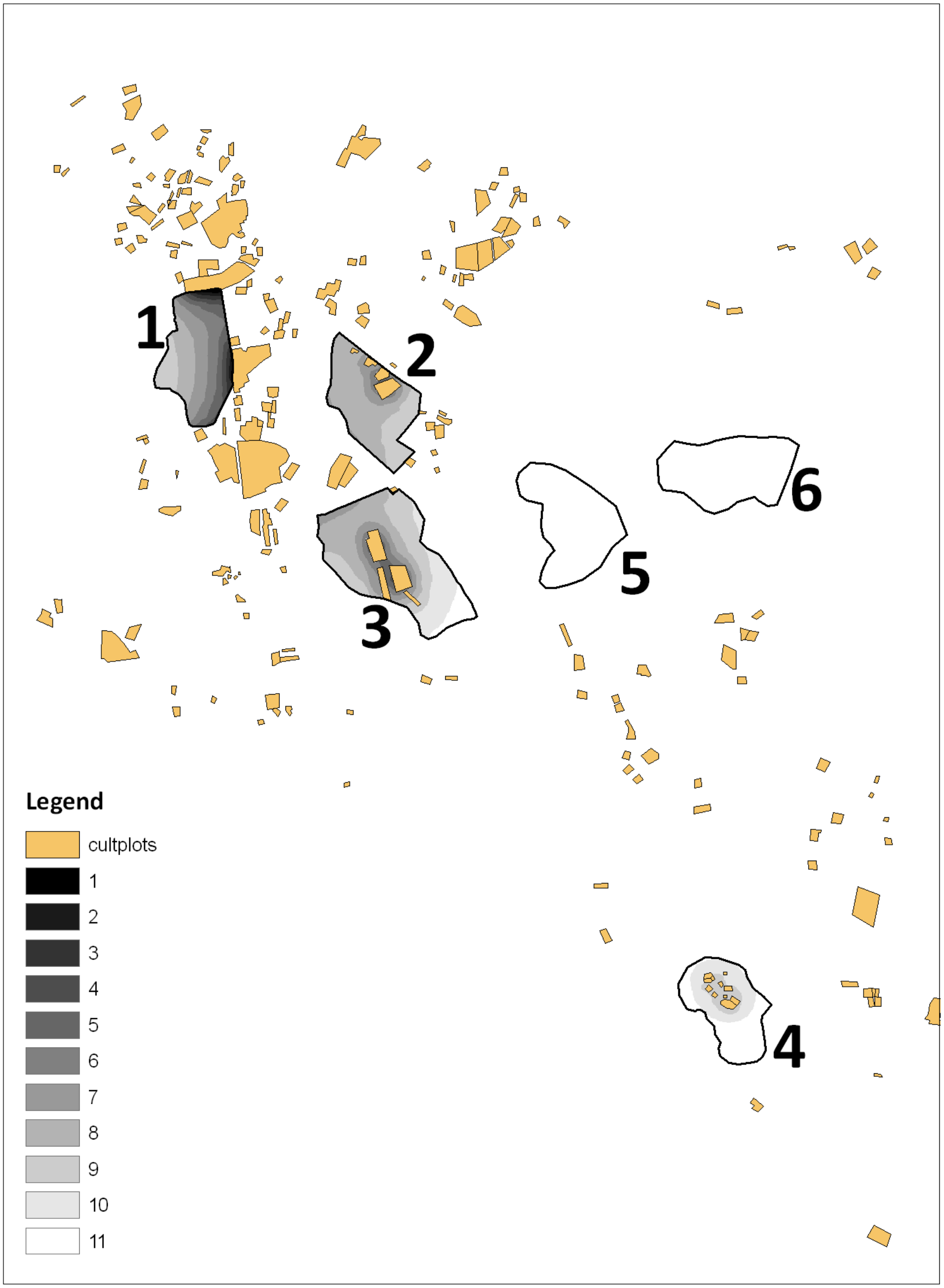


Figure 4.10. 11-class Cultivation Intensity (CI) map. Higher cultivation intensity values are shaded darker, lower values shaded lighter. SA5 and SA6 are located entirely within CI zone 11.

Table 4.2. Sampling Area (SA) ranks according to CI, ED and CIF. Values were calculated for each sampling area on a 0-1 scale, with 1=highest possible value. Sampling areas, which were formerly named by grazing pasture name or code number, were numbered according to their CIF rank, a value that combines CI and ED values. These numbers are used as SA identifiers consistently throughout this document.

SA	CI	ED	CIF
1	0.415	0.799	0.607
2	0.269	0.851	0.560
3	0.226	0.838	0.532
4	0.056	0.847	0.451
5	0.000	0.417	0.208
6	0.000	0.189	0.095

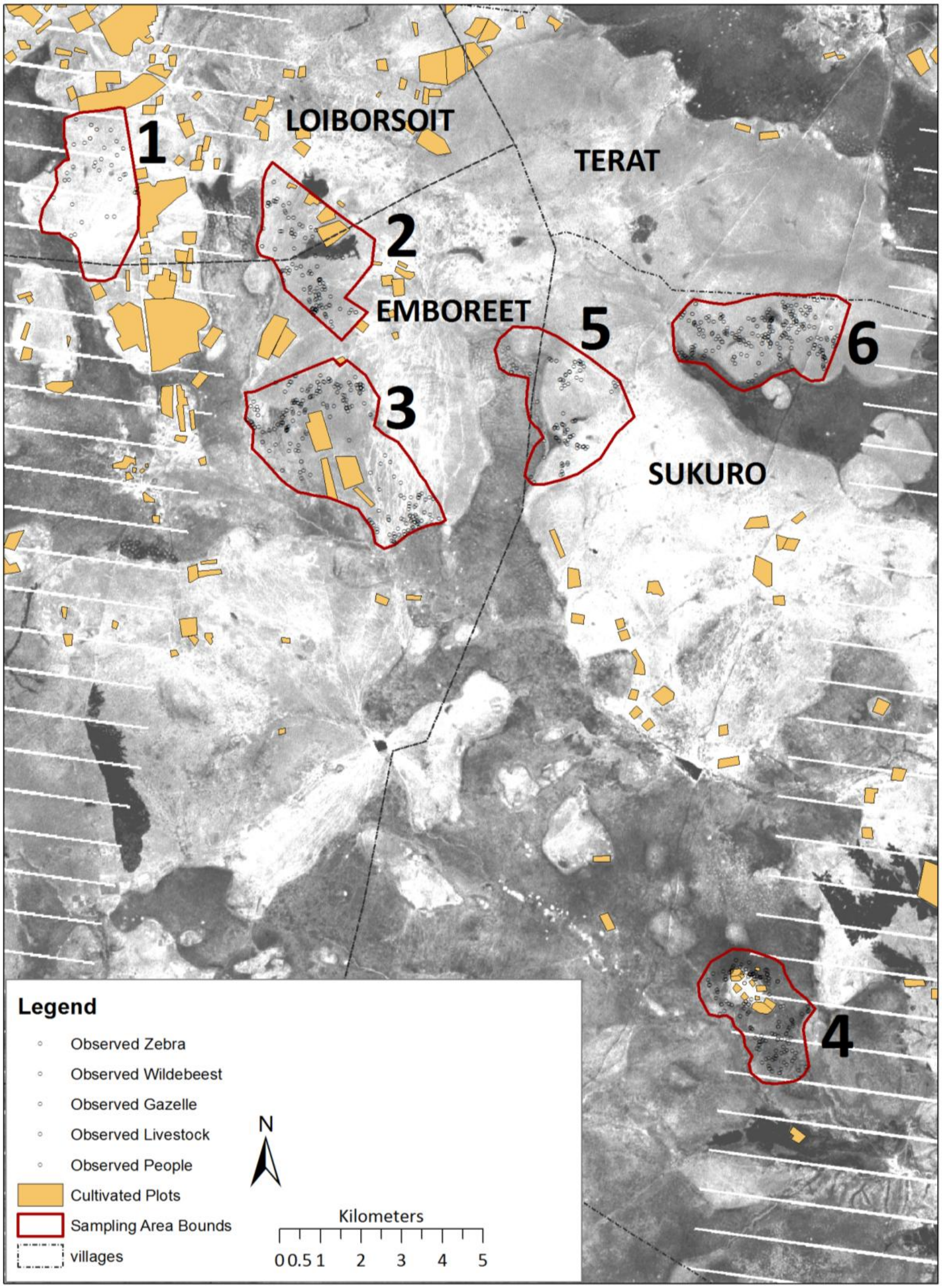


Figure 4.11. All observed groups of zebra, wildebeest, gazelle, livestock and people.

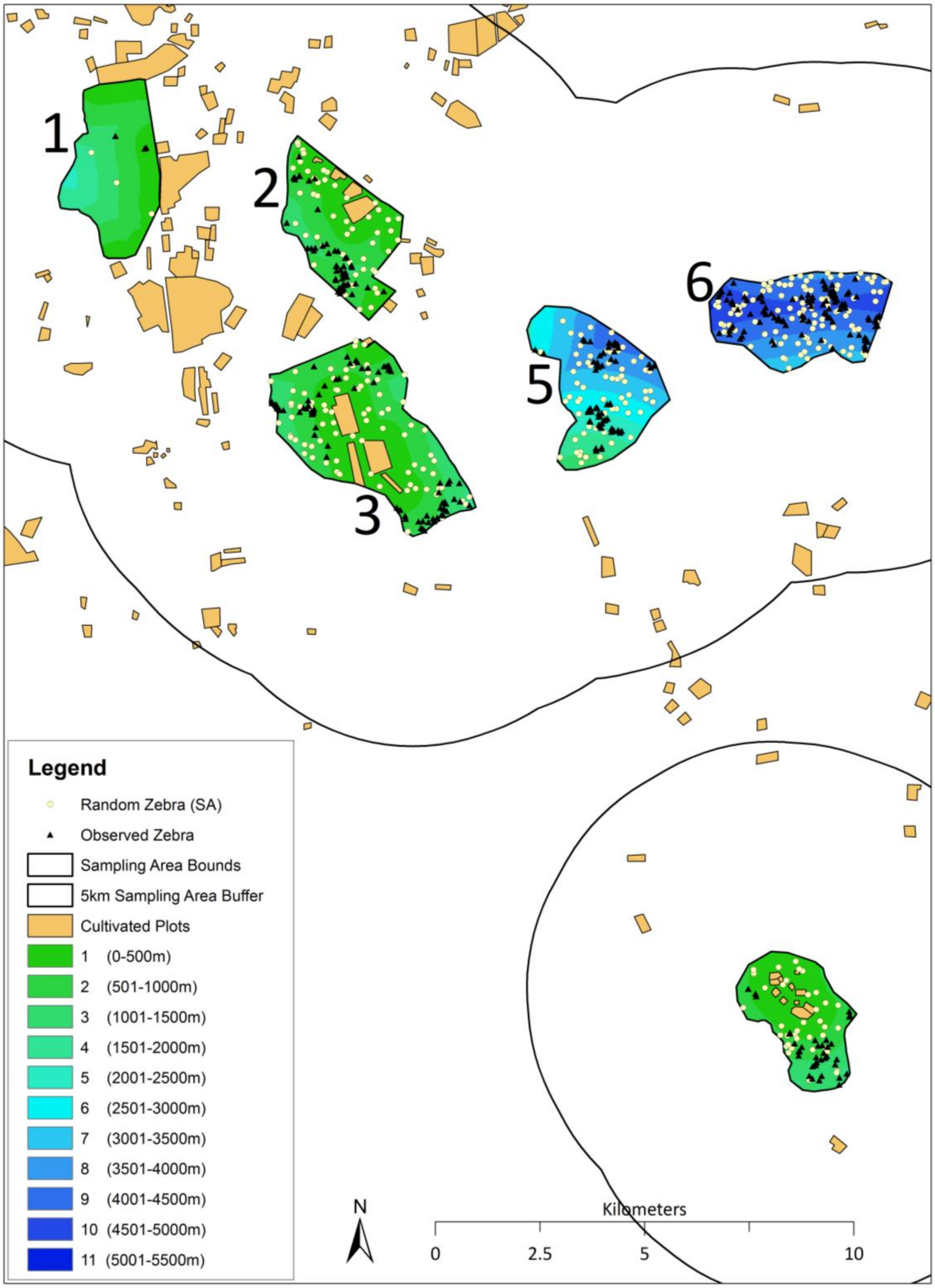


Figure 4.2. Zebra group observations (black triangles) and one of 30 random spatial redistributions of zebra group locations (dots) mapped against an 11-class surface of Euclidian distance (ED) to nearest cultivated plot, prepared for pasture scale analysis.

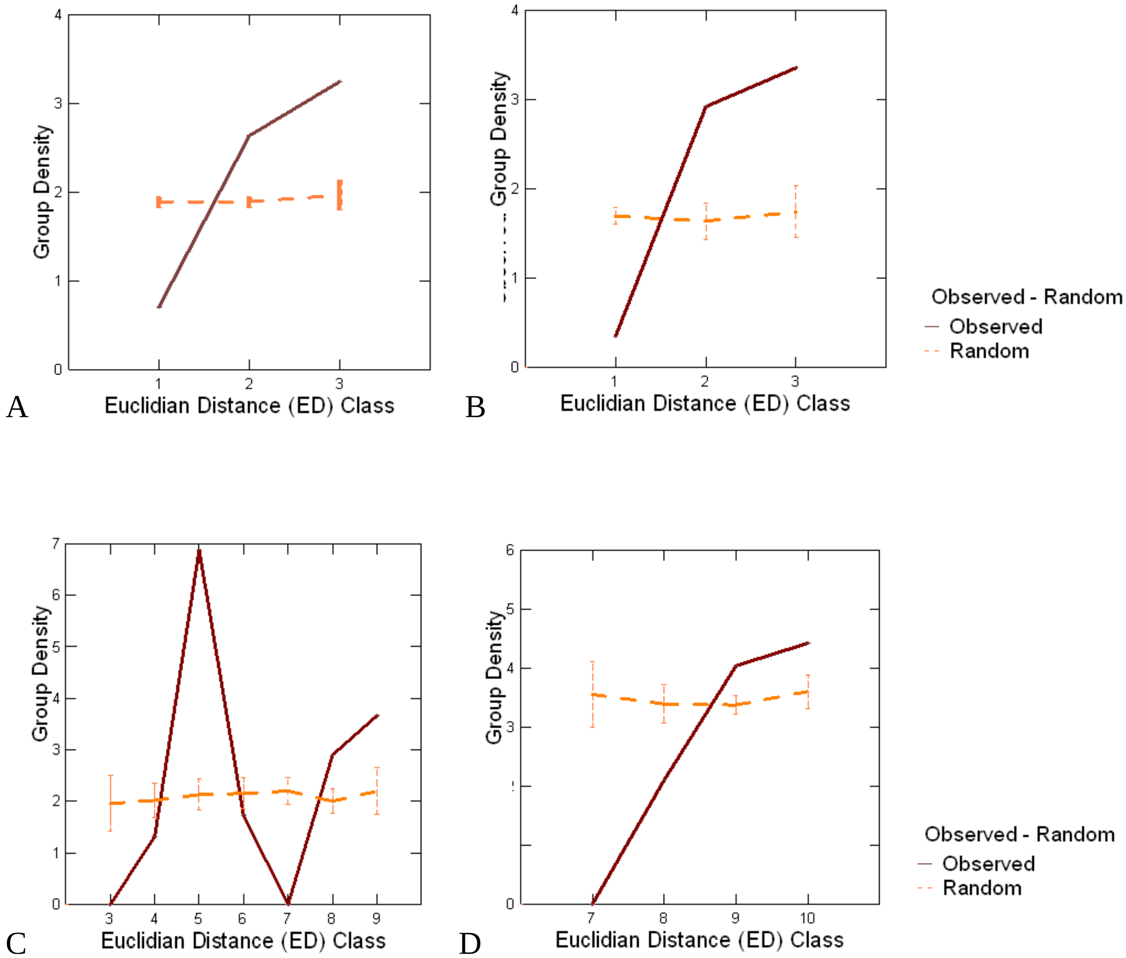


Figure 4.13. Pasture scale analysis of observed distributions of zebra groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the Euclidian distance gradient zones present in each sampling area: SA2+SA3 (A), SA4 (B), SA5 (C), and SA6 (D). Group Density is measured in #groups/km^2.

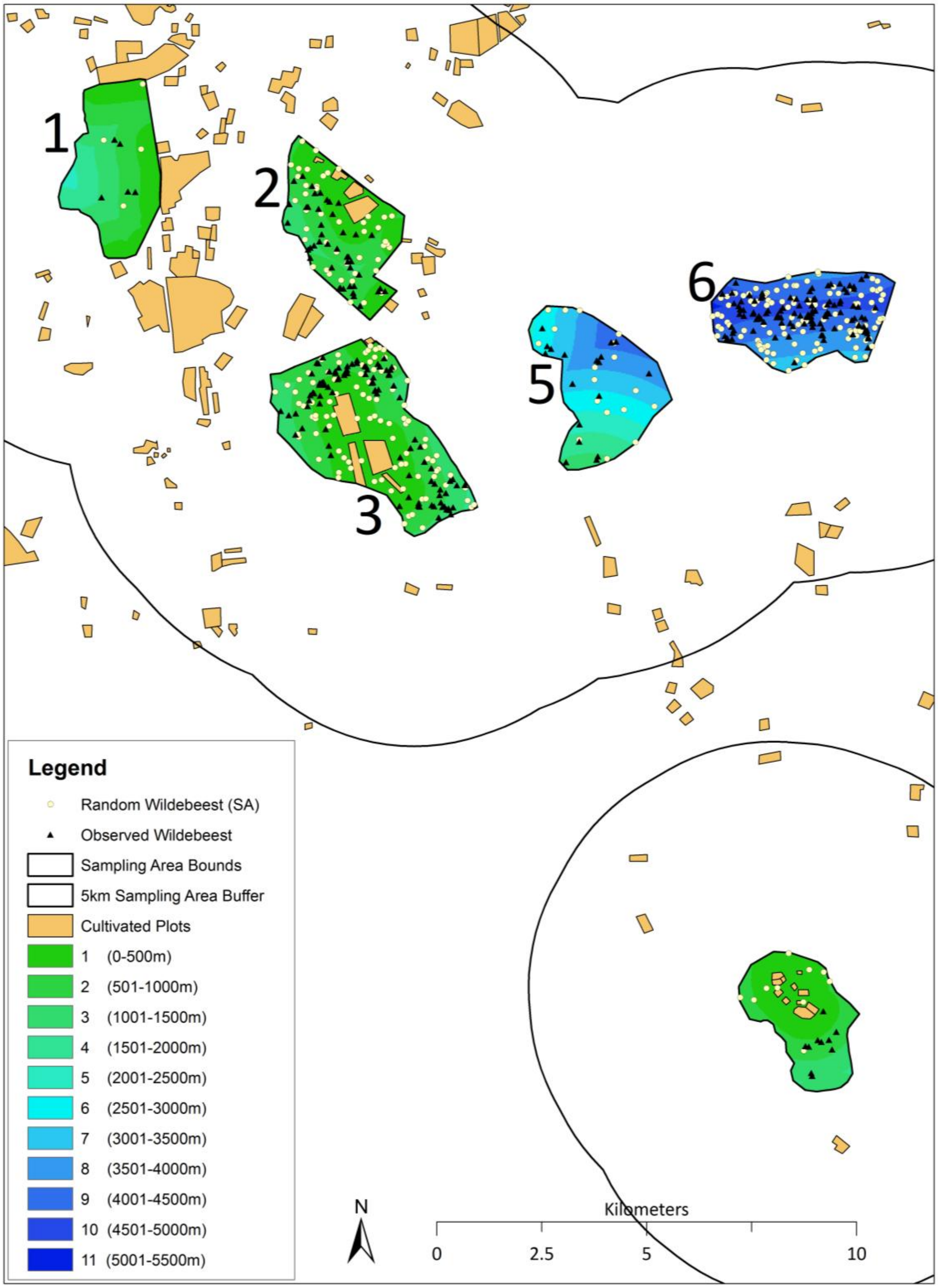


Figure 4.14. Wildebeest group observations (black triangles) and one of 30 random spatial redistributions of wildebeest group locations (dots) mapped against an 11-class surface of Euclidian distance (ED) to nearest cultivated plot prepared for pasture scale analysis.

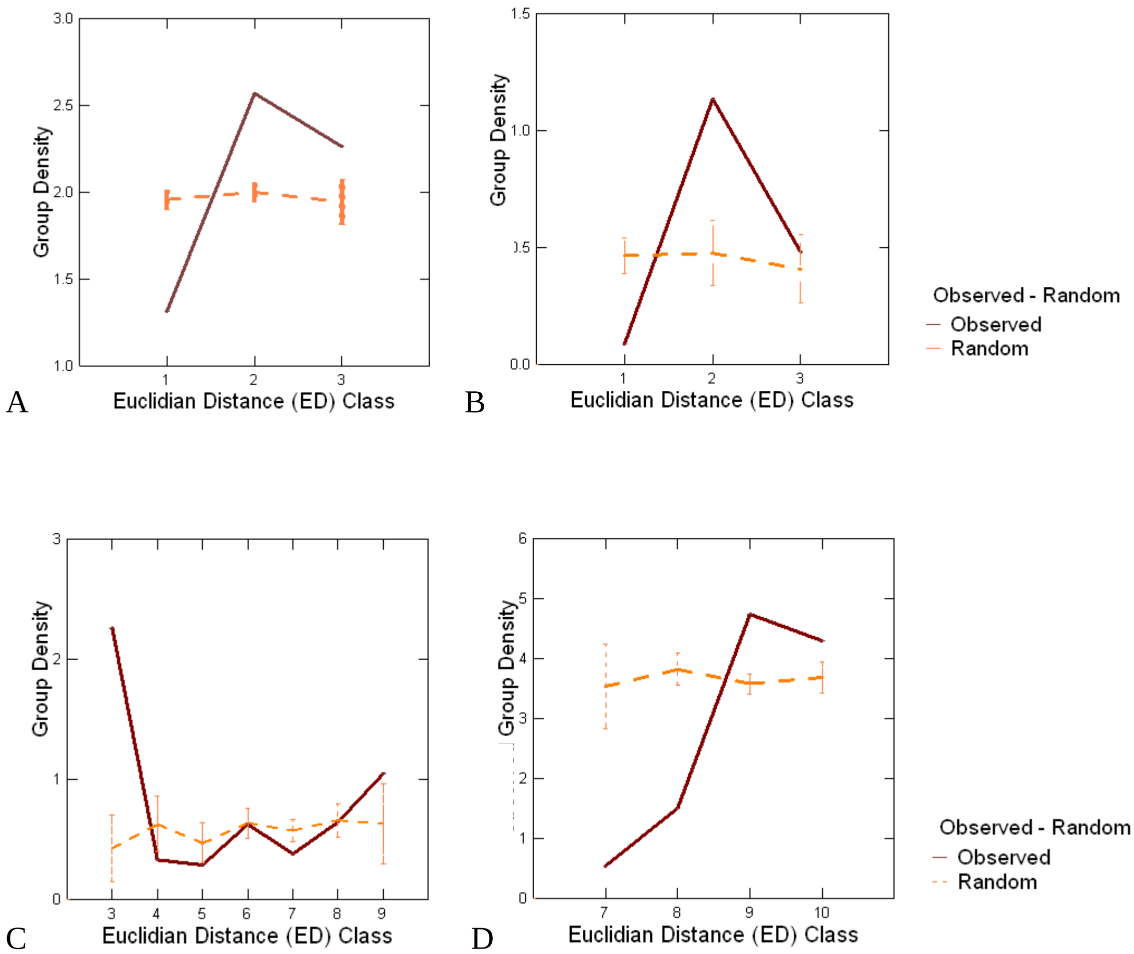


Figure 4.3. Pasture scale analysis of observed distributions of wildebeest groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the Euclidian distance gradient zones present in each sampling area: SA2+SA3 (A), SA4 (B), SA5 (C), and SA6 (D). Group Density is measured in #groups/km^2.

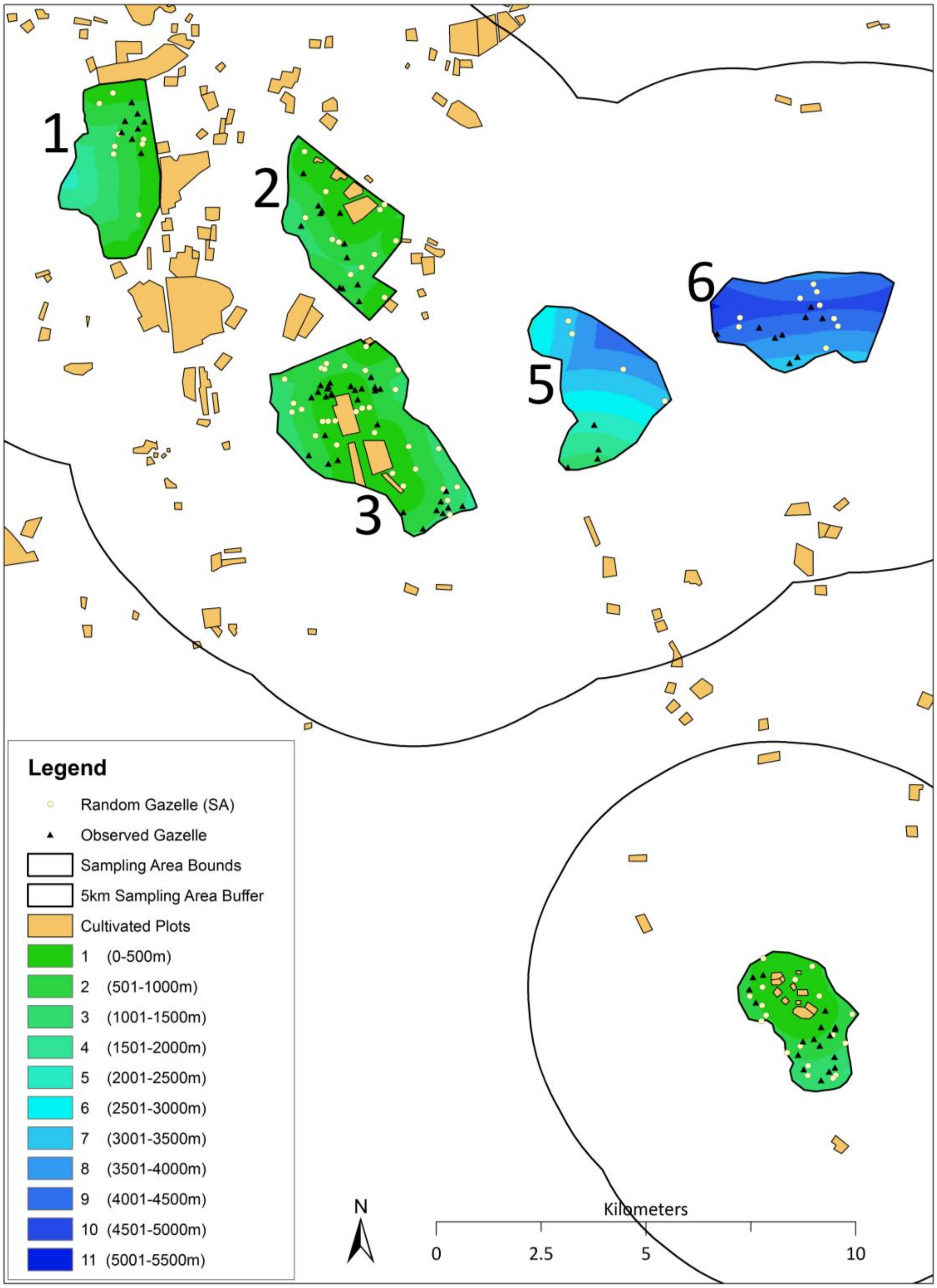


Figure 4.16. Gazelle group observations (black triangles) and one of 30 random spatial redistributions of gazelle group locations (dots) mapped against an 11-class surface of Euclidian distance (ED) to nearest cultivated plot prepared for pasture scale analysis.

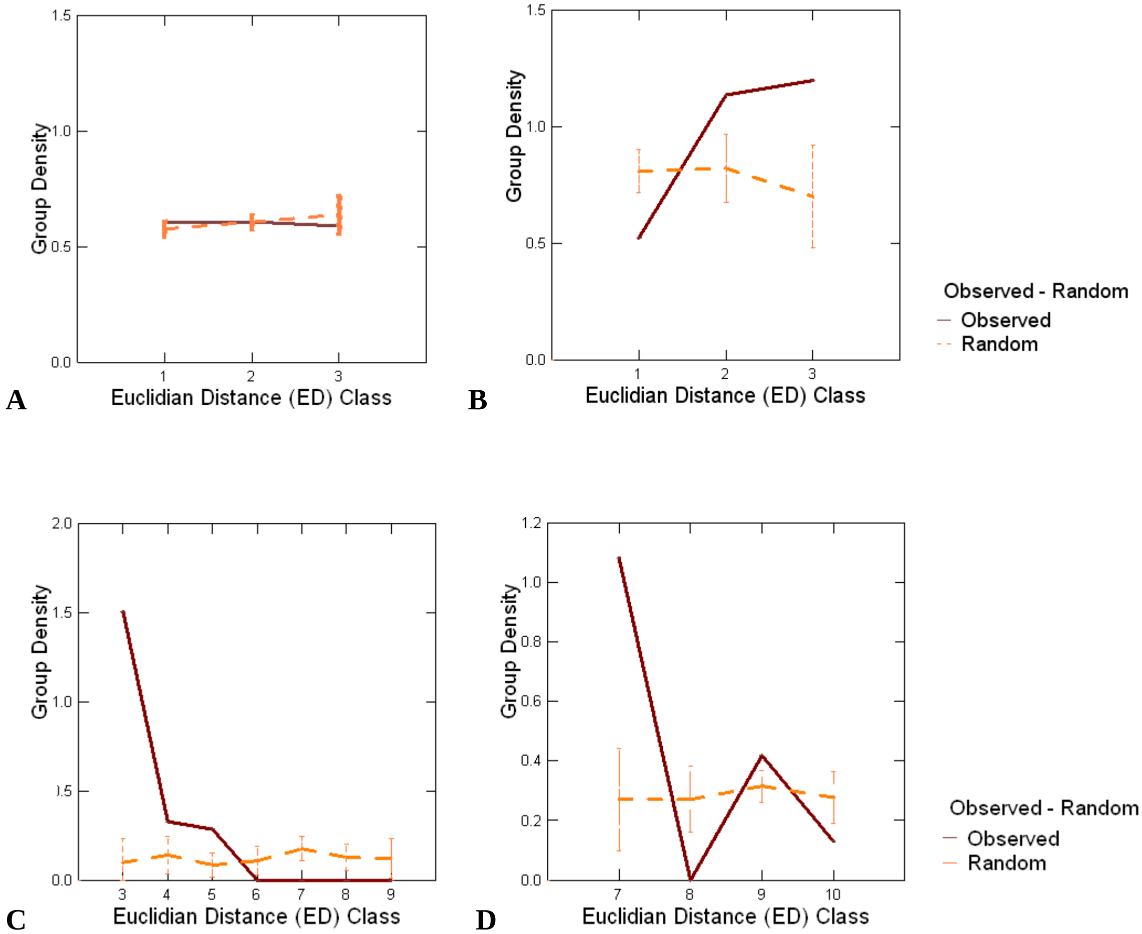


Figure 4.17. Pasture scale analysis of observed distributions of gazelle groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the Euclidian distance gradient zones present in each sampling area: SA2+SA3 (A), SA4 (B), SA5 (C), and SA6 (D). Group Density is measured in #groups/km^2.

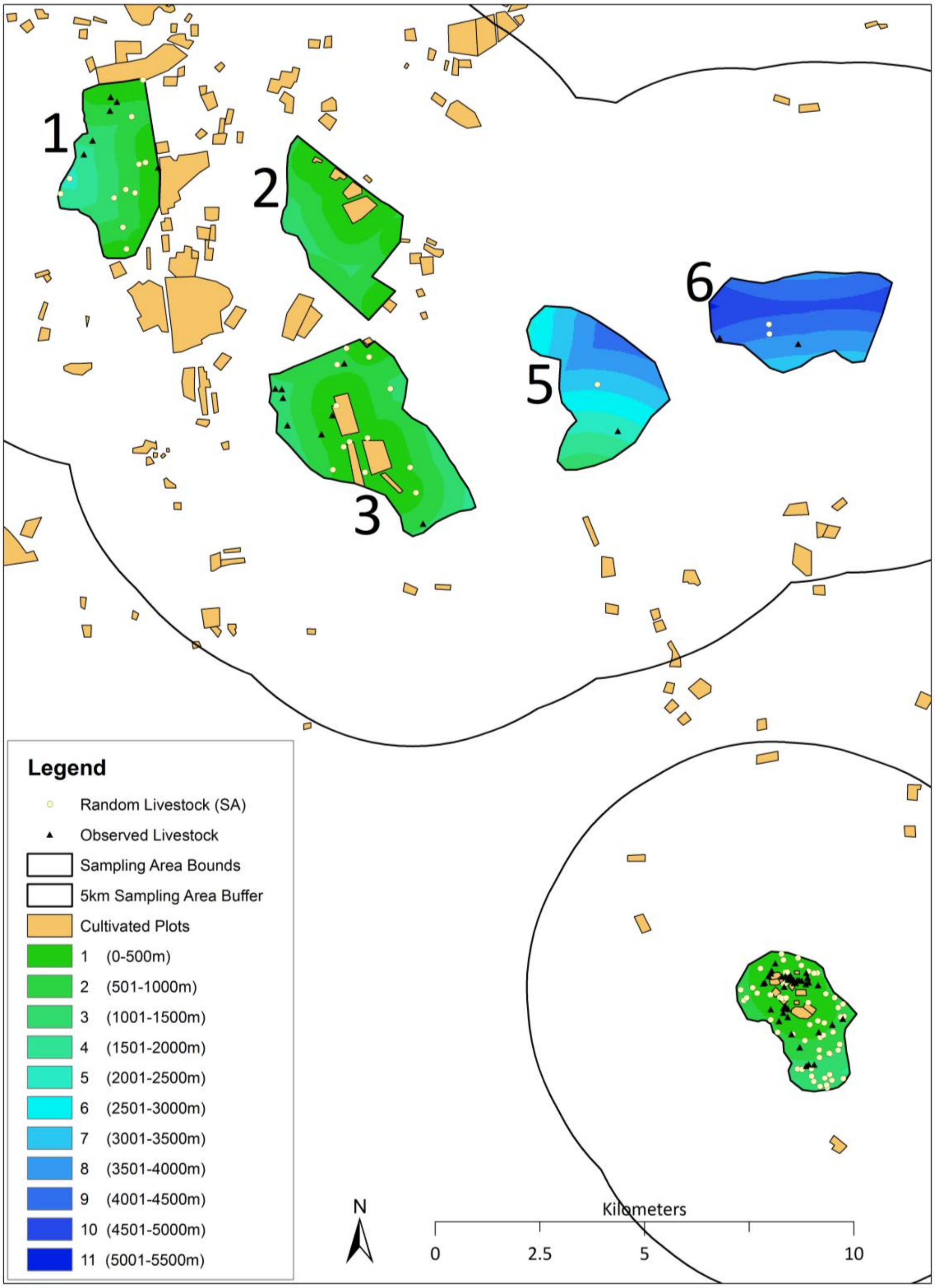


Figure 4.18. Livestock group observations (black triangles) and one of 30 random spatial redistributions of livestock group locations (dots) mapped against an 11-class surface of Euclidian distance (ED) to nearest cultivated plot prepared for pasture scale analysis.

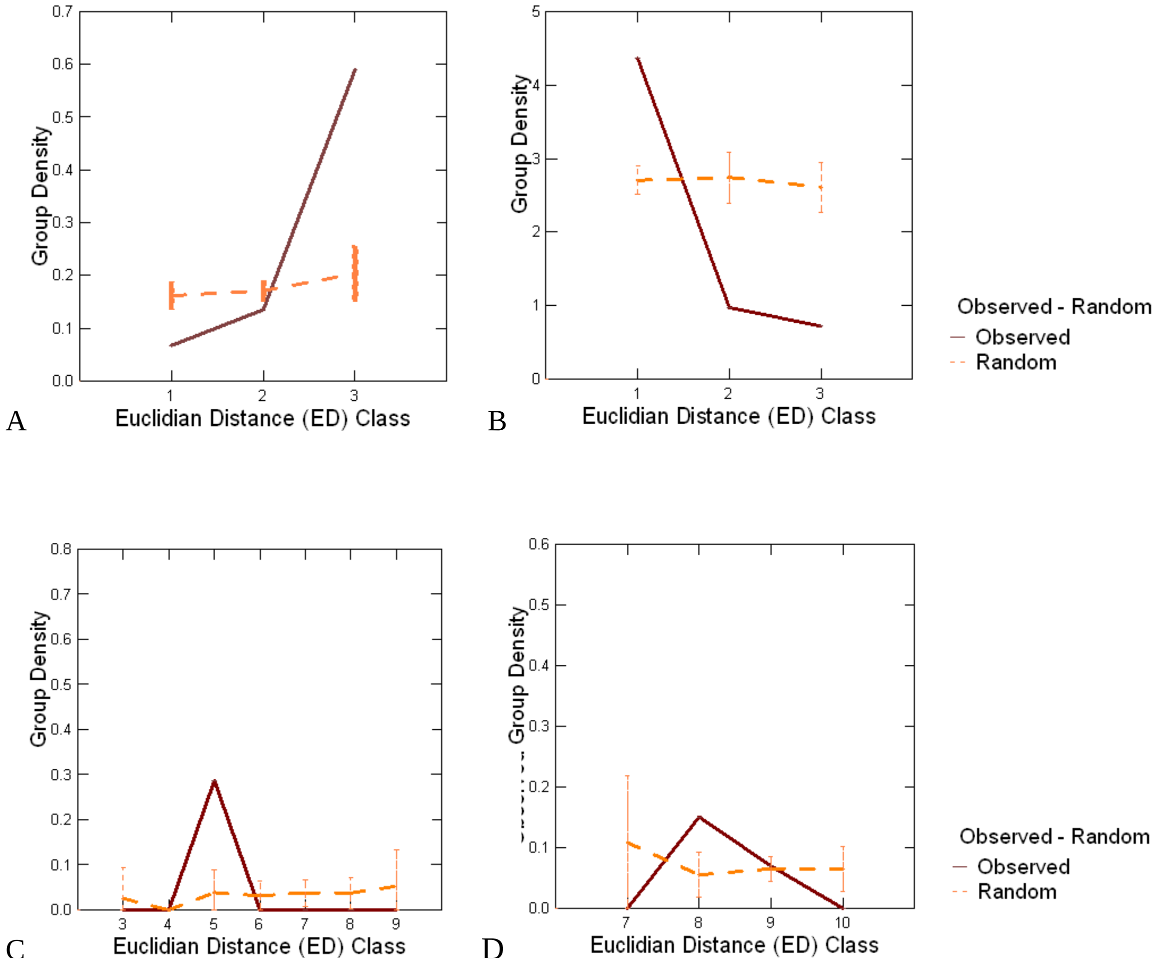


Figure 4.19. Pasture scale analysis of observed distributions of livestock groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the Euclidian distance gradient zones present in each sampling area: SA2+SA3 (A), SA4 (B), SA5 (C), and SA6 (D). Group Density is measured in #groups/km^2.

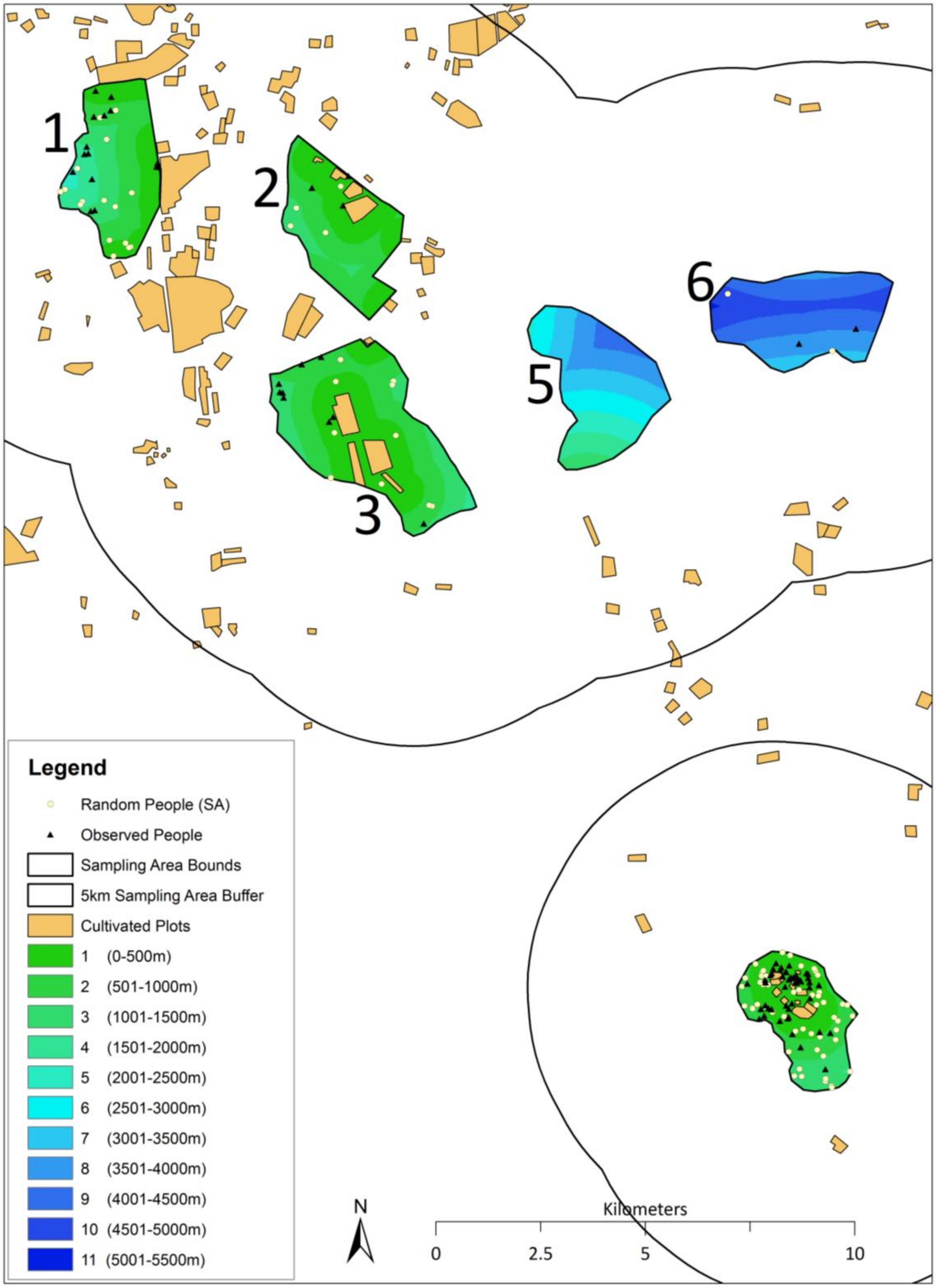


Figure 4.20. People group observations (black triangles) and one of 30 random spatial redistributions of people group locations (dots) mapped against an 11-class surface of Euclidian distance (ED) to nearest cultivated plot prepared for pasture scale analysis.

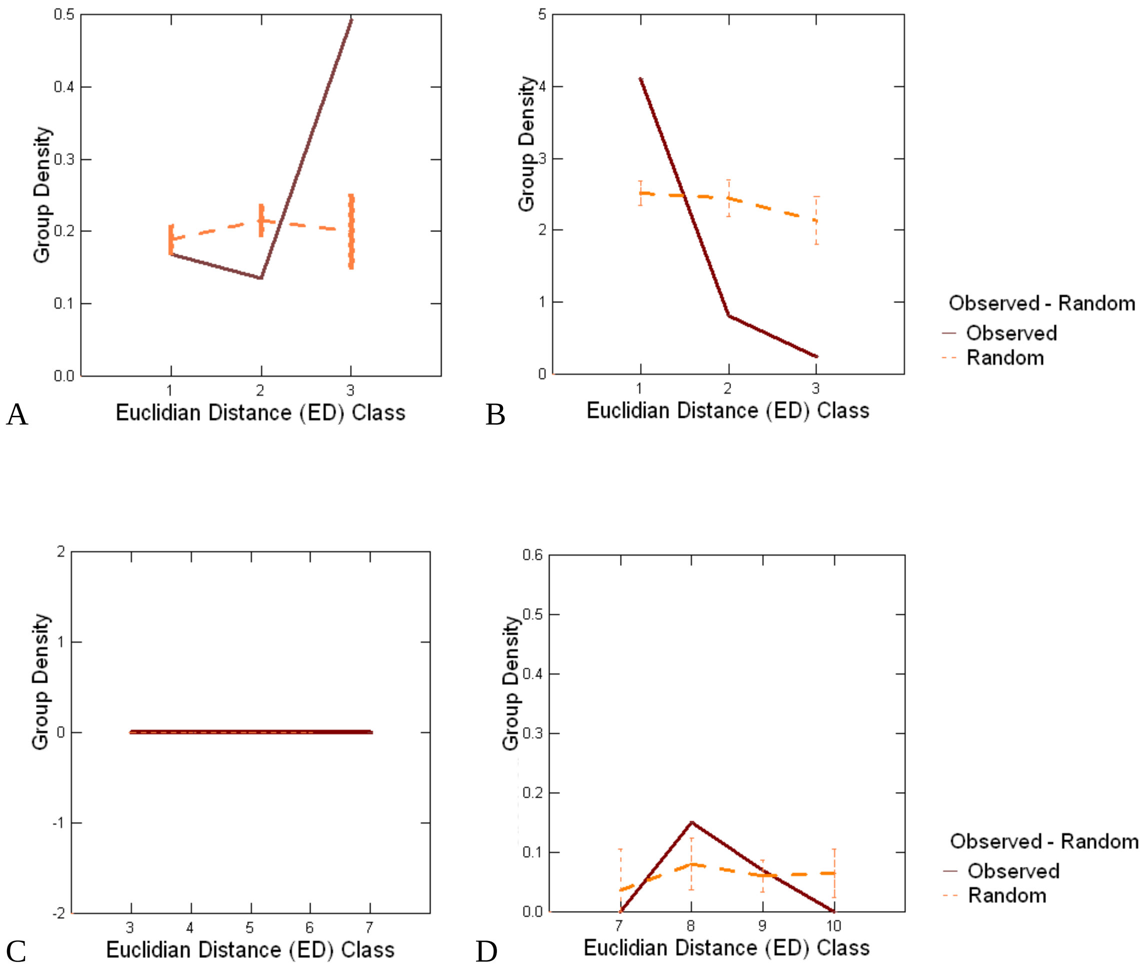


Figure 4.21. Pasture scale analysis of observed distributions of people groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the Euclidian distance gradient zones present in each sampling area: SA2+SA3 (A), SA4 (B), SA5 (C), and SA6 (D). Group Density is measured in #groups/km^2.

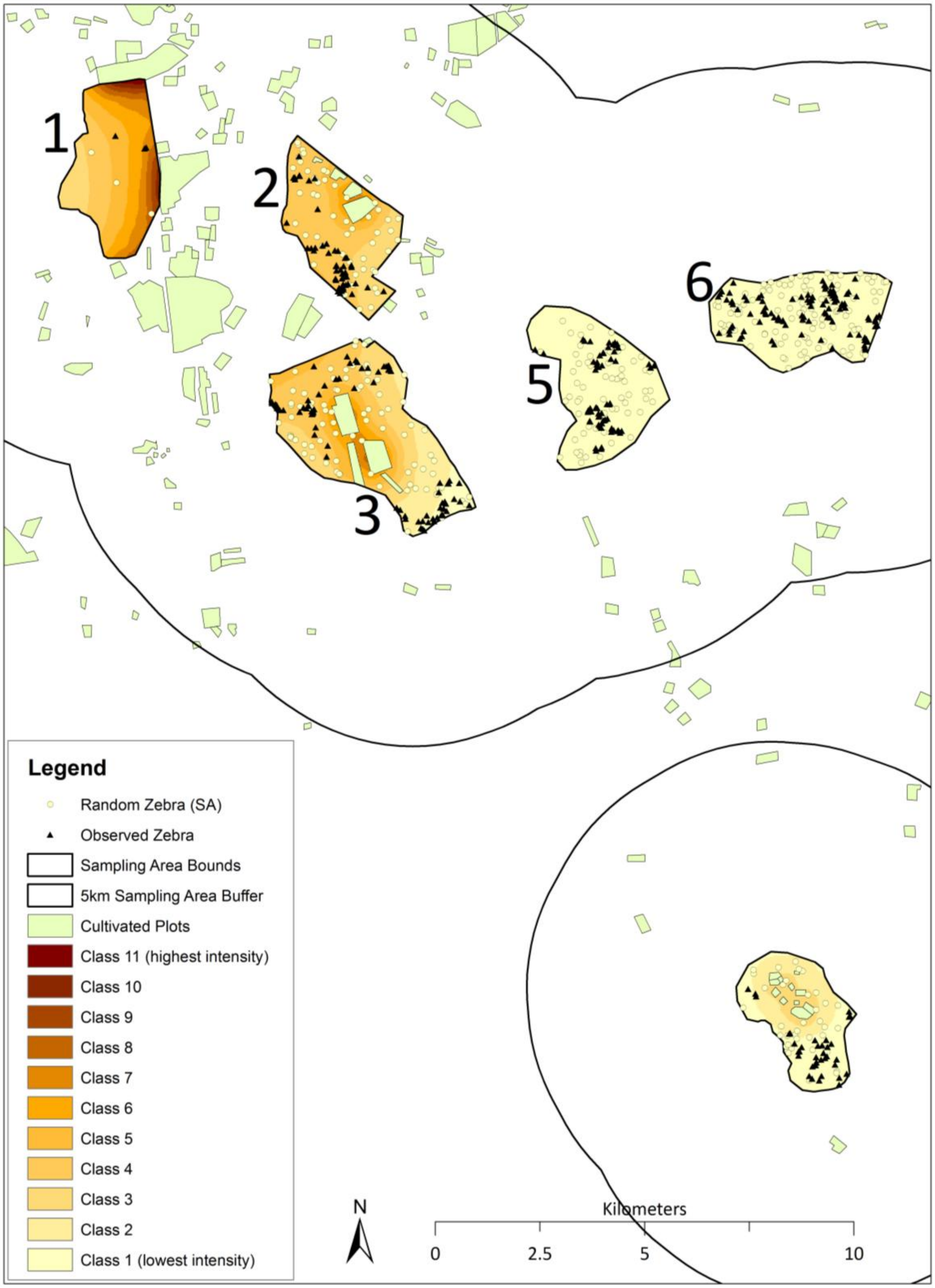
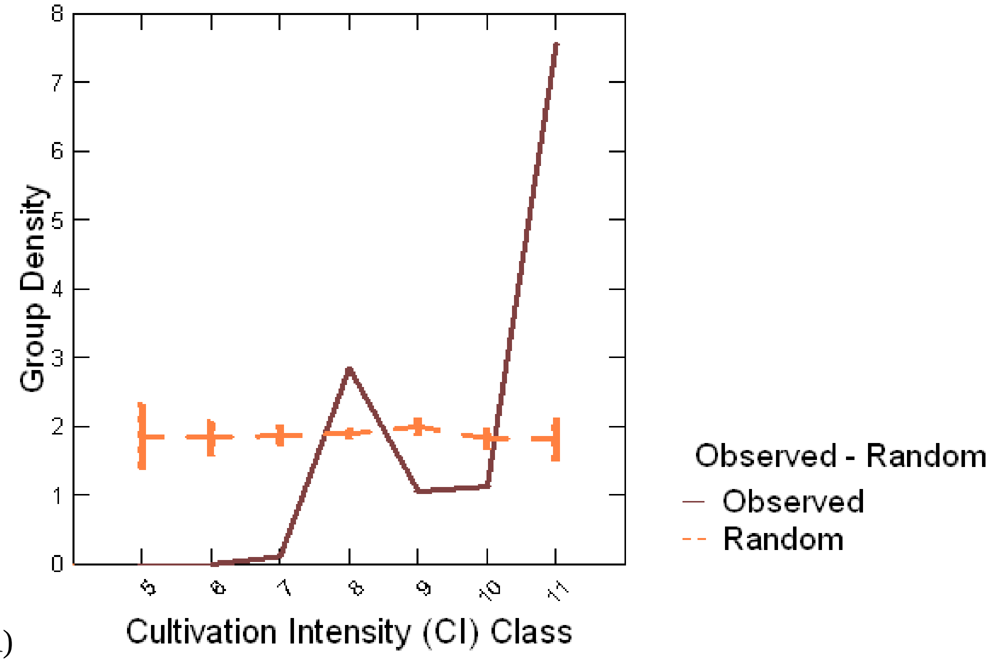


Figure 4.22. Zebra group observations (black triangles) and one of 30 random spatial redistributions of zebra group locations (dots) mapped against an 11-class surface of cultivation intensity (CI).

A)



B)

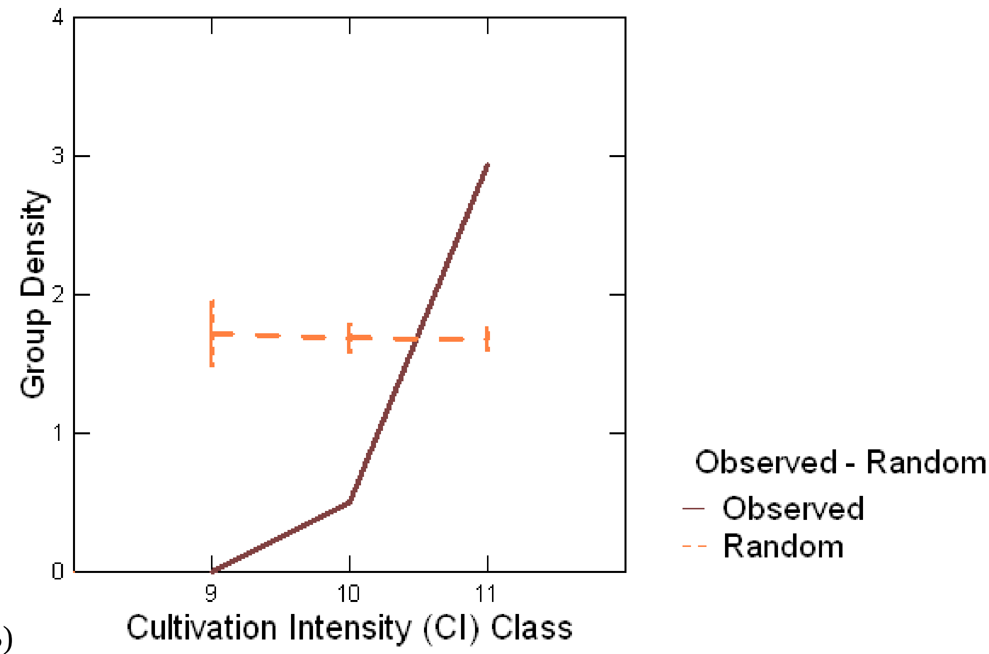


Figure 4.23. Observed distributions of zebra groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the cultivation intensity gradient zones present in each sampling area: SA2+SA3 (A), and SA4 (B). Group Density is measured in #groups/km^2.

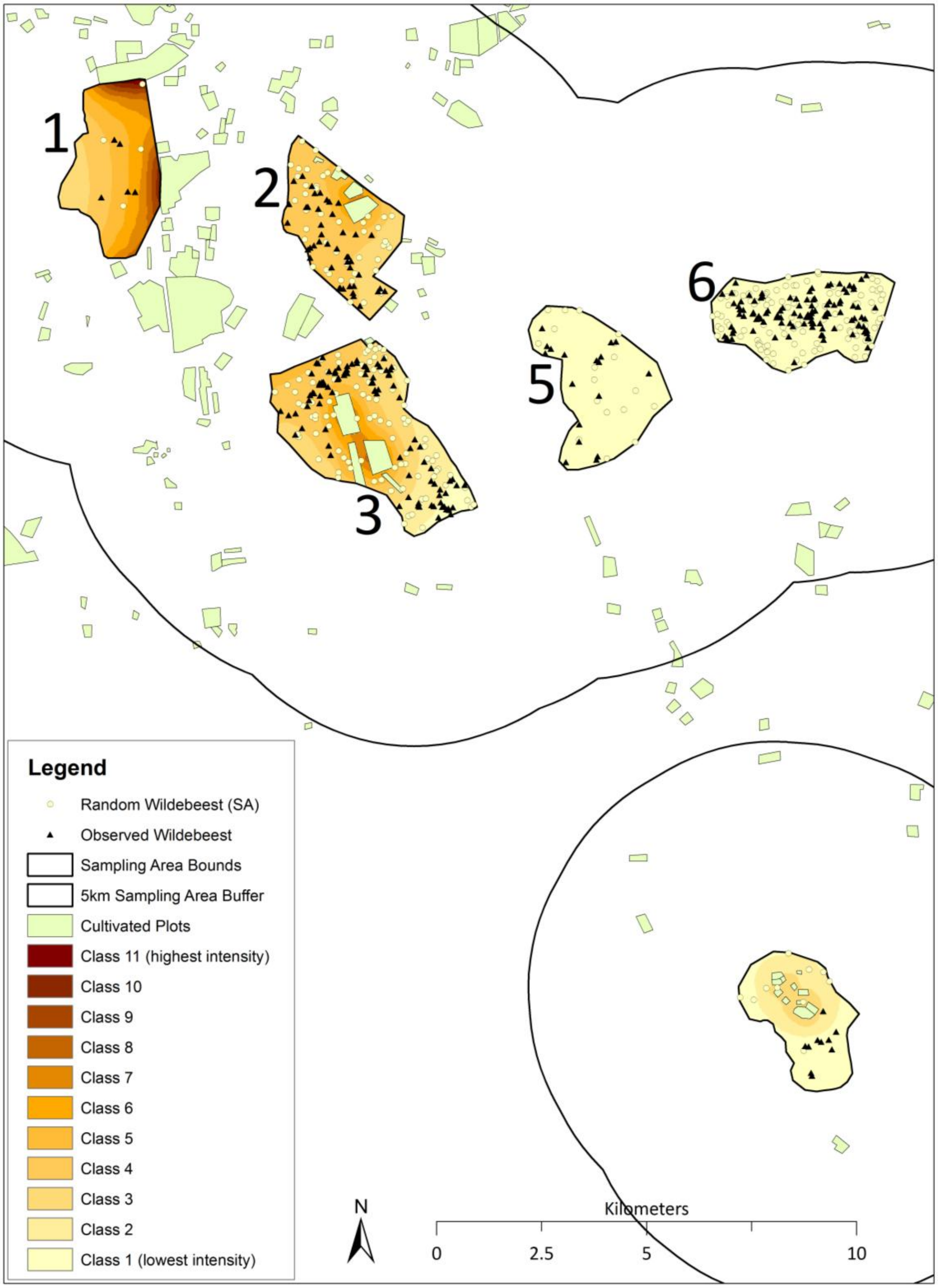
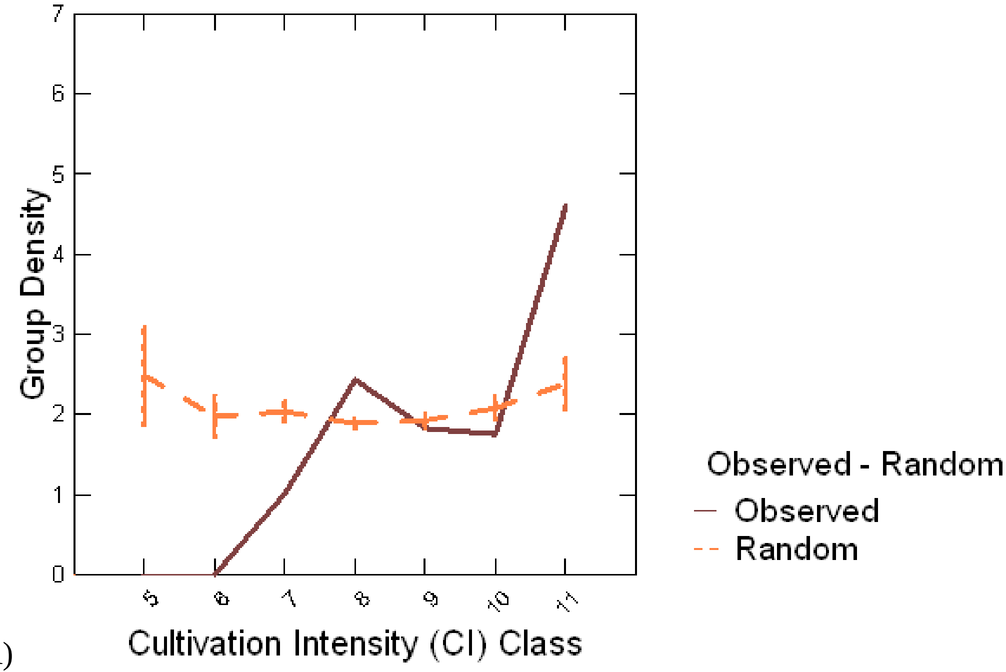
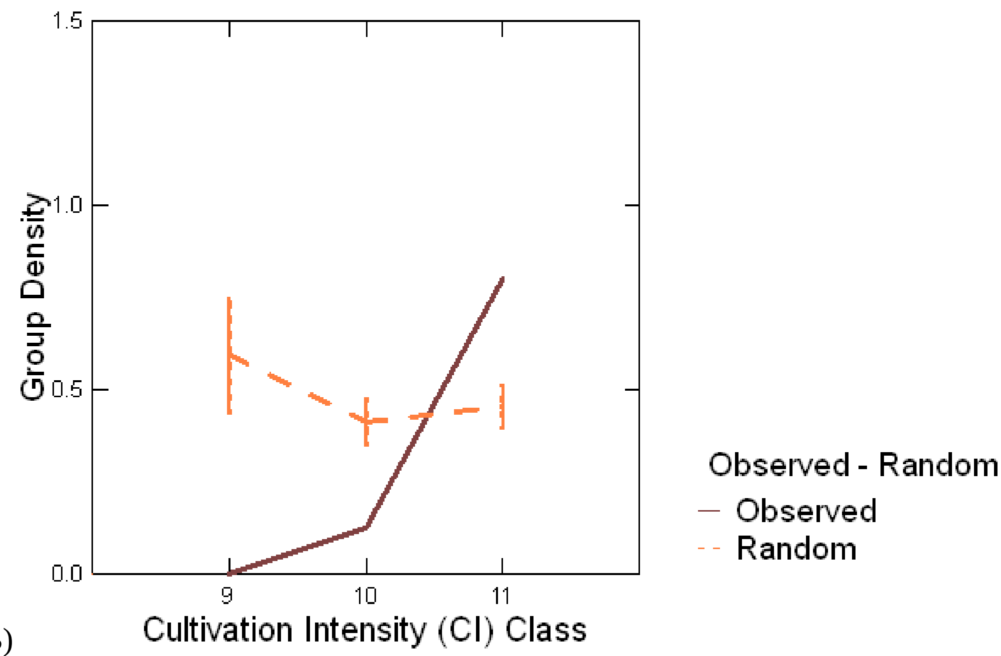


Figure 4.24. Wildebeest group observations (black triangles) and one of 30 random spatial redistributions of wildebeest group locations (dots) mapped against an 11-class surface of cultivation intensity (CI).



A)



B)

Figure 4.25. Observed distributions of wildebeest groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the cultivation intensity gradient zones present in each sampling area: SA2+SA3 (A), and SA4 (B). Group Density is measured in #groups/km^2.

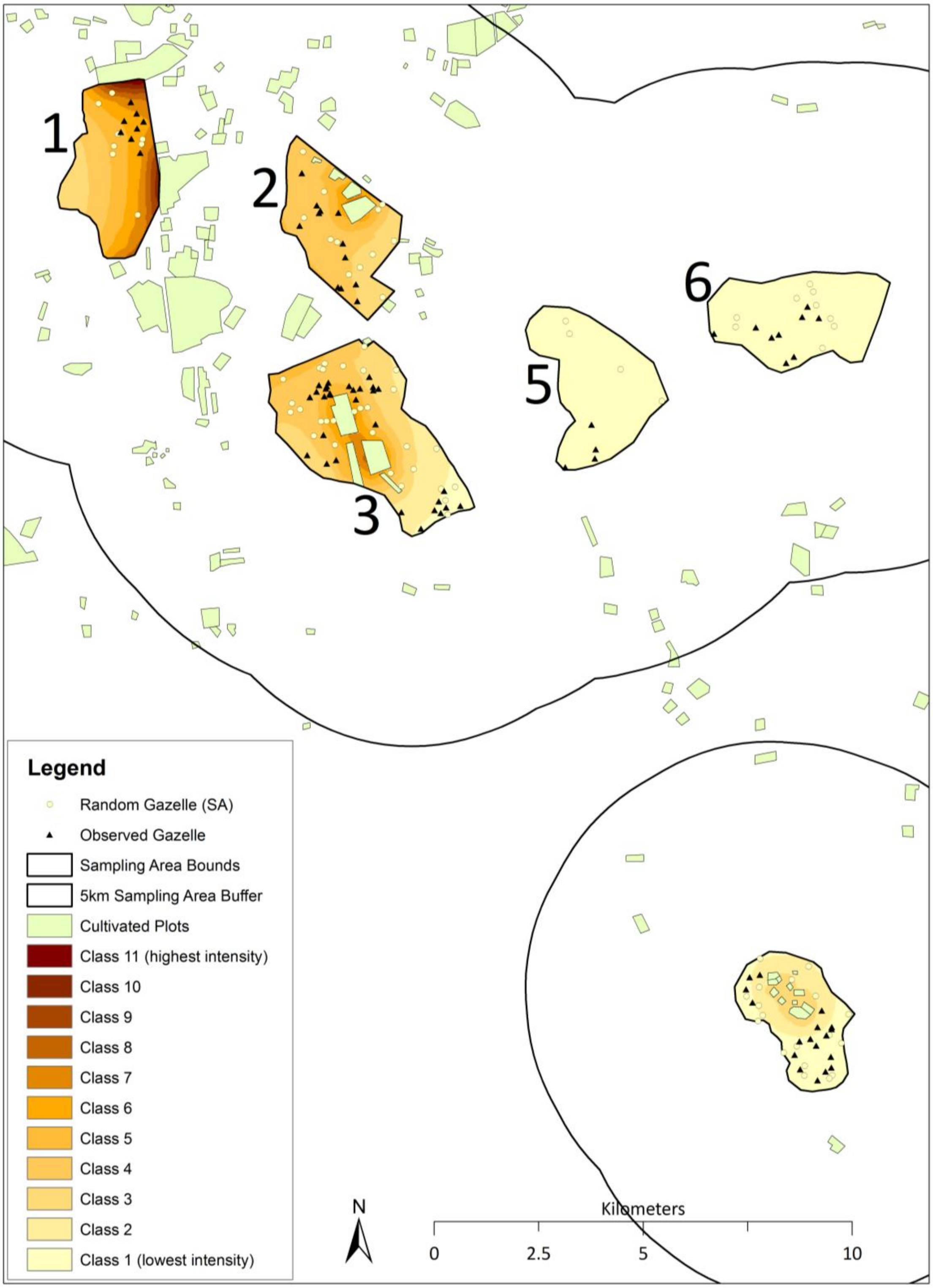
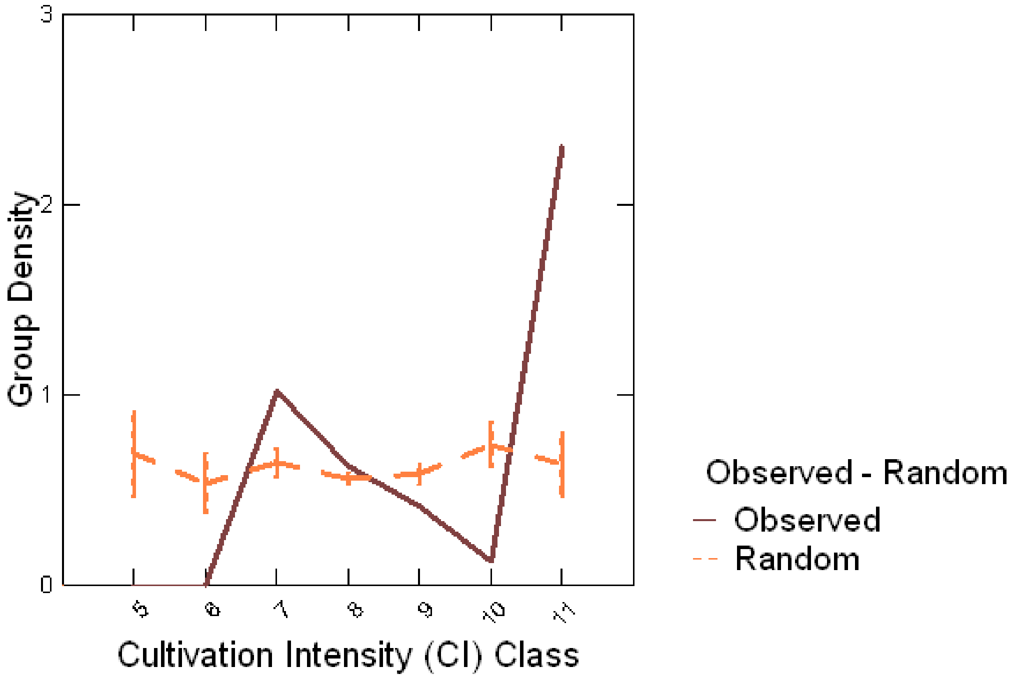
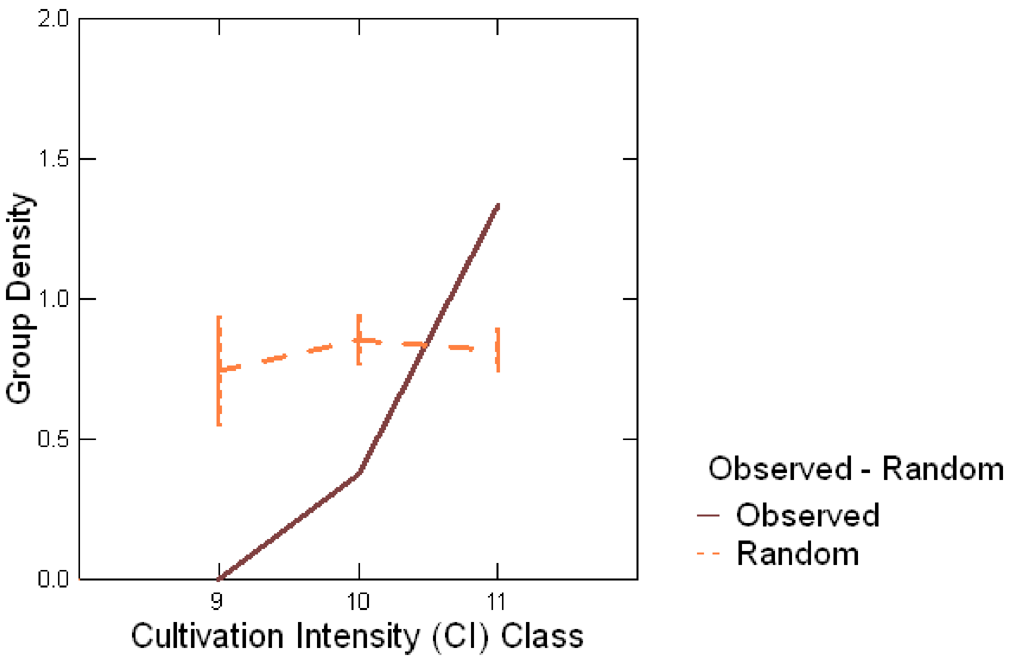


Figure 4.26. Gazelle group observations (black triangles) and one of 30 random spatial redistributions of gazelle group locations (dots) mapped against an 11-class surface of cultivation intensity (CI).



A)



B)

Figure 4.27. Observed distributions of gazelle groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the cultivation intensity gradient zones present in each sampling area: SA2+SA3 (A), and SA4 (B). Group Density is measured in #groups/km^2.

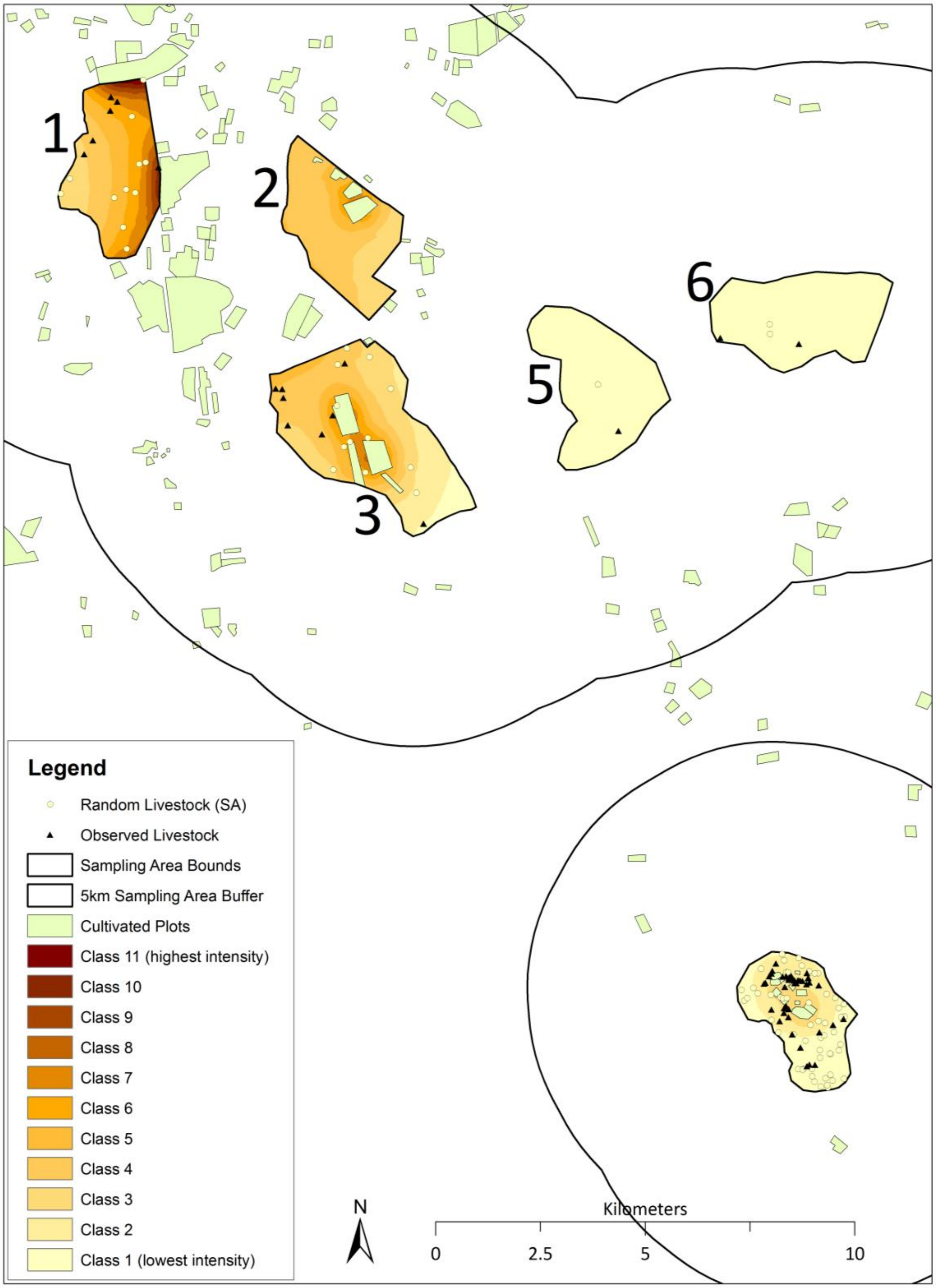
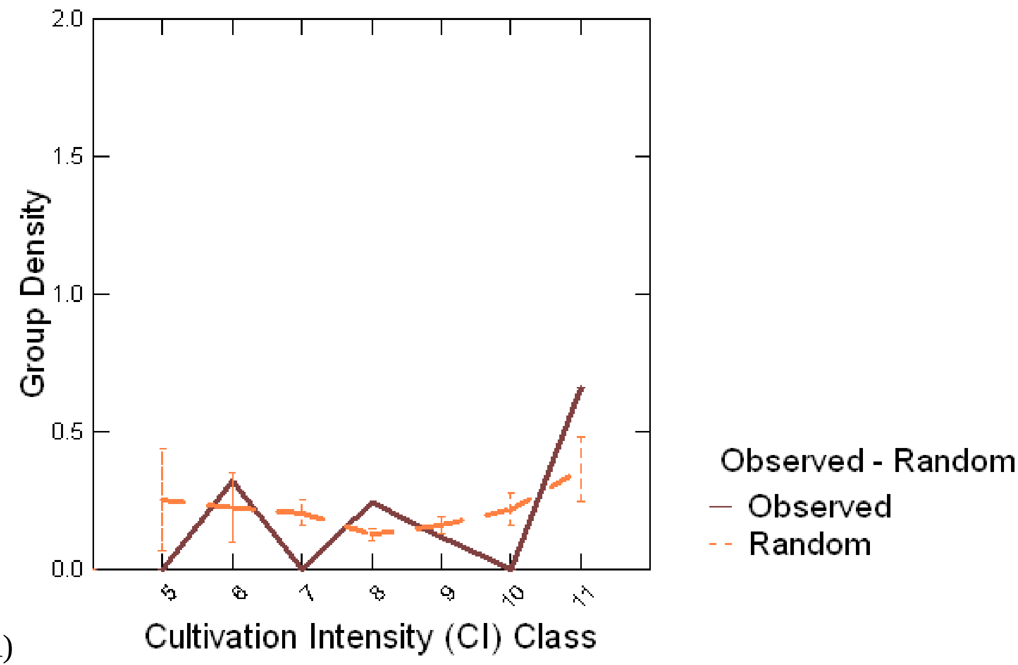


Figure 4.28. Livestock group observations (black triangles) and one of 30 random spatial redistributions of livestock group locations (dots) mapped against an 11-class surface of cultivation intensity (CI).

A)



B)

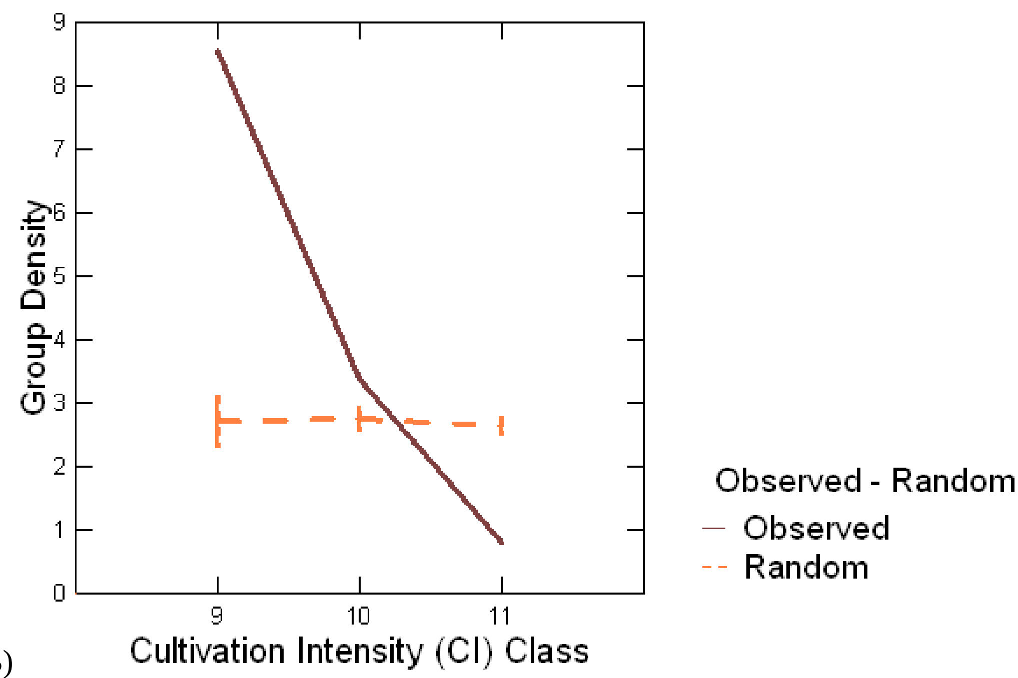


Figure 4.29. Observed distributions of livestock groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the cultivation intensity gradient zones present in each sampling area: SA2+SA3 (A), and SA4 (B). Group Density is measured in #groups/km^2.

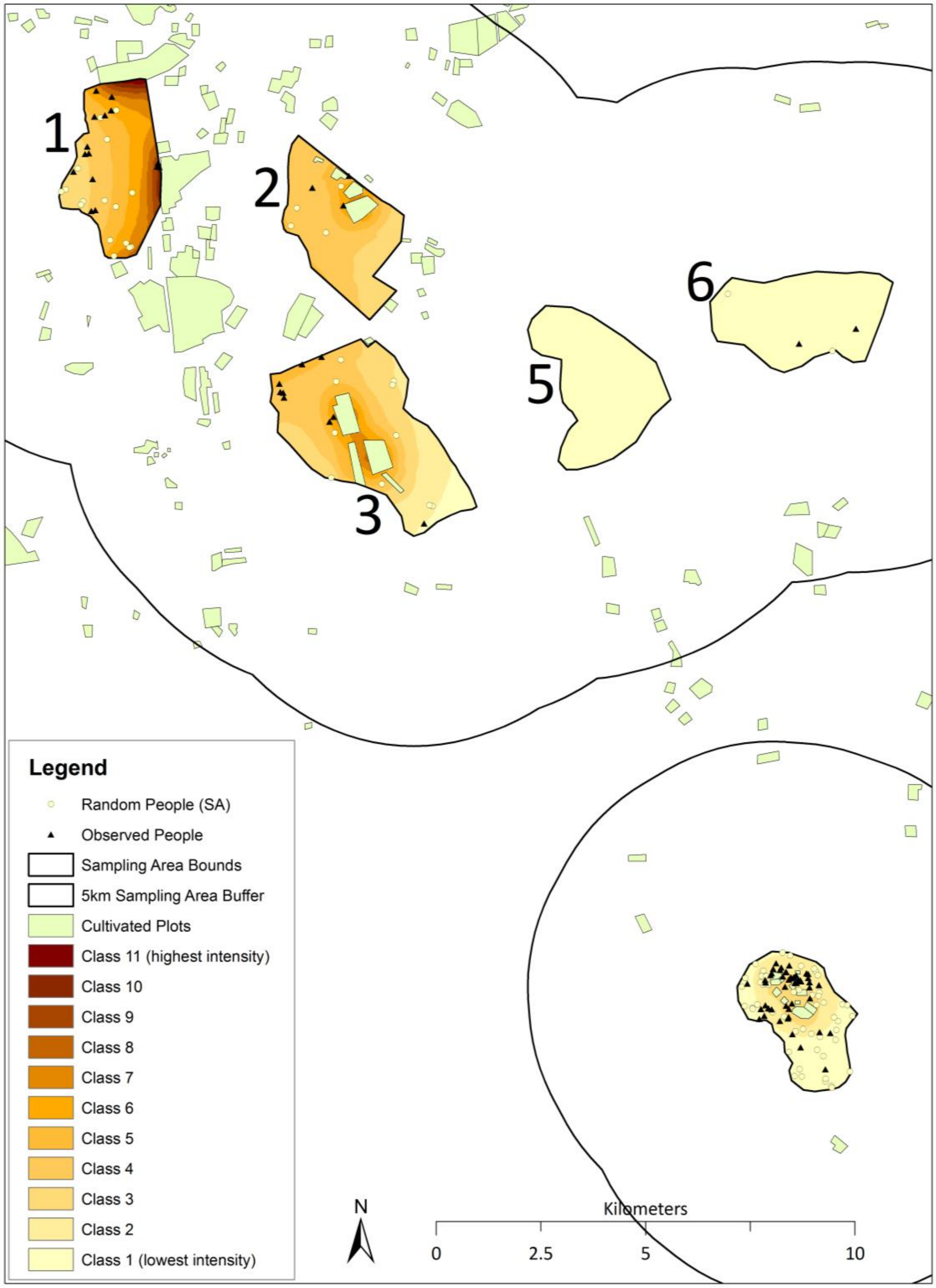
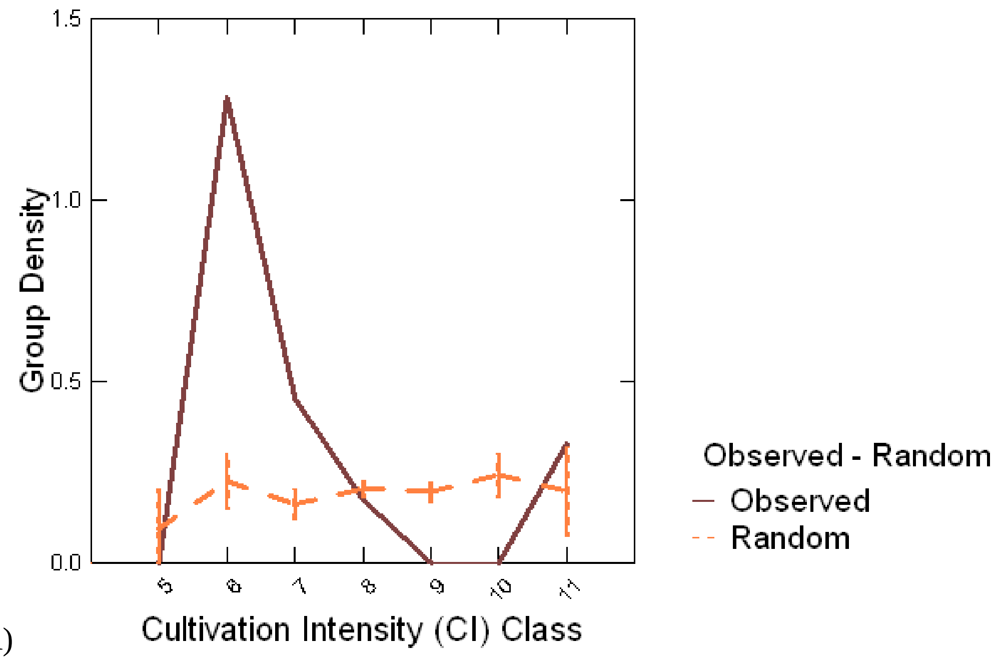
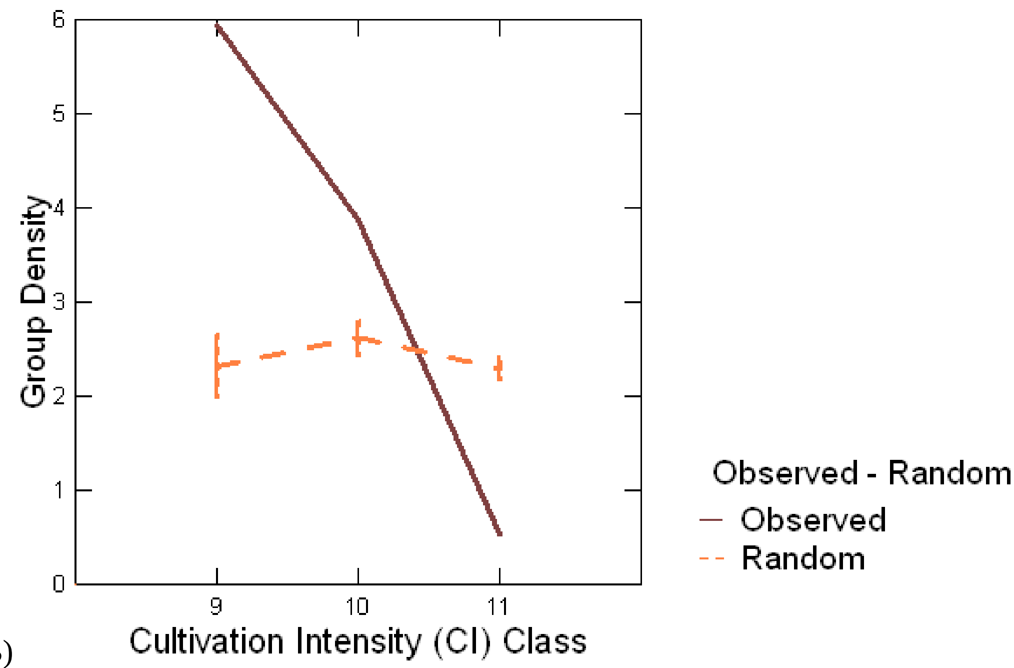


Figure 4.30. People group observations (black triangles) and one of 30 random spatial redistributions of people group locations (dots) mapped against an 11-class surface of cultivation intensity (CI).



A)



B)

Figure 4.31. Observed distributions of people groups in relation to the 95% Confidence Interval of the 30 random spatial redistributions. Group densities are plotted against the cultivation intensity gradient zones present in each sampling area: SA2+SA3 (A), and SA4 (B). Group Density is measured in #groups/km^2.

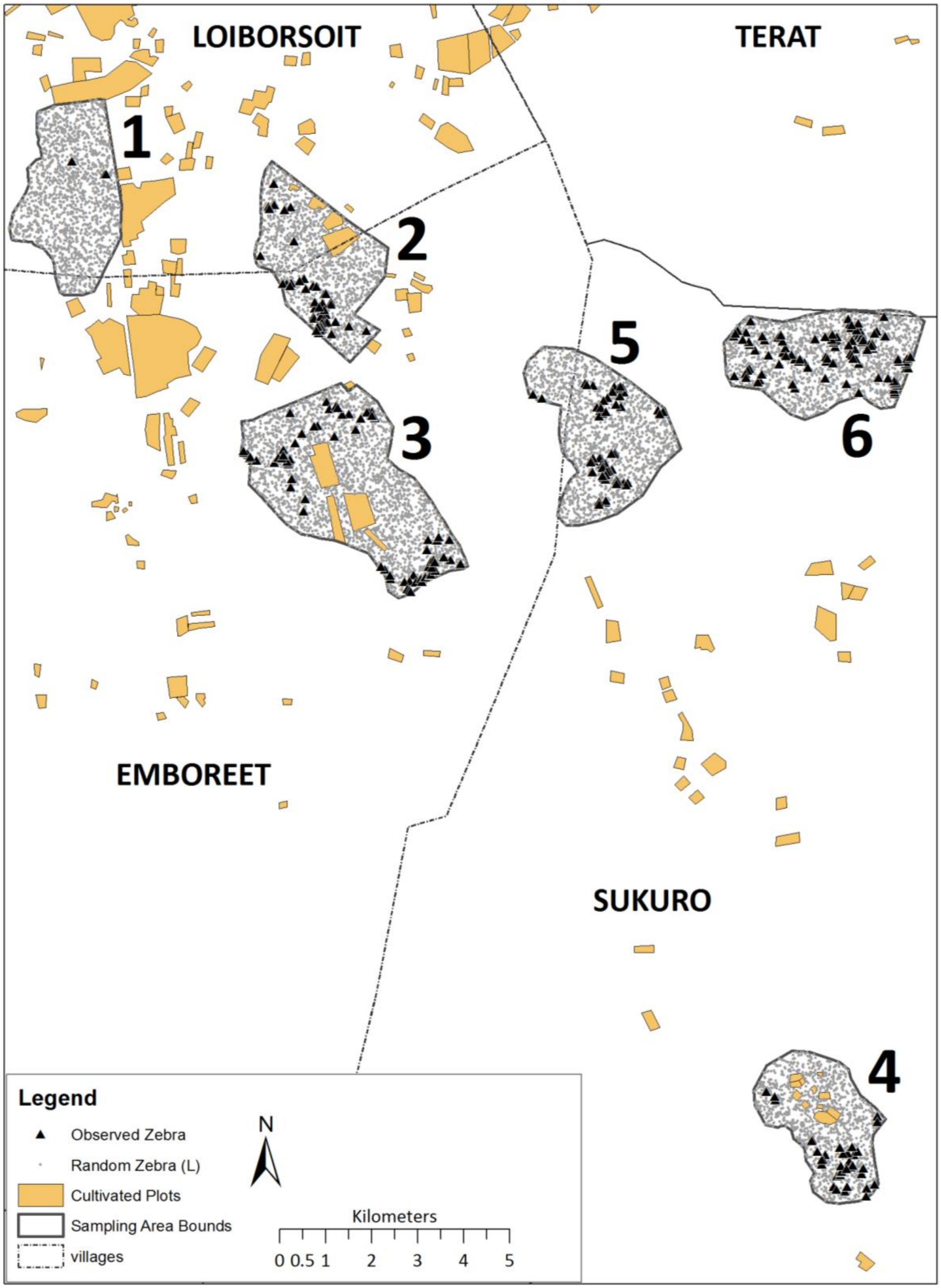


Figure 4.32. Zebra group observations (black triangles) mapped against a background of 30 random spatial redistributions of zebra group locations (gray dots).

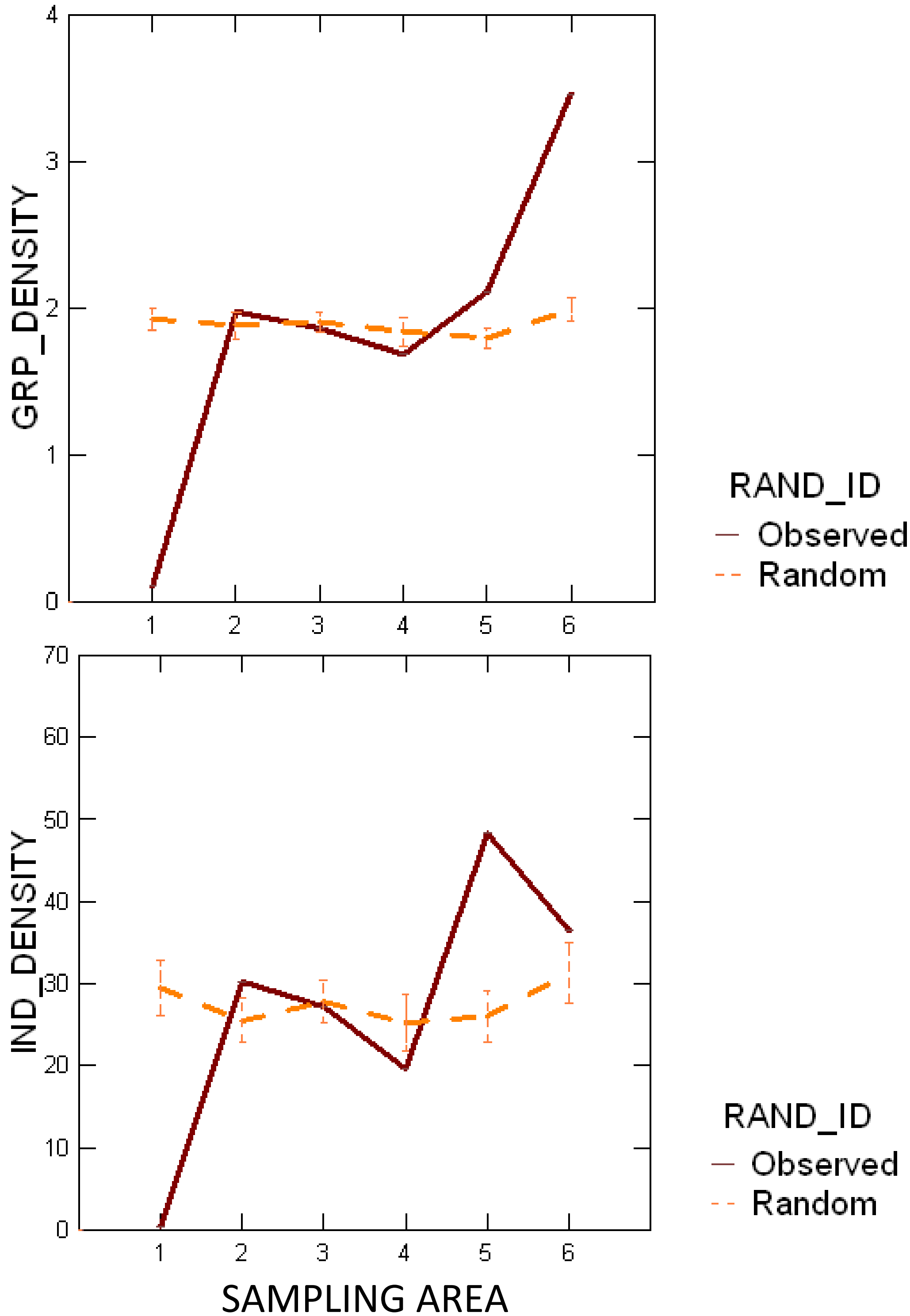


Figure 4.33. Observed distributions of zebra groups (above) and individuals (below) fall outside the 95% Confidence Interval of the 30 random spatial redistributions. Density is measured in #/km2. Observed zebra densities were highest in the sampling area with the lowest CIF, and lowest in the SA with the highest CIF.

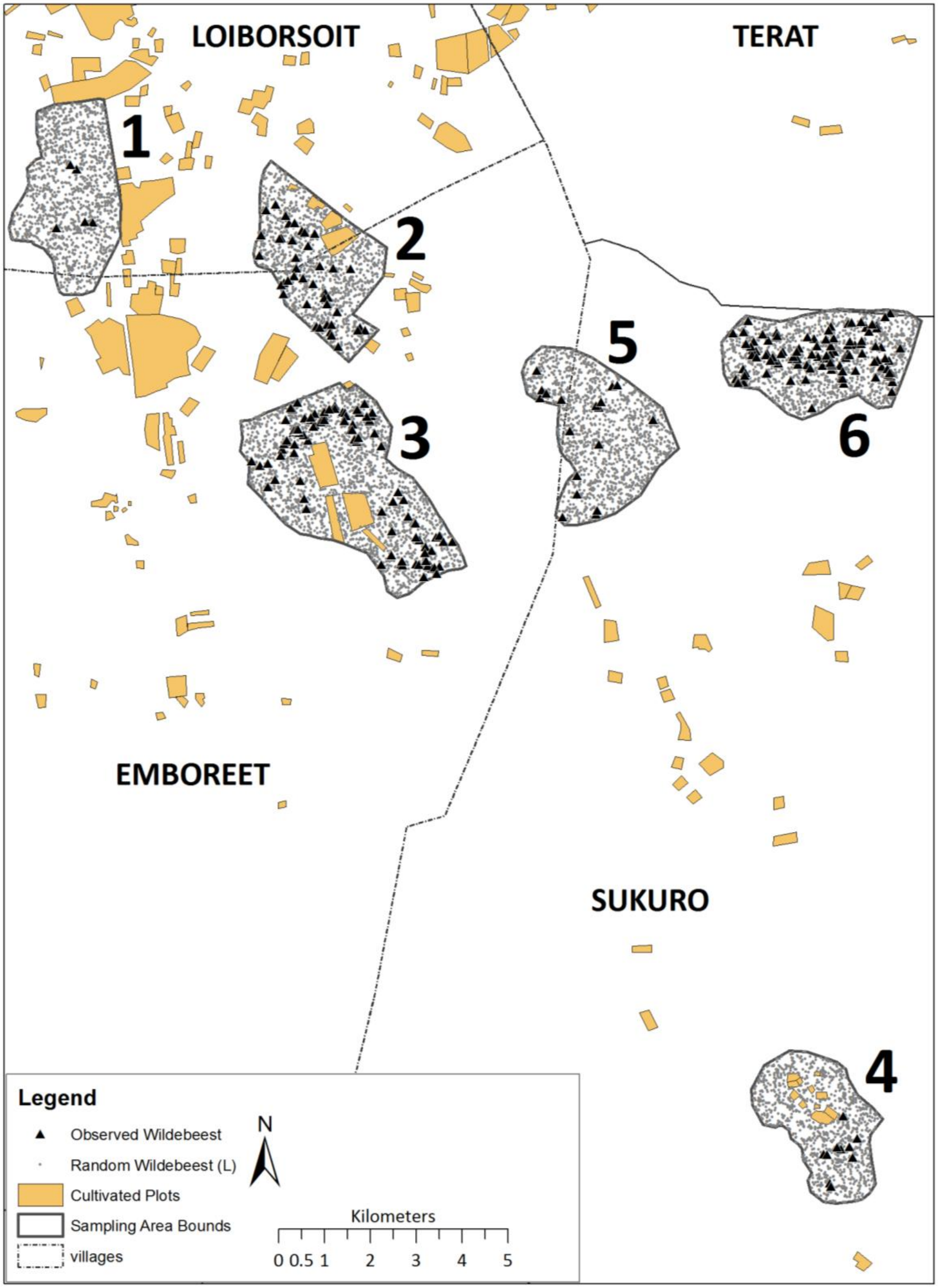


Figure 4.34. Wildebeest group observations (black triangles) mapped against a background of 30 random spatial redistributions of wildebeest group locations (gray dots).

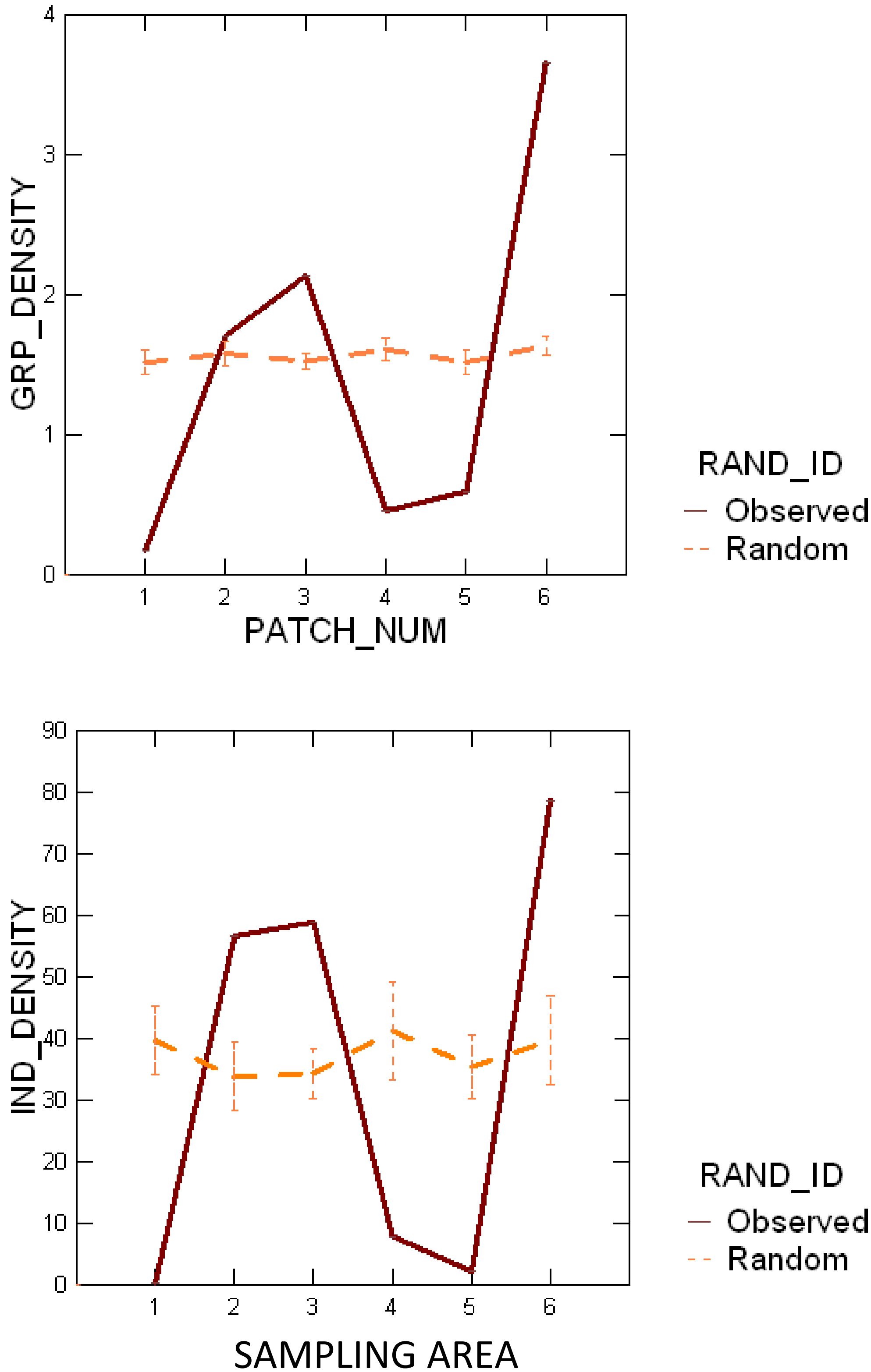


Figure 4.35. Observed distributions of wildebeest groups (above) and individuals (below) do not follow a random distribution, falling outside the 95% Confidence Interval of the 30 random spatial redistributions. Density is measured in #/km2.

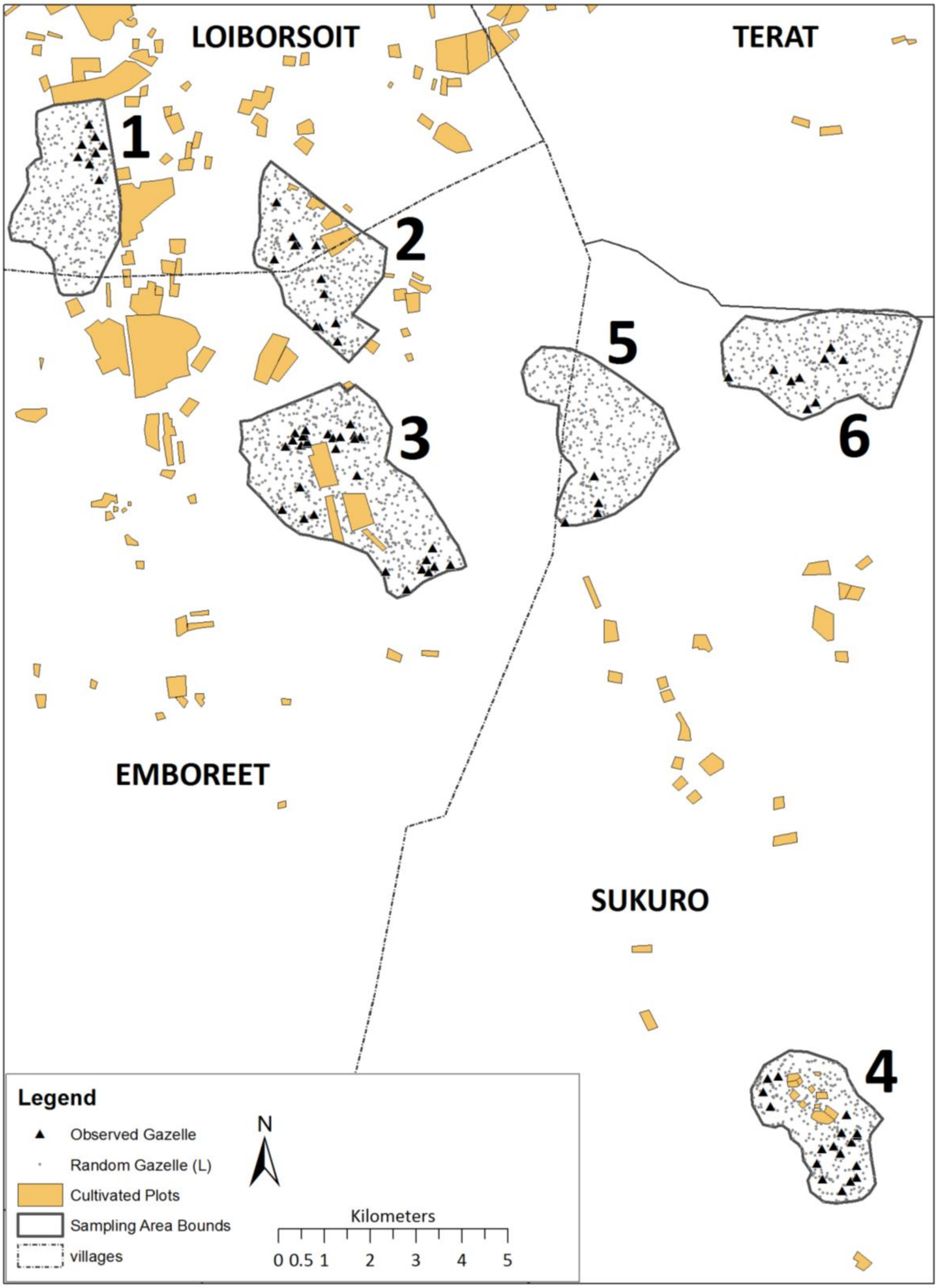


Figure 4.36. Gazelle group observations (black triangles) mapped against a background of 30 random spatial redistributions of gazelle group locations (gray dots).

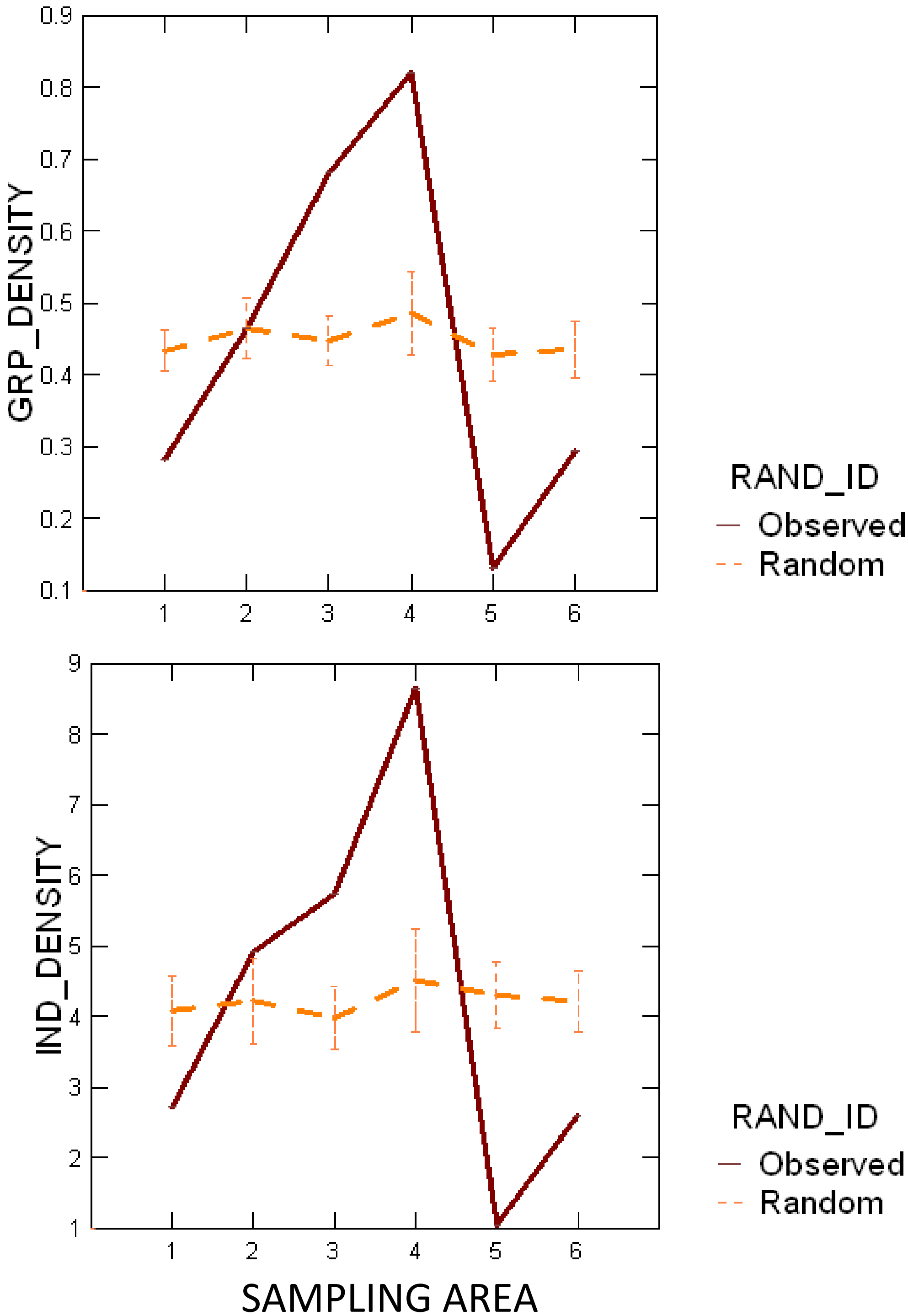


Figure 4.37. Observed distributions of gazelle groups (above) and individuals (below) fall outside the 95% Confidence Interval of the 30 random spatial redistributions. Density is measured in #/km2.

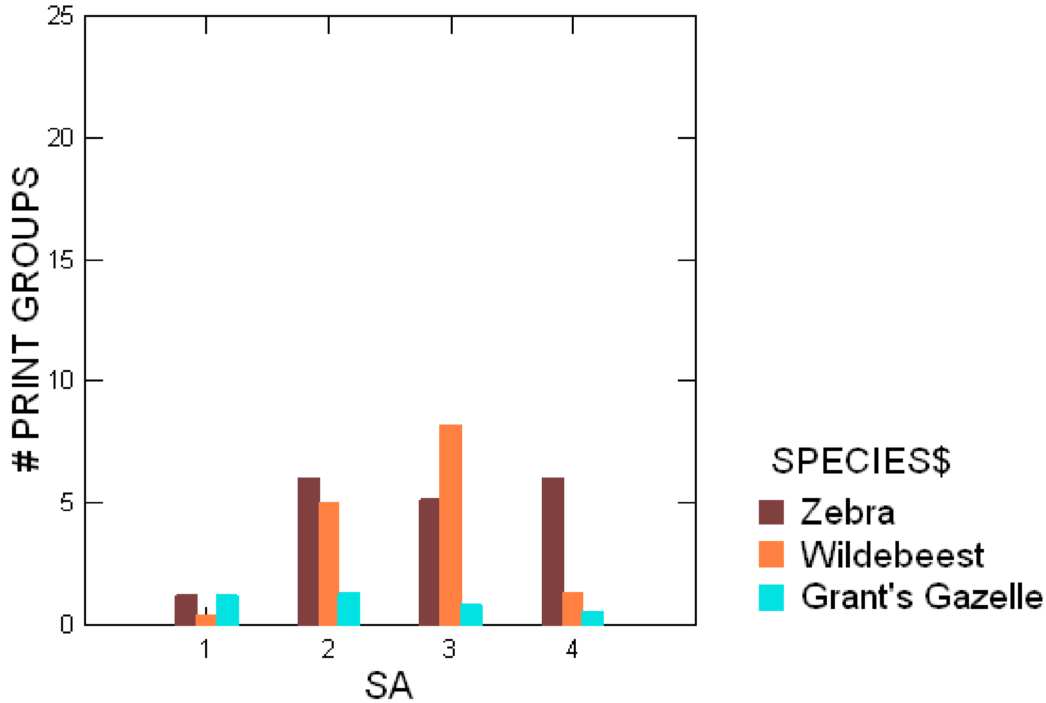


Figure 4.38. Wildlife print groups (#/50m^2) outside of cultivation by sampling area (SA).

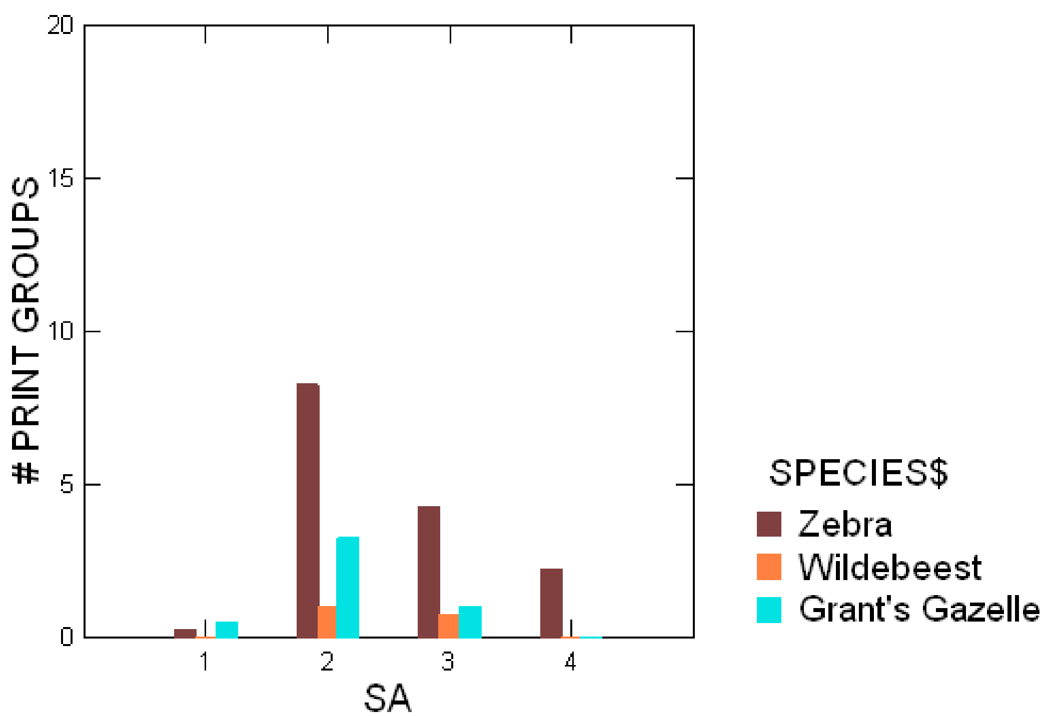


Figure 4.39. Wildlife print groups (#/50m^2) inside of cultivation by sampling area (SA).

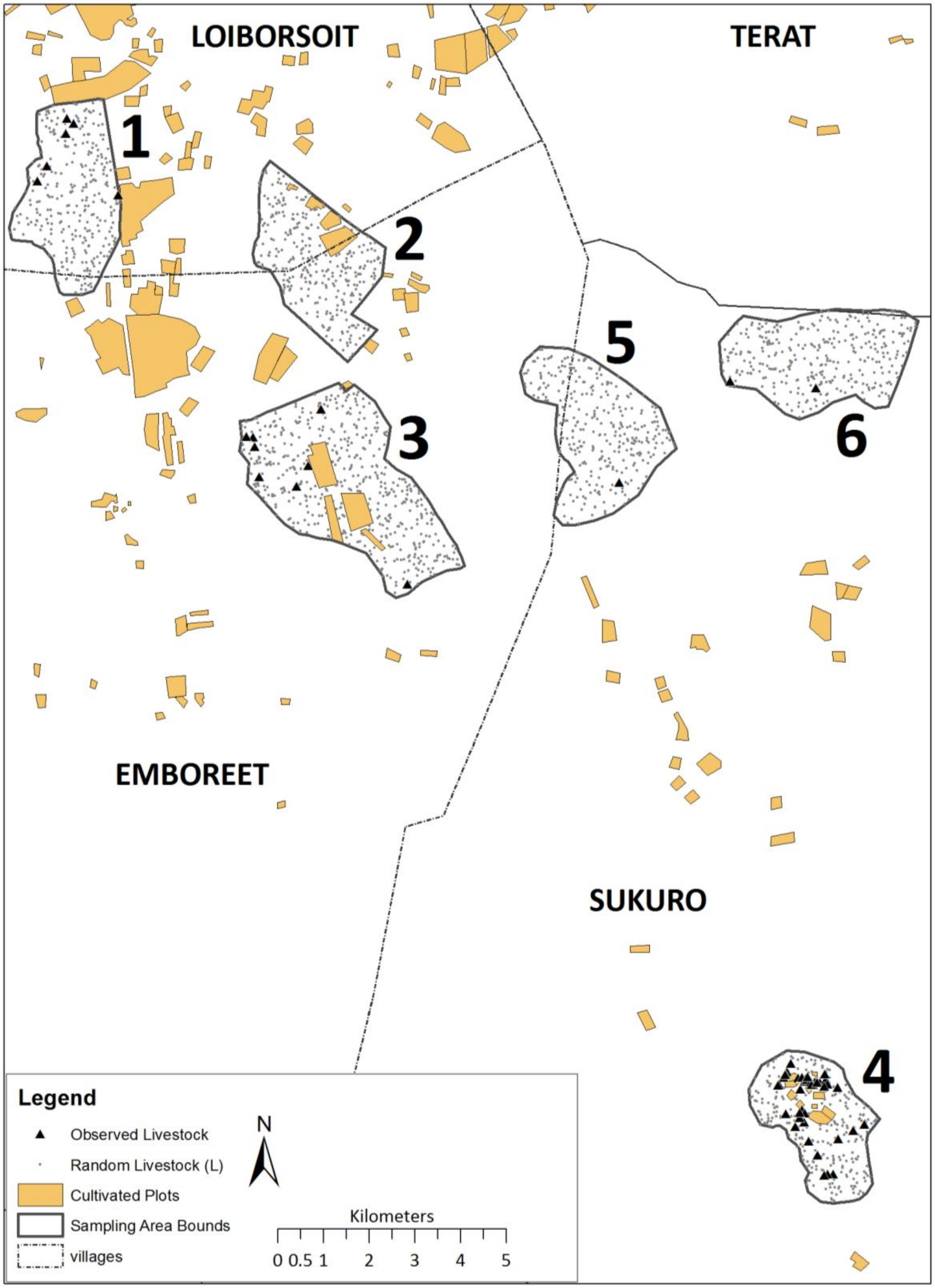


Figure 4.40. Livestock group observations (black triangles) mapped against a background of 30 random spatial redistributions of livestock group locations (gray dots).

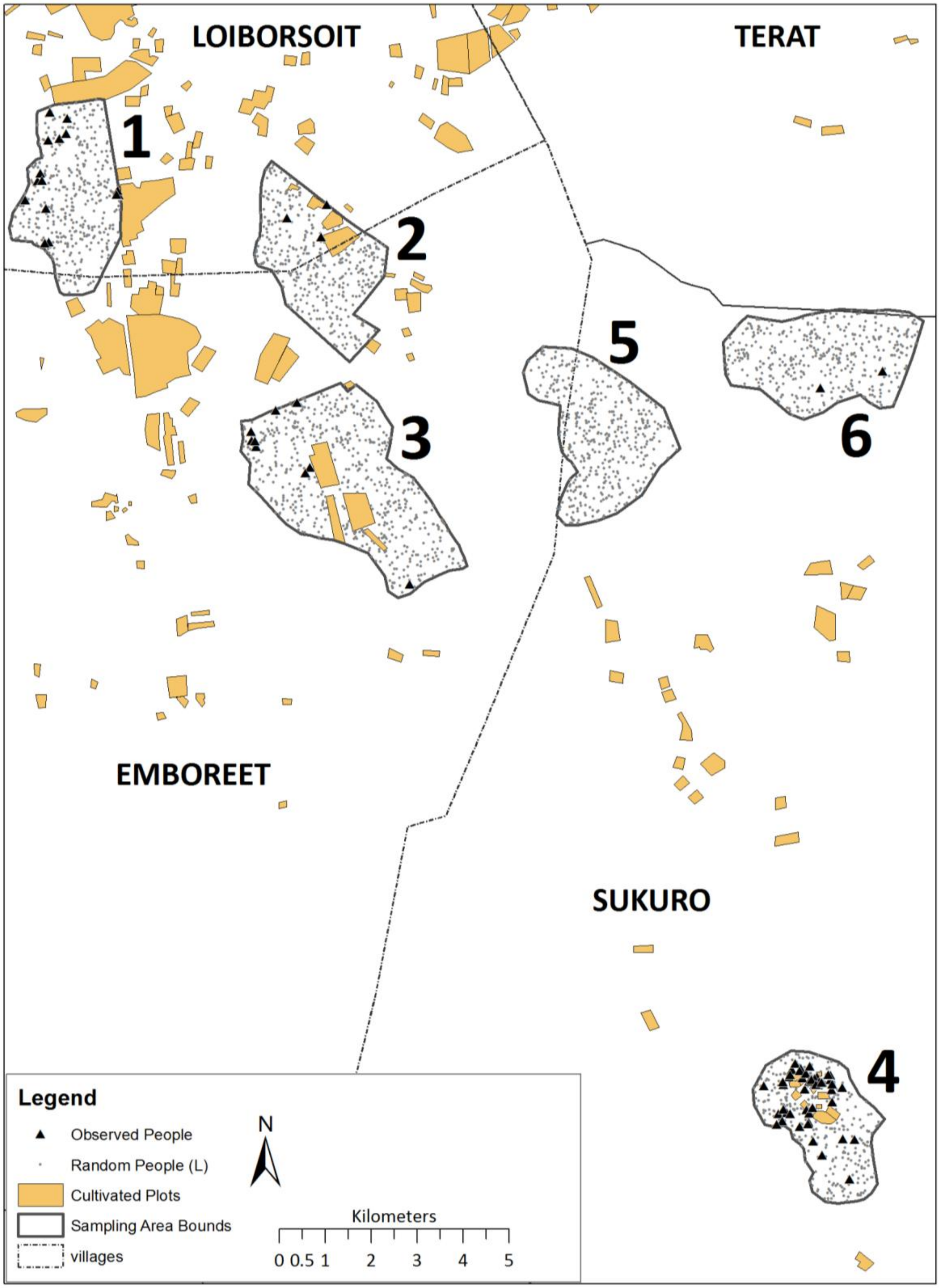


Figure 4.41. People group observations (black triangles) mapped against a background of 30 random spatial redistributions of people group locations (gray dots).

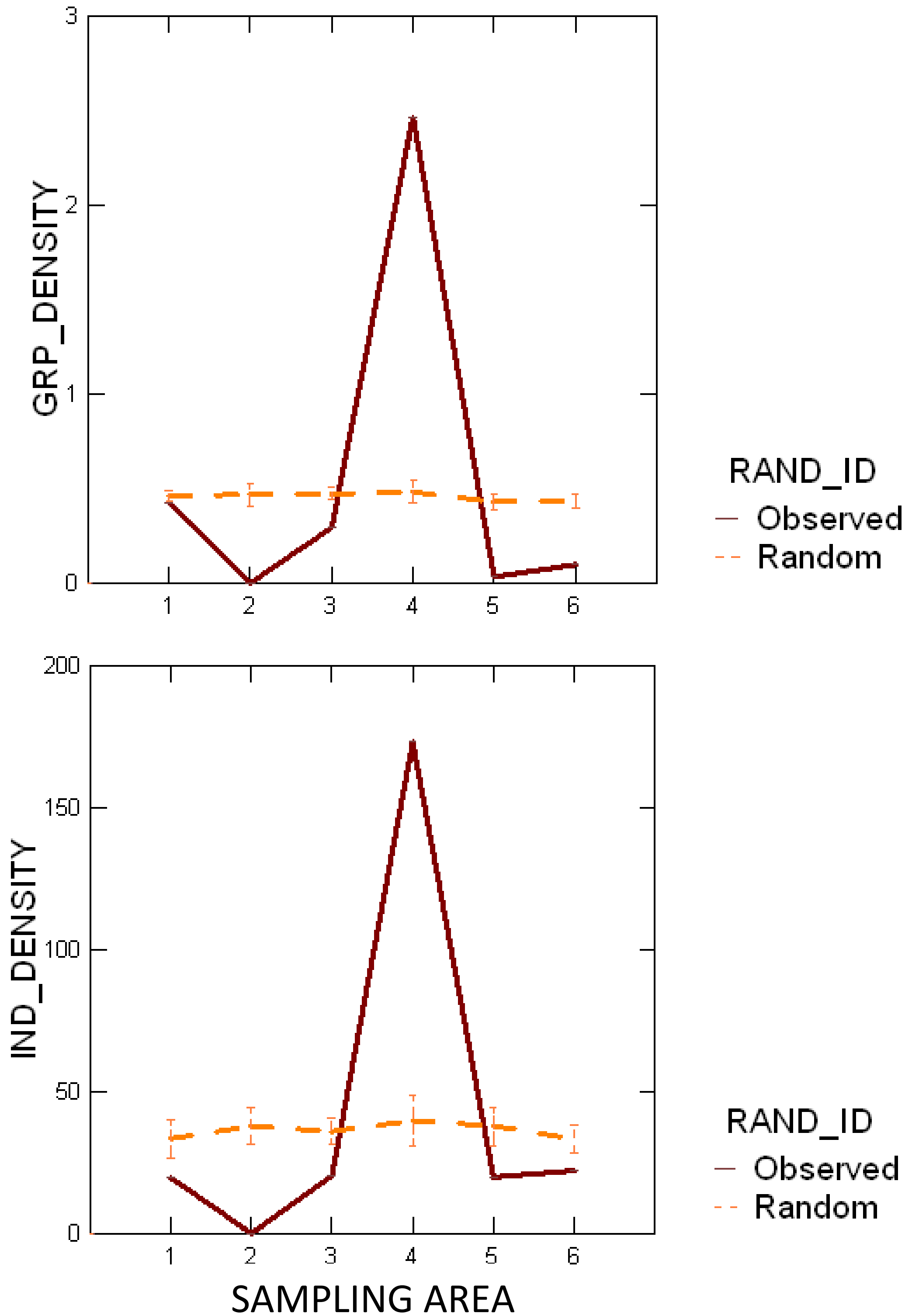


Figure 4.42. Observed distributions of livestock groups (above) and individuals (below) peak in SA4, the SA of greatest human observations. Density is measured in #/km2.

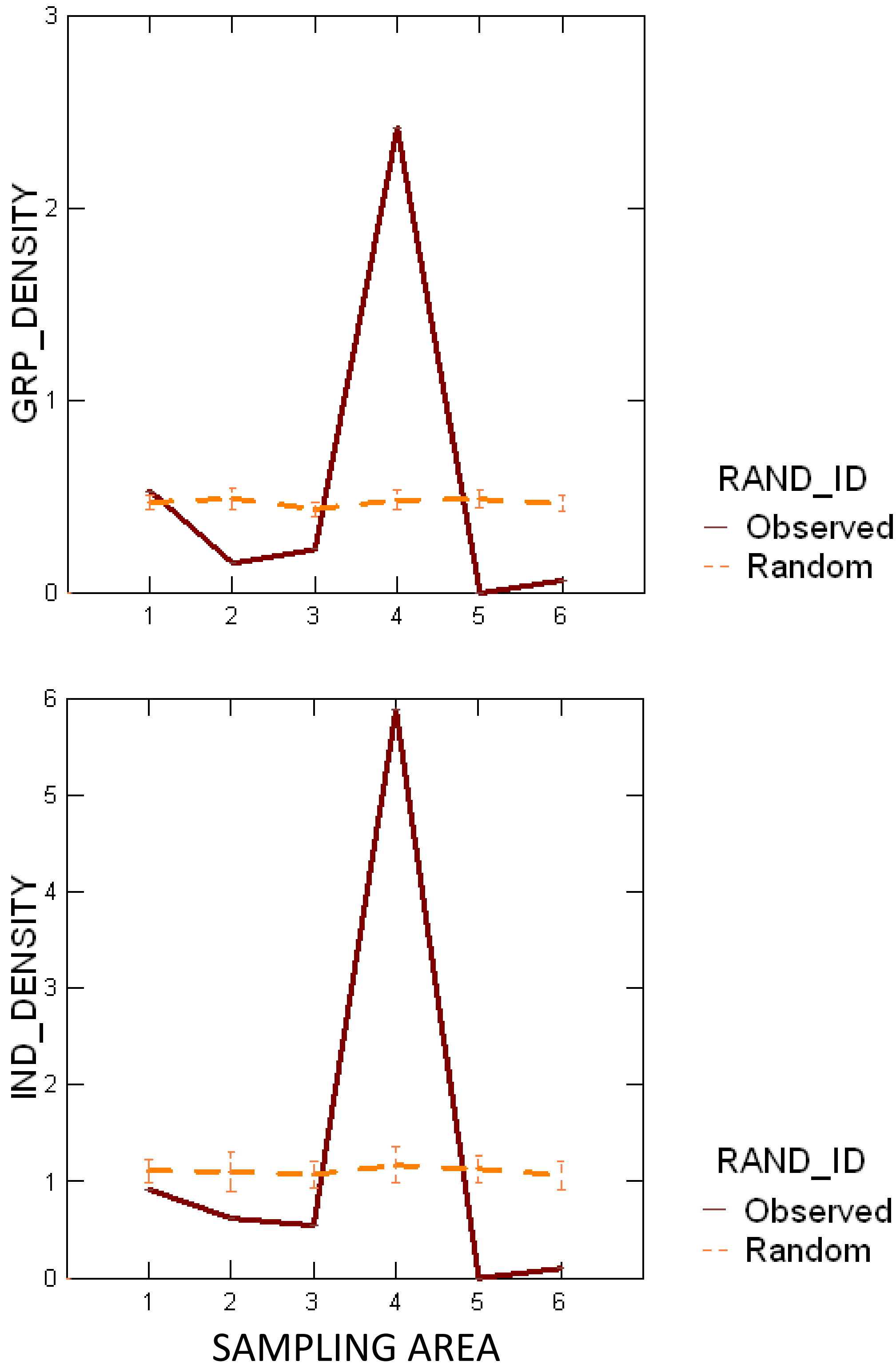


Figure 4.43. Observed distributions of people groups (above) and individuals (below) peak in SA4, similar to livestock. Density is measured in #/km2.

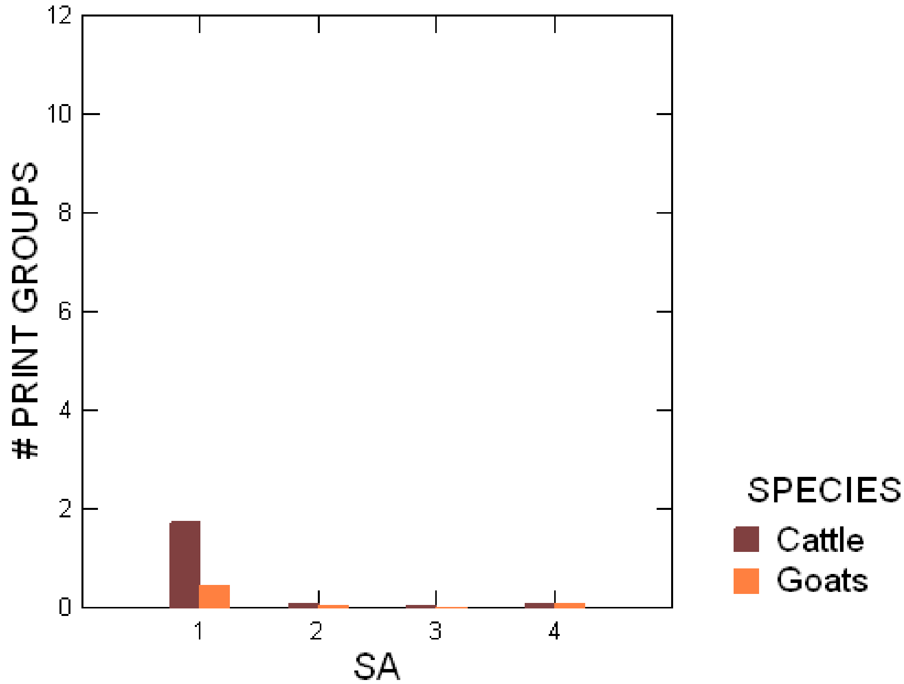


Figure 4.44. Livestock print groups (#/50m^2) outside of cultivation by sampling area (SA).

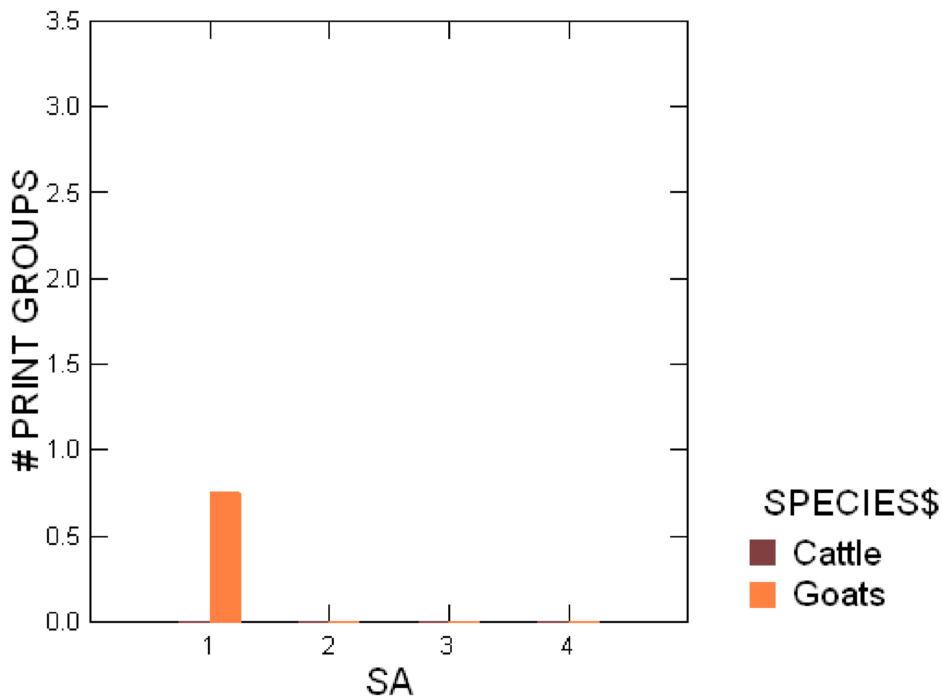


Figure 4.45. Livestock print groups (#/50m^2) inside of cultivation by sampling area (SA).

APPENDIX 4.1A: RANDOMIZATION AML (ARC MACRO LANGUAGE) PROGRAM TO CREATE A PASTURE-SCALE NULL MODEL IN ESRI ARCINFO

RAND_ALL.AML

```
&args cov  seed

/* Running this program with RND_PCH will randomize points within
/* a sampling area (or patch).
/* The random locations may only fall within the sampling area of
/* origin.

/* &sv seed = [ response 'Enter a random seed:' 1 ]
&sv r [ random %seed% ]

arcedit

editc %cov%
backcov patchc
backen arcs

drawen points
editf points
coord keyboard

/* Columns = ID, Patch (orig & rand), UTM-X (orig), UTM-Y (orig)
/* For a full list of points, please see Chapter 4, Appendix 1

&run rnd_sa          1    5  231920.406 9561769.000
&run rnd_sa          2    5  231915.609 9561815.000
&run rnd_sa          3    5  231904.031 9561867.000
&run rnd_sa          4    5  231915.609 9561815.000
&run rnd_sa          5    5  231980.938 9561955.000
…
&run rnd_sa        933    2  219278.969 9563756.000
&run rnd_sa        934    2  219288.547 9563646.000
&run rnd_sa        935    2  219290.969 9563777.000
&run rnd_sa        936    2  219500.094 9563612.000
&run rnd_sa        937    2  219388.578 9563669.000

&type Done with everything
save
coord cursor

quit
```

RND_SA.AML

```
&args  recid  patch  org_x org_y

select rec_id = %recid%

&sv v -1

&do &until ( ( %v% > 0 ) and ( %v% = %patch% ) )
   &sv x [ random  207088  241242 ]
   &sv y [ random  9535163  9577132 ]

   arcplot
     &sv v [ show cellvalue patches %x% %y% ]
   q
/*   &lv v
&end

move
  1, %org_x%, %org_y%
  1, %x%, %y%

draw

&type Done with %recid%
```

APPENDIX 4.1B: RANDOMIZATION AML (ARC MACRO LANGUAGE) PROGRAM TO CREATE A LANDSCAPE-SCALE NULL MODEL IN ESRI ARCINFO

RAND_ALL.AML

```
&args cov  seed

/* Running this program with RND_PCH will randomize points within
/* a sampling area (or patch).
/* The random locations may only fall within the sampling area of
/* origin.

/* &sv seed = [ response 'Enter a random seed:' 1 ]
&sv r [ random %seed% ]

arcedit

editc %cov%
backcov patchc
backen arcs

drawen points
editf points
coord keyboard

/* Columns = ID, Patch (orig & rand), UTM-X (orig), UTM-Y (orig)

&run rnd_sa          1    5  231920.406 9561769.000
&run rnd_sa          2    5  231915.609 9561815.000
&run rnd_sa          3    5  231904.031 9561867.000
&run rnd_sa          4    5  231915.609 9561815.000
&run rnd_sa          5    5  231980.938 9561955.000
…
&run rnd_sa        933    2  219278.969 9563756.000
&run rnd_sa        934    2  219288.547 9563646.000
&run rnd_sa        935    2  219290.969 9563777.000
&run rnd_sa        936    2  219500.094 9563612.000
&run rnd_sa        937    2  219388.578 9563669.000

&type Done with everything
save
coord cursor

quit
```

RND_SA.AML

```
&args  recid  patch  org_x org_y

select rec_id = %recid%

&sv v -1

&do &until ( ( %v% > 0 ) and ( %v% = %patch% ) )
   &sv x [ random  207088  241242 ]
   &sv y [ random  9535163  9577132 ]

   arcplot
     &sv v [ show cellvalue patches %x% %y% ]
   q
/*   &lv v
&end

move
  1, %org_x%, %org_y%
  1, %x%, %y%

draw

&type Done with %recid%
```

Appendix 4.2: Absence Data Insertion VBA (Visual Basic for Applications) Program for Microsoft Excel Database of Wildlife Observations

```
'Cultivation Index data
Option Explicit

Dim Rand_ID As Integer 'ID number
Dim SPP As Integer 'SPP Index
Dim SPP_ID As Integer ' Spp ID
Dim SPP_CHECK As Integer
Dim Patch As Integer 'Patch number
Dim Groups As Integer 'Number of groups in patch
Dim Individuals As Integer 'Number of Individuals in patch
Dim Area As Double 'Area within patch
Dim GRP_DENSE As Double 'Group density within patch
Dim IND_DENSE As Double ' Density of individuals within patch
Dim Dist As Integer ' index for distance class
Dim Min_Dist As Integer ' first distance class with values for patch
Dim Max_Dist As Integer ' number of distance classes for patch
Dim Record As Integer 'index for records

Sub Enter_Null_Records()

Worksheets("WITHIN_CI_RAND_NEW").Activate

Rand_ID = 0
SPP = 1
Patch = 1
Groups = 0
Individuals = 0
Area = 0
GRP_DENSE = 0
IND_DENSE = 0
Dist = 1
Min_Dist = 0
Max_Dist = 0
Record = 1

For Patch = 1 To 6
 Select Case Patch
    Case 1
        Min_Dist = 1
        Max_Dist = 10
    Case 2
        Min_Dist = 5
        Max_Dist = 9
    Case 3
        Min_Dist = 4
        Max_Dist = 11
    Case 4
        Min_Dist = 9
        Max_Dist = 11
```

```
    Case 5
        Min_Dist = 11
        Max_Dist = 11
    Case 6
        Min_Dist = 11
        Max_Dist = 11
 End Select
    SPP = 1
    For SPP = SPP To 10
        Call ID_SPP
        SPP_CHECK = 1
        For SPP_CHECK = 1 To 10
            If Cells(Record + 1, 2) <> SPP_ID Then
              SPP = SPP + 1
              Call ID_SPP
            End If
        Next SPP_CHECK
      For Dist = Min_Dist To Max_Dist
        Area = Worksheets("Lookup_Area").Cells(Patch * 15 - 12 + Dist,
3)
        For Rand_ID = 0 To 30
            If Cells(Record + 1, 1) <> Rand_ID Then
                Call Insert
            ElseIf Cells(Record + 1, 4) <> Dist Then
                Call Insert
            End If
            Record = Record + 1
        Next Rand_ID
      Next Dist
    Next SPP
Next Patch

End Sub
Sub ID_SPP()
        Select Case SPP
            Case 1
                SPP_ID = 101
            Case 2
                SPP_ID = 102
            Case 3
                SPP_ID = 103
            Case 4
                SPP_ID = 104
            Case 5
                SPP_ID = 130
            Case 6
                SPP_ID = 201
            Case 7
                SPP_ID = 204
            Case 8
                SPP_ID = 206
            Case 9
                SPP_ID = 230
            Case 10
                SPP_ID = 301
        End Select
End Sub
```

```
Sub Insert()

                Rows(Record + 1).Select
                Selection.Insert Shift:=xlDown
                Cells(Record + 1, 1) = Rand_ID
                Cells(Record + 1, 2) = SPP_ID
                Cells(Record + 1, 3) = Patch
                Cells(Record + 1, 4) = Dist
                Cells(Record + 1, 5) = Groups
                Cells(Record + 1, 6) = Individuals
                Cells(Record + 1, 7) = Area
                Cells(Record + 1, 8) = Groups / Area
                Cells(Record + 1, 9) = Individuals / Area
                Rows(Record + 1).Select
                    With Selection.Interior
                        .ColorIndex = 6
                        .Pattern = xlSolid
                    End With
End Sub
```

APPENDIX 4.3: SAMPLING AREA CI AND ED AREAS IN KM^2

Sampling Area 1					
CI	CELLS	AREA	ED	CELLS	AREA
1	* 74	0.04625	1	3468	2.1675
2	245	0.153125	2	3898	2.43625
3	437	0.273125	3	2246	1.40375
4	734	0.45875	4	1484	0.9275
5	1568	0.98	5	224	0.14
6	2341	1.463125	6	0	0
7	2523	1.576875	7	0	0
8	2093	1.308125	8	0	0
9	1277	0.798125	9	0	0
10	28	0.0175	10	0	0
11	0	0	11	0	0
TOTALS:	11320	7.075	TOTALS:	11320	7.075

Sampling Areas 2 & 3					
CI	CELLS	AREA	ED	CELLS	AREA
1	0	0	1	11866	7.41625
2	0	0	2	11832	7.395
3	0	0	3	4066	2.54125
4	* 20	0.0125	* 4	170	0.10625
5	424	0.265	5	0	0
6	1247	0.779375	6	0	0
7	3538	2.21125	7	0	0
8	11513	7.195625	8	0	0
9	6787	4.241875	9	0	0
10	3188	1.9925	10	0	0
11	1217	0.760625	11	0	0
TOTALS:	27934	17.45875	TOTALS:	27934	17.45875

Sampling Area 5					
CI	CELLS	AREA	ED	CELLS	AREA
1	0	0	1	0	0
2	0	0	2	0	0
3	0	0	3	531	0.331875
4	0	0	4	1215	0.759375
5	0	0	5	1395	0.871875
6	0	0	6	2556	1.5975
7	0	0	7	3166	1.97875
8	0	0	8	2483	1.551875
9	0	0	9	764	0.4775
10	0	0	10	0	0
11	12110	7.56875	11	0	0
TOTALS:	12110	7.56875	TOTALS:	12110	7.56875

Sampling Area 4					
CI	CELLS	AREA	ED	CELLS	AREA
1	0	0	1	4584	2.865
2	0	0	2	2465	1.540625
3	0	0	3	1669	1.043125
4	0	0	* 4	56	0.035
5	0	0	5		0
6	0	0	6		0
7	0	0	7		0
8	0	0	8		0
9	1077	0.673125	9		0
10	3203	2.001875	10		0
11	4494	2.80875	11		0
TOTALS:	8774	5.48375	TOTALS:	8774	5.48375

Sampling Area 6					
CI	CELLS	AREA	ED	CELLS	AREA
1	0	0	1	0	0
2	0	0	2	0	0
3	0	0	3	0	0
4	0	0	4	0	0
5	0	0	5	0	0
6	0	0	6	0	0
7	0	0	7	739	0.461875
8	0	0	8	2659	1.661875
9	0	0	9	5741	3.588125
10	0	0	10	3073	1.920625
11	12252	7.6575	* 11	40	0.025
TOTALS:	12252	7.6575	TOTALS:	12252	7.6575

Figure A4-3. Sampling Area CI and ED area calculations (km^2). These areas were used to compute density. Areas with a (*) were eliminated from analysis due to skewed density results for these small area slivers. Sampling Areas 2 and 3 were combined for analysis due to similarities in their CI and ED composition.

CHAPTER 5

SUMMARY, SYNTHESIS AND EMERGENT OUTCOMES: LAND-USE CHANGE AND CONSERVATION IN SIMANJIRO, TANZANIA

REVIEW

Key issues in the Simanjiro Landscape

Land use policies and projections of the future role of land use change must not only capture complex socio-economic and biophysical drivers of land use change but must also account for the particular human-environment conditions under which the drivers operate (Lambin et al. 2001). As the human population expands and space becomes more limited, human and ungulate land use conflicts increase, and it becomes increasingly important to understand the spatial components of plant-herbivore and human-ungulate interactions (Coughenour 1991). Research in the area of land use and land cover change also needs to be cognizant that non-linearities in system feedbacks can create surprises (Malanson 2003) and unintended consequences. Performing a multi-scale assessment of landscape disturbances, and pairing that with information about land use and habitat structure facilitates the context-specific understanding of a particular landscape and hence the formation of appropriate regional conservation networks (Zaccarelli et al. 2008). Where people are involved, it is also important to incorporate the livelihood needs of those involved. Otherwise there is a risk of creating conflict over natural resource management and land use, and this can impact both conservation and livelihood outcomes.

Levin (1992) explains that the concept of scale, and the inter-related processes and patterns that occur at different spatial, temporal, and organizational scales are fundamental to the development of proper principles of management. He emphasizes that not only is environmental heterogeneity fundamental to the coexistence of species, but that the description of species distributions across space and time is by definition a description of pattern. How animals choose to move within and between landscapes depends on the availability of necessary resources and their spatial arrangement. It also depends on working around hard and soft barriers to movement that fragment and block portions of the landscape, making those areas unusable, inaccessible, or unsuitable sources of resources. Lesorogol (2008) makes a parallel argument for social-ecological systems using the example of the Samburu pastoralists of Kenya. She concludes that looking at spatial and temporal scales of social organization, heterogeneity of wealth and cultural values, distribution of power, and changes in these things over time is critical to context-specific land use decision-making.

In the 20,000 km^2 historically-pastoral Tarangire-Manyara Ecosystem (TME) of northern Tanzania, people and wildlife share the wet season range located on village lands outside of the established protected areas (PAs) of Tarangire National Park (TNP) and Lake Manyara National Park (LMNP). Land-use change in the PA borderlands, the

Simanjiro Plains, has the potential to interrupt wildlife processes and have a negative impact on biodiversity in general. Mitigation of these effects begs the study and identification of thresholds (abrupt tipping points of ecological condition) and response ranges (more continuous changes in ecological condition). But unfortunately thresholds are inherently difficult to predict and more often than not are discovered only after they have been crossed (Hunter et al. 2009). In addition, customary perceptions, values and aspirations of young Maasai are changing rapidly, and this could potentially undermine the symbolic attributes and social institutions that until recently have provided a measure of protection for wildlife and the environment (Ogutu et al. 2009). These changes are occurring in different ways and to different degrees across Tanzanian and Kenyan Maasailand, but they are occurring.

In Simanjiro, interactions and relationships between the human and natural components of the system are shifting as a result of land use and its consequent landscape changes. Integration of natural and social sciences as well as recognition of the increasing role of global factors is required to meet the challenge of addressing such changes (Lambin et al. 2001). The application of an integrated analysis approach allows consideration of impacts for both the social and natural components of an ecosystem. One cannot be legitimately studied without the other because of the feedbacks and interdependencies that occur between them.

The Simanjiro landscape is home to both people and myriad wildlife. Because of the necessarily extensive nature of resource use in this semi-arid landscape, changes in landscape pattern can have significant effects on wildlife, human, and livestock access to resources such as water and forage. People living in the TME have in large part been denied direct benefit from wildlife hunting [and tourism proceeds], while having to pay the costs incurred from problem animals on their land (Nelson 2000; Msoffe et al. 2007; Nelson et al. 2009). Without incorporating local knowledge and needs of locals into land use plans, it is not possible to balance adequately the needs of people with those of wildlife (Msoffe et al. 2007), and one or both will often lose. McCabe (2003) and Boone et al (2006) both found that some level of household cultivation would not be deleterious to conservation in the Ngorongoro Conservation Area of northern Tanzania, yet cultivation was banned in 2009 and cultivators evicted to protect wildlife and tourism interests. The fact that current land use policies in Simanjiro are based upon inadequate information about human livelihoods and wildlife ecology (Baird et al. 2009) has contributed to an air of mistrust between local land-users (mostly Maasai) and official land managers (Government and NGO groups).

When science is used for predictive or diagnostic purposes, as it so often is in environmental policy making, its limitations may lead to overlooking some potential causes of problems, or to framing problems too narrowly (Jasanoff and Martello 2004). The overarching goal of this research was to determine the consequences of cultivation for wildlife movement and livelihoods in Simanjiro to provide a basis for land-use and land-use policy decision-making. This knowledge will improve our capacity to balance objectively the resource needs of people with those of wildlife.

Research Approach

This project is novel in its integrated human and ecological methodologies. This integrated assessment approach captures the relationship between what is happening at the household and landscape levels. The complementary transect and patch counts are noteworthy, since no published study was found that utilized both methods jointly. Methods and results will be of interest not only to local residents and land-use planners, but also to other regions with similar land-use – conservation conflicts. Findings from this project have the potential to directly impact local land-use planning and Wildlife Management Area (WMA) development, as all stakeholders and authorities were involved in the study. This research has the potential to support objective decision-making to maintain the integrity of the TME for wildlife and people alike.

I used a framework of landscape ecology to plan the structure of the study. The goal of landscape ecology is to design and manage land use to promote the well-being of both people and nature, as well as the overall sustainability of the landscape (Msoffe et al. 2007). Wiens (2009) outlined four ways in which landscape ecology can contribute to conservation: 1) through understanding how conservation-oriented protected areas exist in a landscape context that may influence movement into and out of the PAs; 2) Through understanding how the contents of the landscape outside of PAs may impact biodiversity within them, often as a result of human activities; 3) through understanding why the scale of management may not coincide with the scale of patterns and processes of interest, presenting challenges to both landscape ecology and conservation; and 4) by increasing the sustainability of conservation by considering tradeoffs between human use and biodiversity values of the landscape.

All of these contributions of a landscape ecology approach are relevant to this project. In Simanjiro, TNP and LMNP were created to protect wildlife, but 85% of the wildlife-based ecosystem lies outside of the Parks. Land conversion from savanna to cultivation in the village zone therefore impacts mobility of wildlife and access to key resources when they are outside the park in the wet season. Management decisions made in government offices trump those made in local village meetings, not considering what and how residents choose to regulate land use, and with little consideration for the local bottom line, maintaining livelihoods and families. The lack of communication regarding different scales of management and use and their respective agendas has led to mistrust on the part of local people, which has implications for sustainability of both conservation and livelihoods in this ecosystem.

The scales of interest to this study were determined by wildlife movement patterns combined with scales of land use decision-making. Daily to seasonal movements occur across scales of individual pastures to entire landscapes. Land use decisions are made at the level of the boma (where to take the livestock that day), the subvillage (which areas can be cultivated and which cannot), and the village (greater questions and negotiations of resource use and access within and across village boundaries). These levels of land use decision-making on the part of people and wildlife have led to the development of this multi-village integrated assessment of Maasai livelihood and wildlife movement as both drivers and outcomes of landscape change.

In 2003 I conducted 207 household interviews in three Simanjiro villages (Sukuro, Loiborsoit 'A' and Emboreet) on the topics of land use, household demographics, livelihoods, human-wildlife conflicts, and perceptions of conservation and wildlife. In the wet season of 2004 I conducted a multi-method and multi-scaled wildlife study that consisted of driving and walking transects to determine species-specific wildlife responses to cultivation in Simanjiro. The species of interest were primarily zebra, wildebeest and Grant's and Thompson's gazelle. Observed wildlife distribution data were compared to a null model composed of 30 randomized re-distributions of the observed data to detect wildlife responses to cultivation intensity and Euclidian distance to cultivation.

CHAPTER SUMMARIES

Chapter 2

Despite regionally high temporal and spatial rainfall variability, most Simanjiro Maasai have diversified their land use to cultivate. The goal of Chapter 2 was to investigate the effect of Maasai land use diversification into cultivation on livelihoods to see whether households are making a profit or losing money, and to look at the role of the gem trade in land conversion through cash inputs into the system.

This study found that in two of three villages cultivation profits were largely positive, raising some below-subsistence pastoralists above the subsistence threshold and others toward it. Resilience was increased as a product of both intermittent food production and a source of household cash. This cash allows the purchase of household items and hospital and school fees without selling livestock to do so. In addition, this cash can feed directly into the livestock sector through the purchase of animal drugs or animals themselves. Cultivation can also provide a quick potential food pulse following drought while livestock populations recovers. The success of cultivation in one year is not dependent upon the success or conditions of the years before, but this is not true for livestock herd size and health condition. Smallstock herds can take several years to recover their numbers after a drought or disease outbreak, and cattle herds take even longer. Cultivation provides an important interim source of food for herdowners who may no longer have livestock sufficient to feed their families. This rescue mechanism can help households to recover from bad years, and relieve the pressure that would otherwise be concentrated on the livestock herd.

Cultivation success was correlated with herd wealth in two villages, Loiborsoit 'A' and Emboreet. Data from a third village, Sukuro, showed widespread crop failures across the entire wealth gradient, demonstrating that success is also highly variable across space, likely due to uneven rainfall distribution. The opportunity to cultivate may prove increasingly important if rainfall variability increases as predicted by climate change models. Future wildlife conservation may either enhance or compromise pastoral resilience. Strictly limiting cultivation in Simanjiro would remove a subsistence alternative, but allowing use of key restricted resources during drought would help communities mitigate risks associated with climate change.

The gem trade also contributes to livelihoods and land use change in Simanjiro. I found that cash inputs from the gem trade were limited to a small proportion of Simanjiro residents. Those 2% who made very large profits contributed disproportionately to land conversion to cultivation by making purchased tractors available for rent by others to plow their fields. The gem trade is in effect facilitating the conversion of large portions of the Simanjiro landscape to cultivation.

Chapter 3

The goal of Chapter 3 was to see if there is detectable response of wildlife to cultivation at the scale of the individual cultivated plot, as well as to determine which species are problem animals. These analyses used data collected via wildlife transects walked inside and outside of cultivated plots, as well as interview data collected across the three villages. The cultivated plots were located within four of the pastures in the landscape investigated in Chapter 4. The households interviewed for this study are the same as those interviewed for Chapter 2.

The fact that only 2% of interviewees reported positive interactions with wildlife and 99% reported negative interactions is symptomatic of an imbalance in costs and benefits of wildlife for local people in Simanjiro. There was no evidence of any species of interest responding to the gradient of distance to cultivation outside of the cultivated fields. All species demonstrated approximately equal distributions across this gradient. This suggests that there is little aversion of wildlife to cultivation at the scale of the individual cultivated field.

However, comparisons between the interior and exterior of cultivated plots varied among species. Wildebeest prints were rarely observed in fields. Zebra prints occurred at lower densities inside of cultivated fields than outside, but the zebra response was weaker than the wildebeest response. The apparent tendency of zebra to concentrate slightly (non-significantly) more in the proximal zone indicates that zebra may be attracted to cultivation but have a difficult time getting inside. Grant's gazelle print densities did not display any response to the cultivation distance gradient, and prints were found in relatively equal densities inside and outside of cultivated plots. However, even though gazelle were inside the fields, they were the species with the lowest damage rank of all wildlife-cultivation conflict species reported on interviews. Prints of small resident herbivores and predators were detected almost exclusively inside of cultivated fields, and appear to prefer tall maize to short grasses. In summary, the results of this study indicate that wildlife habitat loss due to cultivation is restricted to the area that is cultivated and does not include an impact/avoidance zone beyond that.

While Hobbs et al (2008) make the point that spatial isolation in grazing ecosystems can limit the ability of people and both wild and domestic animals to exploit heterogeneity in vegetation, this study presents a counter-argument that for some species, cultivation acts as an agent of increasing heterogeneity (small resident herbivores, gazelle and predators), and that for other species (zebra and wildebeest), a barrier to movement and landscape access occurs at the boundary of cultivation rather than at some buffer distance of avoidance. The study demonstrated that it is necessary to explicitly study and assess impacts of land use change for wildlife on a species-by-species basis at a small spatial scale (in addition to larger scales) in order to make objective and constructive management decisions that have implications for both wildlife and land users.

Chapter 4

The first goal of Chapter 4 was to investigate the effect of cultivation on zebra, wildebeest and gazelle at the scale of individual 5-10 km^2 pastures, the scale at which wildlife generally move on a daily basis. Since data were collected in the morning hours, results reflect distribution during the first half of the day, rather than over a 24-hour period. The pastures investigated contained all of the cultivated plots that were studied in Chapter 3 of this dissertation. I was interested in the effects of both Euclidian distance to cultivation (ED) and cultivation intensity (CI), a measure of distance-weighted density.

Based on comparisons of observed animal and null model distributions, analyses pointed to daytime avoidance of cultivation, which in combination with Chapter 3 results that showed no gradient effect for any species, indicated that wildlife approach cultivation primarily during the nighttime. One possible implication of this for cultivators is that heavy guarding of fields needs to occur at night. Not only is it dangerous to guard fields at night, but some herders need to do double-duty herding livestock during the daytime and guarding fields at night. Some of the avoidance of cultivated fields during the daytime may be due to human and livestock activity around these areas at that time. In areas where wildlife avoidance of cultivation could be interacting with a negative response to livestock and people, those livestock and people will be confined inside of settlements at night, leaving all areas available for wildlife use. Wildlife may concentrate their daytime grazing to the portions of the grazing landscape that are more distant from cultivation and/or livestock and people, but over the course of 24 hours they are able to utilize the entire grazing landscape. It is important to point out that a lack of data that account for nighttime wildlife movements and distributions may erroneously lead to the conclusion that wildlife avoid foraging in areas close to cultivation as a rule.

The second goal of Chapter 4 was to investigate the effect of cultivation on the same species at a landscape scale over an area of approximately 500km^2 in the wildlife dispersal zone, the scale at which wildlife generally move on the order of weeks or months. This landscape contained all of the subset pastures and cultivated plots, plus the matrix between them. Of particular interest was how well the various endemic wildlife species move through the Simanjiro landscape, and to see if there is an identifiable threshold of percolation, where habitat connectivity levels are low enough to significantly inhibit movement (Malanson 2003). All animals were counted in the sampling areas on four dates in a single rainy season, March-May 2004.

Based on comparisons of observed animal and null model distributions, as well as evaluation of observed print density distributions, all wildlife species of interest appeared to be responding in some way to cultivation in Simanjiro at the landscape scale. Zebra demonstrated a clearly negative response to cultivation. Wildebeest demonstrated a somewhat weaker negative response that appeared to be intensified when high densities of people and livestock were present. This negative relationship with livestock and people could also be due at to herders herding their cattle away from wildebeest to avoid disease transmission to cattle. Gazelle appeared to demonstrate an intermediate response to cultivation, with higher densities in the areas of intermediate cultivation density. But they also exhibited higher densities in the study area with the highest densities of people, contrary to wildebeest, suggesting they are attracted to people and livestock.

All three species groups, however, were present at lower densities in SA1, the area of highest CI, than in other SAs. Densities were significantly lower than would be expected without a cultivation effect. Zebra and wildebeest were present in SA6, the area of lowest CI, at higher densities than in the other SAs. Densities were significantly higher than would be expected without a cultivation effect. Intermediate-CI sampling areas generally had intermediate densities of wildlife, with a few species-specific exceptions. This indicates that a threshold of desirability for at least zebra and wildebeest may lie in the range of densities between SA1 and SA2.

Print data confirm that fewer animals use SA1 than the other SAs with cultivation (SA1 to SA4). Print densities inside cultivation demonstrated that the lowest wildlife invasion rates occur in the sampling area with the lowest overall wildlife densities, which is the area of the highest cultivation intensity. This suggests that people with a denser arrangement of cultivation actually realize benefits from such an arrangement. One explanation is that the animals simply are not in proximity, due to avoidance of the whole area. But this could also be due in part to the fact that clustered cultivation has less edge relative to the area cultivated, so there is less opportunity for invasion and relatively shorter boundary to guard.

EMERGENT OUTCOMES

Interview data reveal that despite the risk of crop failure in this semi-arid ecosystem, cultivation is an important component of contemporary pastoral livelihoods, boosting food production, directly and indirectly maintaining livestock herds, and buffering household vulnerability simply by providing another livelihood option. The conservation of wildlife generates monetary benefits for the country of Tanzania, but these benefits rarely reach local people who bear the costs of wildlife through land loss to protected areas and private hunting concessions, land use restrictions, and direct and indirect conflicts with wildlife that threaten their safety and livelihoods. As a result there is no incentive, monetary or otherwise, for people to conserve wildlife. The costs are too high.

The three scales of wildlife analysis that I undertook for this study form a natural progression that matches, at least to some degree, the temporal scale of movements of the species under scrutiny as I observed them over the course of 1.5 years spent in the study area. While of course there is variation in these movement patterns by species, by individuals, and from day to day and year to year, the combined study of three scales of response during a single rainy season reveal some overarching relationships to patterns of cultivation across the study area.

Cultivated forage (primarily maize) that is directly edible by humans increases resilience and buffers risk.

There is a question as to the amount of profit (food plus cash) that can be generated by cultivating in semi-arid rangelands. Cultivation by Simanjiro Maasai does bring agriculture to a marginal and variable environment, but it also increases the number of available options for food production, and hence increases adaptability and resilience to livelihood threats. While Chapters 3-5 discuss the implications of new landscape spatial patterns for wildlife, it is important to consider the implications of these changing patterns for people and livestock as well. Cultivation represents an increase in functional diversity of food resources available to pastoralists in that it is a food resource that is *directly* consumed by humans, as opposed to the existing grass and browse that must be converted to milk and meat by foraging livestock. This increased functional diversity and alternative energy production pathway may serve to increase the ability of Simanjiro Maasai to acquire resources sufficient to support their families in an increasingly stressful and variable environment.

While there has always been access to grain through markets, at times it is difficult to obtain, and market prices are extremely volatile. In addition, since livestock are allowed to forage in the fields after harvest, they can receive a pulse of benefit from the new landscape arrangement. Simultaneously, they deposit and concentrate fertilizer in these patches of the landscape, potentially increasing crop productivity. Frequent use of maize by-products as livestock fodder by the Maasai in Kajiado, Kenya was observed during the 2009 drought, with maize stalks sometimes being the only food available to livestock that were on the brink of death from starvation (Joanna Roque de Pinho, personal communication).

Wildlife demonstrate daytime aversion to boundaries of cultivation, but nighttime attraction.

What becomes apparent when integrating the results of Chapters 3 and 4 is that wildebeest and zebra display a negative response to cultivation during the daytime hours, concentrating in areas of the individual pastures with low cultivation intensity (CI) and high Euclidian distance (ED) values. But Chapter 3 demonstrated nighttime movement toward cultivation, evident through transect data. This combination of results supports the assumption that these species demonstrate a pattern of movement over the course each 24-hour period, toward and away from cultivation at the scale of individual 5-10 km^2 pastures (the size of the study pastures). The daytime response to ED is so strong, that it was evident even at 5 km away from cultivation in SA6. Some portion of this pattern may be due to the fact that the areas closer to cultivation become more available for wildlife at nighttime when livestock are contained in bomas.

Wildlife respond to ED in a diurnal cycle at a fine spatial scale, but to CI at the larger scale

Patterns of utilization uncovered in Chapters 3 and 4 demonstrated that wildlife move in response to ED at daily time scales and intra-patch spatial scales, moving toward the cultivation edge at night, and away during the daytime. The study in Chapter 3 did not show any detectable lack of wildlife utilization of areas near the boundaries of cultivation, so use across individual pastures equilibrates across space over this 24-hour cycle. However, Chapter 5 demonstrated that over larger temporal and spatial scales of movement decision-making, wildlife tend to respond to cultivation intensity (CI). Gazelle appeared to be less sensitive to cultivation at both the small and large spatial scales than zebra and wildebeest. Thus, there is value to using both metrics to measure wildlife responses to cultivation in that it was possible to determine that one factor is the dominant driver at a smaller scale, while the other the dominant driver at a larger scale.

While the findings in Chapter 3 led to a conclusion that at a fine spatial scale there is no buffer-area loss with cultivation, and that area loss is limited to the cultivated area itself, Chapter 4 findings showed that larger areas are lost as viable wildlife habitat once CI reaches a particular threshold despite the availability of open pastures within the area.

Fewer wildlife-cultivation conflicts occur in high-CI areas, so dense arrangements repel wildlife, and benefit people.

Integration of multiple scales of analysis, plus information on human-wildlife conflict obtained from interviews, suggests that dense cultivation repels migratory wildlife at the landscape scale, but benefits cultivators due to less wildlife ingress and damage. Conversely, scattered cultivation allows wildlife passage through the landscape but encourages crop invasion. Dense cultivation benefits people for two hypothesized reasons. First, fewer wildlife occur in high-CI areas, so there are fewer opportunities for intrusion. But there is also a lower edge:area ratio in areas where cultivation is clustered tightly. This decreased edge ratio reduces the required guarding effort, an important consideration for households with few members to guard the fields. Conversely, scattered cultivation increases the edge and is not as repellant to wildlife. This combination of factors leads to a higher probability of raids, more difficult guarding of fields, and potentially higher losses to WL damage.

ONGOING CHANGE AND POTENTIAL FUTURES

If resilience is based on flexibility and adaptation, then pastoralism is showing some of both (Galvin 2009). In Simanjiro this takes the form of incorporating cultivation and gem trade activities into the pastoral livelihood regime. Land use in Simanjiro is being driven by conservation as both a reactionary mechanism – cultivating to diversify and to improve livelihoods and resilience in reaction to both real and perceived risk, in part because of lost access to key livestock resources – and a defensive mechanism – cultivating to prevent land disenfranchisement under the auspices of wildlife conservation.

One apparent stimulus of cultivation occurred nearly a decade ago in 2002, immediately before the onset of this study, when the former Arusha Region was divided. Simanjiro was separated out of the Arusha Region and incorporated into a new political region, the “Manyara Region”. The new region includes the southern portion of the Tarangire-Manyara Ecosystem, including TNP, Simanjiro, and some areas to the west of the TNP that are not part of Simanjiro. When Simanjiro was re-districted, residents became fearful that outsiders would be encouraged to settle and cultivate land within the new region, and that Maasai would be pushed out (M. Goldman, personal communication). Cultivation was used to defend land rights from migrants. During the term of this study, discussions of cultivation to protect land from expansion of Tarangire National Park were common. Land conversion to cultivation in Simanjiro has continued at a truly astounding rate since the conclusion of data collection in 2004. A cultivation ban and eviction of cultivators from the nearby Ngorongoro Conservation Area in 2009 has only fueled rumors (M. Goldman, personal communication) of future park expansion, as strong linkages exist between these communities, and Simanjiro residents believe that they are next in line.

The rapid expansion of cultivation in the study area is concentrated primarily in the villages of Loiborsoit 'A' and Emboreet, the villages bordering Tarangire National Park. But cultivation in Sukuro is also expanding. Interview data collected in 2003 demonstrates that 45% of households would cultivate their entire land allocation if given the opportunity (Figure 6.1). Fully 98% of respondents mentioned cultivation to some extent, while only 51% of respondents mentioned livestock. This signifies an important shift in priority among this traditionally pastoral population. The responses may be indicative of the difference in perceived control over resources for each of these land uses. While livestock grazing necessarily happens over extensive grazing pasture commons, cultivation typically happens within one's own land allocation. But what did not appear to be recognized was the risk of widespread cultivation for livestock, as only one interviewee mentioned this risk when directly asked about the risks of cultivation for livestock. This has changed somewhat since 2004, since during village meetings in 2007 and 2010 community members did talk about these risks.

Research findings suggest that concentrating cultivated plots in large clusters strategically placed on the landscape could allow subsistence farming to continue while minimizing the impact on wildlife by reducing the cultivation impact on the surrounding landscape. Concentrated plots would also produce less edge per area cultivated, reducing wildlife intrusions with effective guarding. It may also be possible to invest in higher-quality fencing if there is less fence length to construct.

The most intuitive level at which to cluster cultivation would be at the subvillage level. The subvillage is the level of social organization at which most local land use decisions – including but not limited to cultivation restrictions and grazing reserve locations – are made. Spatially, all areas of an individual subvillage are within reasonable walking distance of all subvillage residents, yet subvillage centers are also fairly dispersed from each other. Subvillages also act as neighborhoods, with strong social relationships occurring within them. This makes the subvillage an ostensibly good foundation for cultivation clusters that could be managed by a group of households, yet spatially dispersed on the landscape to allow free movement of wildlife between.

There are several caveats to this suggestion. The first is the fact that entire village landscapes have been allocated to individuals, creating a problem with regard to deciding where to put clusters of cultivation. Subvillage members know their local landscape, and know the best areas to set aside for grazing, areas that should be held as reserves, and areas that would be acceptable for cultivation. This is already being done at the Subvillage level, but some areas are now being cultivated that were originally set aside for livestock grazing (and by default wildlife grazing) because of soil quality, rainfall, and other factors. The scale of rainfall variability ranges from droughts that occur across entire regions and multiple years, to the scale of villages and smaller. The western side of Simanjiro is somewhat higher than the eastern side, which could explain lower rainfall in Sukuro. In any case, the variability across villages demonstrates that success rates will also be highly variable. Soils are also a factor in placing cultivation, as high clay soils are not workable.

At the time that this research was completed in 2002-2004, maize was not commonly shared amongst households, much less so than milk produced by a household's cows. But some level of common management would be necessary to share the responsibility of guarding clustered cultivation boundaries, deciding which households would cultivate at the edge vs. the interior, or whether labor (planting, weeding, guarding and harvesting), inputs, and profits (both food and cash) should be shared or whether each household would have control over all aspects of a particular portion of the field.

Perhaps an even larger stumbling block to the clustering of cultivation on the landscape is the combination of weak land rights and expectations of further land dispossession, which together encourage dispersed cultivation as a means to secure land tenure. Changes occurring on the TME landscape over the last decade has been truly astonishing, and this trend will only continue in the absence of conservation planning that is truly collaborative and provides for the livelihoods of local people. It may be possible to identify areas of greatest suitability for cultivation through an analysis of long-term NDVI (Normalized Differentiated Vegetation Index) greenness to determine not only the areas of highest rainfall, but also the variability of rainfall across space, and therefore areas of high precipitation and low variability (Theobald, personal communication). Soil boundaries are visible on satellite images. Areas of higher quality soils, higher rainfall, and low rainfall variability would be likely areas to target for cultivation.

Turner et al (Turner et al. 2003) caution against assuming that all parts of a social-ecological system are equally vulnerable, since subsystems and components, especially social units, may experience exposure differently, register different impacts, and maintain different response options. In Simanjiro the areas of the ecosystem that are at greatest risk to cultivation change are those where residents perceive the least security in terms of land rights because of proximity to Tarangire National Park. Fear is a major driver of land conversion to cultivation in the villages of Loiborsoit ‘A’ and Emboreet, and in some areas has had a significant impact on the sustainability of the landscape that is most critical to maintaining migratory and resident wildlife populations in the Tarangire-Manyara Ecosystem.

As landscapes become increasingly fragmented, conservation decisions will need to rely on predictive models of how multiple species are expected to respond to landscape changes (Ries and Sisk 2004). This study’s results on the impacts of cultivation on wildlife populations can provide information that can be used to inform wildlife and land use management in the TME from both the local land user perspective and the government perspective. But it is critical that local land users are assured secure land tenure, and that multiple sources of information, including local knowledge and scientific knowledge, are considered in the development of alternative management scenarios. The “optimal” management regime of choice may vary from village to village, or even subvillage to subvillage based upon local social, ecological, political and other conditions. In order to be locally appropriate, land use policies and development interventions need to be designed with the fundamental spatial and temporal dynamics of target system resources in mind so that interventions and policies facilitate rather than constrain local strategies of access (Ellis and Swift 1988). Flexible and adaptive management are critical to any plan in this area if it is to be successful.

New knowledge on the contributions of livestock, the gem trade, and cultivation to household and village economies forms a much needed basis for informed policy-making. This information will encourage more objective dialogue and decision-making between land users and land managers. Three scales of wildlife analysis are mutually reinforcing, which lends strength to inference as well as to applicability of conclusions to future management decisions.

Due to the inherently observational (rather than experimental) nature of these wildlife investigations, results are suggestive, rather than rather than conclusive, of patterns of response to cultivation that are biologically and managerially important (USGS 2006). However, based upon this multi-scaled study it *cannot* be concluded that "all cultivation is bad for wildlife" as many of those who hold the power to make land use decisions have pursued as their agenda for several decades in Simanjiro. But what can likely be concluded from the compilation of results from Chapters 3, 4 and 5 is that wildlife *do respond to cultivation in a both species-specific and scale-specific manner*, responding to cultivation boundaries at a daily timescale, and to pasture spatial scale and cultivation density at the larger landscape scale over the course of weeks, months or seasons. This scalar interaction can make important contributions to planning. In addition, Chapter 2 results indicate that cultivation has become an important component of the Simanjiro Maasai household economy through contributions to year-to-year food production and income, as well as long-term livelihood resilience and adaptability.

The trade-offs between environment and development outcomes are difficult to integrate into a consistent approach and set of priorities for management (Homewood 2004). It is important both to ask the right questions, and to integrate a wide variety of multidisciplinary data to encompass both environmental and development dimensions in research and outcome evaluation (ibid). Species-cultivation relationships can, together with information on livelihood-cultivation relationships and other livelihood information, be used to inform land-use decision-making at the local level and policy-making at the regional level and beyond. The process of integrating the needs and desires of diverse stakeholders who operate and make decisions at different spatial scales and in different ecological, cultural and economic contexts is difficult. Power differentials, both real and perceived, and operating both within and between scales of social organization and governance, affect the weighting and value given to available options for consideration in the decision-making process.

At the household to village levels these decisions are taken to maximize livelihoods and protect the interests of pastoral neighborhood networks that operate and weigh options collaboratively on a daily to weekly to seasonal basis. At the regional to national level, however, decisions are taken largely to maximize regional and national interests, and to encourage contribution to the national economy. Since much of livelihood income and production, particularly that of pastoralists, occurs through trade at the local level, this trade and cash-flow through local relations and markets is not recognized as contributing to regional and national markets, and therefore generally not valued at these large scales. The government does not realize a direct benefit from small-scale cultivation, and in fact may stand to lose financially if wildlife are negatively affected by cultivation. Conversely, while the benefits of wildlife conservation are felt at the national level, the costs are felt by local people who do not realize any profits to offset those costs. Most Maasai do not realize direct benefits from conservation, or perceive relevance to their livelihoods (Galvin 2009). In fact, Tanzanian wildlife policy explicitly limits individual rights to protect their lives and their livelihoods by putting the burden on those who have killed or injured a wild animal to prove that the animal was indeed presenting a threat (see Tanzanian Wildlife Conservation Act 2009, Part VIII).

This conflict of interests between local and more expansive levels of social organization and governance is, I believe, one of the root causes of communication breakdown between local decision-makers and regional to national policymakers. This cost-benefit mismatch and communication breakdown has engendered policies and actions that in the long run hold a potential to destroy the ecosystem and the services that it provides, ecosystem services that all stakeholders have some interest in preserving. Information at appropriate spatial scales increases the credibility of that science for collaborative landscape planning, relevance to the needs of the decision makers makes it salient (Termorshuizen and Opdam 2009), and legitimacy is gained through respect of stakeholder values and elimination of bias, transparency, and keeping the interests of the end-users in mind (Cash et al. 2003).

African protected areas have expanded significantly in the past 30 years, but the capacity of these areas to support viable populations depends on human influences both inside and outside of reserves that lead to reserve degradation and isolation (Newmark 2008). While protected area and restrictions on land use may bring benefits to national economies, local people are the ones who bear the brunt of the cost of wildlife through crop losses, livestock predation, and loss of human lives (Nelson 2000). From the local perspective, conflicts with wildlife on village lands are difficult to reconcile with local loss of control and options when it comes to use of natural resources. The negative relationship that has ensued between people and wildlife as a result of some of these processes and their outcomes has generally resulted in wildlife declines rather than sustainable conservation (ibid).

Cultivation is having a dramatic impact on the Simanjiro landscape that will likely impact resource access by both wildlife and livestock. The pattern of land conversion concentrating in known wildlife corridors, combined with the rate at which change is occurring, is indicative of defensive cultivation to secure land tenure. Not only do these changes portend potentially negative consequences for wildlife, but if the density of cultivation increases across large portions of the landscape, they may also prove to be maladaptive by threatening the sustainability of the livestock sector that Maasai pastoralists have nurtured for millennia, and that is so suited to this semi-arid ecosystem. Continued rapid change may actually undermine the very foundation of local pastoral livelihoods and culture. Yet with wildlife policies that give the President the authority to designate wildlife corridors and dispersal zones as a protected area, rights to the landscape are not secure. In reality, wildlife policy may be contributing to considerable landscape changes that, if continued at current rates, could threaten the very wildlife that the policy was meant to protect.

People and animals have co-evolved with intact, unfragmented rangelands in most of the drylands of the world, where pastoral economies have existed for thousands of years (Hobbs et al. 2008). Fragmentation of once contiguously intact rangelands spatially isolates portions of the landscape, leading to compartmentalization of important components of the environment (Boone and Krohn 2000; Coughenour 2004; Hobbs et al. 2008; Galvin 2009). Extensive use of the landscape is crucial to accessing widespread but necessary resources in non-equilibrial systems such as the TME, and this is true for both migratory wildlife and domestic livestock. It is important for local people to be integrally involved in land use planning so that livelihood benefits of cultivation can be maintained while limiting the consequences for wildlife, and so that conflict among local and national interests can be minimized.

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FIGURES AND TABLES

Land Use Plan for Household Allocation	Percent of Households
Cultivate Only	44.9
Livestock Use Only	2.0
Livestock and Cultivation	45.9
Cultivate and Build Boma	4.0
Cultivate, Livestock, and Build Boma	3.0

Figure 5.1. Interviewees were asked their future plans for their allocated plot of land. 98% of respondents mentioned cultivation to some extent, while only 51% of respondents mentioned livestock.