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EVALUATING RANGELAND CONDITIONS IN NEIGHBORING PROTECTED AREAS OF RUSSIA AND MONGOLIA

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With the collapse of the Soviet Union in 1991, demands on the vast steppe rangelands and other natural resources in Mongolia, Russia, and other Central Asian states experienced drastic changes. Moving from a socialistic system into a free-market economy of supply and demand saw regulatory institutions, which historically managed natural resources like rangelands, dissolved or without the capacity to enforce their work requirements. Like other places in Russia, the region of the Kosh-Agach Wildlife Refuge experienced a decrease in demand for livestock products, which forced many rural peoples to move to urban areas in search of work. The opposite occurred in the region of western Mongolia where the so-called Cluster A of the Siilkhemiin Nuruu National Park is located. That Region saw an increase in migration from urban to rural areas to embrace their traditional pastoralist lifestyle in order to make a living. This study uses satellite imagery, remote sensing analysis, and field data to assess rangeland conditions in these two protected areas over the past twenty years. The study concludes that rangeland conditions are deteriorating in both areas. Yet more research is needed in order to assess the levels at which climatic and anthropogenic factors are influencing this decline.

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CHAPTER I

INTRODUCTION

According to a World Resource Institute (WRI) report released in 2000, grassland ecosystems currently cover approximately 40% of the land surface, yet primarily owing to anthropogenic factors such as conversion to agriculture, overgrazing, fragmentation, excessive use of fire, and urbanization, many of these ecosystems are in a state of decline (White *et al.* 2000, 36-38). This WRI report (2000) also claims that Asia, unlike other continents, has faired far better in the conversion or loss of grasslands, with approximately 50% - 70% still remaining. The arid and semi-arid regions of the steppe are highly vulnerable to anthropogenic impacts, and it has been observed in Mongolia that despite an increase in moisture over the last few centuries, xerophytic features are increasing in grasslands owing to degradation of rangelands (Gunin *et al.* 1999, vii) Additionally, raising the importance of monitoring semi-arid grasslands such as the steppes of Central Asia, is the role of these fragile ecosystems as sensitive indicators of climate change (Liang, Shao, and He 2005, 2901).

In order to better monitor and track these types of changes and natural processes, land managers and scientists are using remote-sensing technologies. Remote sensing utilizes sophisticated sensors on board airborne and satellite platforms to capture electromagnetic radiation (EMR), which is emitted and reflected from surface features on Earth (Lillesand, Kiefer, and Chipman 2004, 2). Capturing these energy changes and analyzing the datasets allow scientists to quantify change and sometimes even predict change at a landscape scale.

To study landscape change, scientists use a remote-sensing process called "change detection." Change detection uses multi-temporal datasets to identify specific landscape change between imaging dates (Lillesand, Kiefer, and Chipman 2004, 596). An understanding of biophysical conditions, such as vegetation phenology, soil moisture, and cycles of man-made phenomena, must be known when determining dates of satellite images to be used in such an analysis (Jenson 1996, 261). This study will utilize these technologies and analytical approaches.

CHAPTER 2

STATEMENT OF PROBLEM

In Central Asia, the mobile-pastoralist culture can be found in most countries. The pastoralist way of life, and animal husbandry in general, have long been the main drivers of rural economies, and accordingly, large land areas of the grassland steppe are required to maintain this way of life (Humphrey and Sneath 1999, 4). During Soviet times, the socialist governments of this region worked to integrate pastoralists into their larger national economies by opening their goods to larger markets through mere extensive distribution systems and collectives. These measures, along with state subsidies, regular wages and better access to medical services, raised the standard of living among pastoralists during this period. Additionally, with the Soviet system came "top down" social and economic policies which have proven to have had numerous negative impacts, such as increasing use pressure upon fragile rangeland ecosystems in order to increase production in areas with limited production capacity, as well as policies which encouraged a more sedentary mode of livestock production versus a more mobile pastoralist production system (Sheehy *et al.* 2006, 62).

However, with the fall of the Soviet Union, the move to privatization of goods, and the loss of any existing distribution networks, conditions throughout much of Russia and Mongolia dropped to a subsistence level (Humphrey and Sneath 1999, 4). It has been noted that as these traditional economies have begun to assimilate into the market economy, no formal institution has emerged to assist with the regulation or monitoring of pastoral land use. This lack of oversight may have led to increasingly unsustainable land-use patterns (Fernandez-Gimenez 2004, 33). It has been concluded after a 10-year study of Mongolia's vegetation that there is considerable regressive vegetation change occurring with increasing anthropogenic activities, even in years of adequate precipitation (Gunin *et al*. 2000, 238; Johnson *et al*. 2006, 15). It is also a matter of concern that impoverished people may be more likely to implement unsustainable practices for quick returns in order to survive (*United Nations Convention to Combat Desertification and Drought Report, 2003*).

CHAPTER 3

OBJECTIVES OF STUDY

This paper will examine the current and most recent historical grassland habitat conditions for Mongolia’s Siilkhemiin Nuruu (Sailugem Range) National Park (Cluster A) and Russia’s Kosh-Agach Wildlife Refuge, using remotely sensed satellite data and ground-truth data collected in the field. These protected areas lay adjacent to one another in the Sailugem (Siilkhemiin) Range of the Altai Mountains in Central Asia directly across their shared national border (fig. 1). This research tests the hypothesis that Mongolia’s rangeland conditions have deteriorated considerably since entering into a free market economy and capitalism a little over a decade ago. Additionally, it is presumed that Russia’s Kosh-Agach Wildlife Refuge is experiencing reduced pressure from overgrazing since the fall of the Soviet Union Empire. Using Landsat satellite imageries and ground-truth data, this research will attempt to quantify land cover changes through a multi-temporal analysis spanning the last two decades.

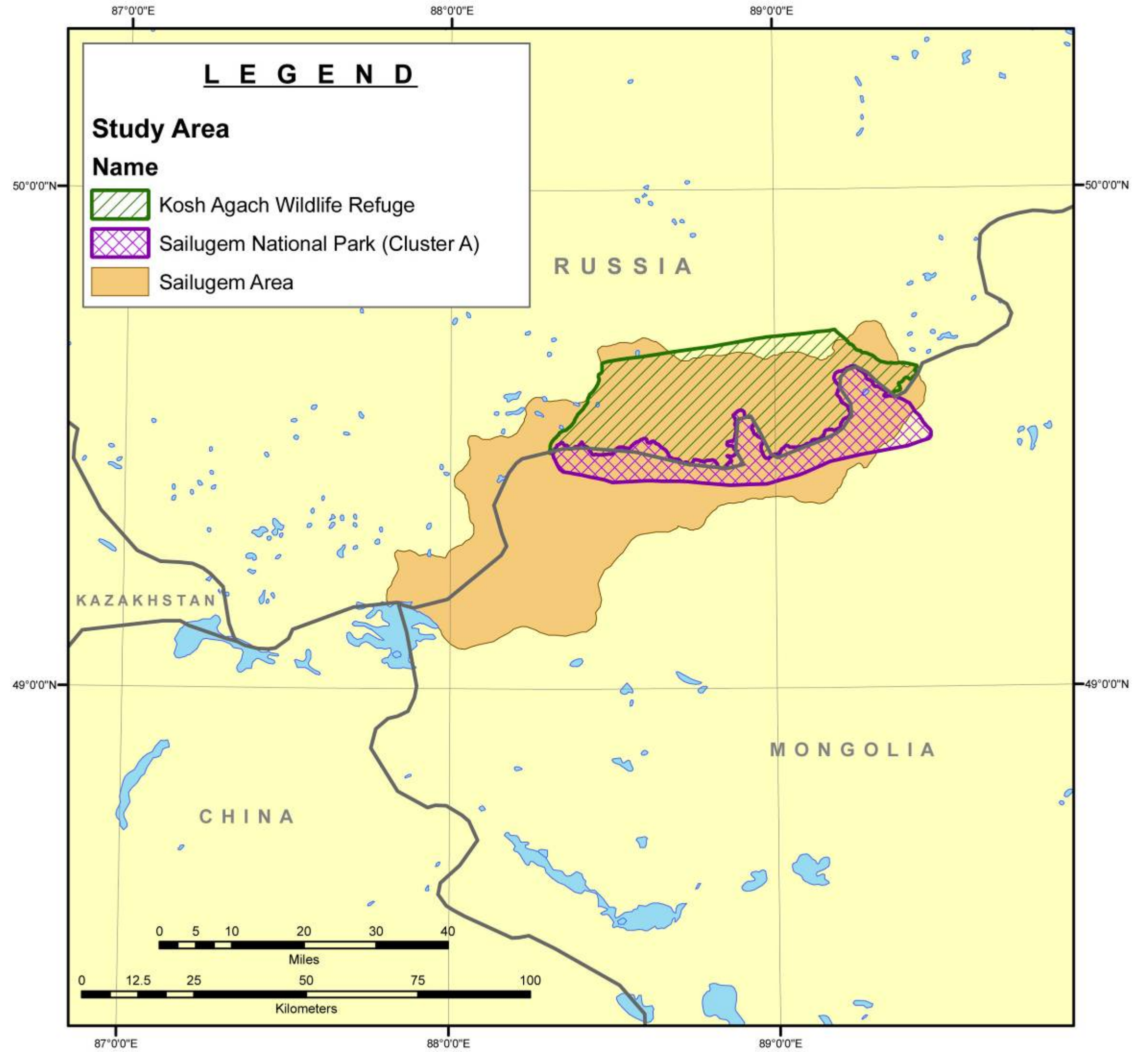

Fig. 1 Study Area Map

CHAPTER 4

GEOGRAPHICAL BACKGROUND

Study Area

Located in the Sailugem Range of the Greater Altai Mountains, the study area is composed of two protected areas. The Kosh-Agach Wildlife Refuge is found in the Republic of the Altai, Russia, and the Siilkhemiin Nuruu (Sailugem Range) National Park (Cluster A) is situated in the province (*aimag*) of Bayan-Olgii in westernmost Mongolia. Their combined area spans approximately 310,000 hectares. The coordinates for the location are approximately as follows: western boundary (88° 29' 4.27" E); northern boundary (49° 43'30.33" N); eastern boundary (89° 29'4.26"E); and southern boundary (49° 23'9.11"N).

The Greater Altai Mountains extend along the borders of Russia, China, Kazakhstan, and Mongolia in north-central Asia, with an arc reaching to the northeast along the Russian – Mongolian border into Russia, and a southeastern arc, stretching into southwestern Mongolia and the Greater Gobi Desert. Found in the northeastern region of the Altai, the Sailugem Range runs west and east, starting in the west near the confluence of the Chinese, Russian, and Mongolian borders, then stretching eastward along the Russian-Mongolian border to the intersection of the Chikhachev Range and the Repubic of Tuva in Russia.

The Kosh-Agach Wildlife Refuge is approximately 241,300 hectares in size, while the Siilkhemiin Nuruu National Park (Cluster A) is approximately 70,488 hectares. Elevations in the area range from 2473 meters (m) at the Bor Borgusen River to 4029m at Ikh Turgen Peak (Maroney 2004, 41).

Owing to its higher elevations, the area receives 300-400 millimeters (mm) of annual precipitation, and is characterized by an extreme continental climate with severe winters and a very short summer growing season (Hilbig 1995). The majority of Mongolia's precipitation (85%) occurs from the middle of June to late August, limiting vegetative productivity (Kogan *et al*. 2004, 2880). More specific meteorological data for this area is not available, as the entire nation of Mongolia only has thirty-five weather stations for an area of almost 150 million hectares, or roughly 4.3 million hectares per station. Hence, they are unable to capture the variability of this alpine-mountain steppe environment (Kogan *et al*. 2004, 2880).

The vegetation of this alpine-mountain steppe landscape is sequentially composed of semi-desert, short-steppe grassland, *taiga*, wetlands, mountain steppe, and montane tundra at the higher elevations. The vegetation is also characterized by high rates of endemism (around 12%) (USDA Foreign Agricultural Service Report 2001, 9). Additionally, the Sailugem Range and the Altai Mountains are home to two large endangered species, the snow leopard (*Uncia uncia*) and the Altai Argali Sheep (*Ovis amon amon).*

Siilkhemiin Nuruu National Park (Cluster A) was created in 2000 by the Peoples Republic of Mongolia, primarily to protect the Altai Argali sheep habitat. The park is currently managed by the Mongol Altai Nuruu Special Protected Areas Administration (MANSPAA), which also oversees the management of three other protected areas (Maroney 2004, 40). The Bayan-Olgii Province is predominantly Kazakh (roughly 90% of the population), and most all of the herders living in the Siilkhemiin Nuruu National Park are Kazakh (Maroney 2004, 7). National Parks are categorized into Special Use

Zones, such as Travel and Tourism Zones, and Limited Use Zones. However, during years of drought and deep snows, grazing can be allowed on all areas (Bedunah and Schmidt 2004, 169). Currently, there are believed to be between 80,000 and 90,000 head of livestock roaming the counties where Siilkhemiin National Park is located, down from the 1997 peak of a little over 100,000 animals (Bayan-Olgii Office of Statistics 2002; Maroney 2003, 10).

In the Kosh-Agach Wildlife Refuge located in the Altai Republic, livestock was intensively managed in the "collective systems" throughout the Soviet era. Created in 1973 to protect the habitat of the endangered Altai Argali sheep, the refuge has always supported the herds of the Altai Telengit peoples, and in the last century more Kazahk herders have moved into the area, making them the second largest ethnic group (Badenkov 2002, 320). Stocking densities here were extremely high, as this area of the southern Altai Republic was known to supply most of the meat requirements of the Soviet army, causing overgrazing in certain areas (USDA Foreign Agricultural Service Report 2001, 9). After the fall of the Soviet Union, there was a drop in demand from the army. Thus grazing pressures in this region are believed to have declined considerably.

Human Settlement

Although the Sailugem Mountains were probably heavily glaciated most of the Lower to Middle Pleistocene, there are numerous petroglyphs and flints from inhabitants dating back to the late Pleistocene (Sinor 1990, 45-46). The Middle Palaeolithic saw technological advances in weapons and tools, the coexistence of Neanderthal cultures and modern *Homo sapiens*, as well as extinctions of cave bear and cave lion-probably caused by direct competition with these groups (Sinor 1990, 54-56; Gritzner 2001, 117). By the

Upper Palaeolithic, *Homo sapiens* had exerted their dominance in the area, and their populations showed signs of both nomadic and sedentary lifestyles, leaving the beautiful frescoes in the Khoit-Tsenker Cave in western Mongolia as well as artistic figurines made of bone and ivory (Sinor 1990, 57; Gritzner 2001, 118-119).

Hunting and gathering and a traditional semi-nomadic life continued in the Central Asian steppes through the Mesolithic with some advances in weapons and the development of pottery (Gritzner 2001, 120-121). The Neolithic Era saw a rise in animal domestication and large expansions of animal husbandry. Additionally, horse riding and breeding arose during this period, around 4000 B.C., increasing peoples' mobility and interactions with others (increasing trade and fighting), as well as demands for adequate forage (Gritzner 2001, 122). Variations of horse pastoralism, animal husbandry, farming, and/or hunting and gathering began to flourish (Christian 2000, 8).

However, by the time of the Bronze Age (c. 1700 B.C. to 800 B.C.), evidence from excavations suggest that dwellers were not only traversing long distances, but also making elaborate horse harnesses and equipment (Bashilov and Yablonsky 2000, 9). With these new technologies came new weapons, tools, and objects which facilitated mass movements of people during this period. Palaeogeographic studies suggest that large population movements also occurred deep in the Asian steppe, owing to increasing aridity, thus forcing peoples to look for better pastures for livestock (Bashilov and Yablonsky 2000, 9). Studies of the Androvono people, a more sedentary agricultural group occupying the steppe, have confirmed this with discoveries of herding camps detached from their village sites, suggesting that lack of adequate pastures forced them to move livestock seasonally (Gritzner 2001, 123).

Also during this period, the Great Altai Mountain area was home to a booming metallurgy industry. The Karasuk culture soon evolved out the Androveno Culture, and continued and further developed these skills and this craft. At one site in Kazakhstan, Karasuk miners had excavated over one million tons of ore, and were producing items such as weapons, armor, bracelets, rings, and many other functioning tools, leading many to believe that these works led to the origins of archaic Chinese bronzes (Gritzner 2001, 122).

Although, historians quibble over exact dates, it can be argued that during this period (if not much sooner), elaborate trade routes were developing from East and Central Asia, westward to the Black and Mediterranean seas, eventually forming parts of the famous trade routes known to us as the "Silk Roads" (*Die Seidenstrassen*), a phrase coined by German geographer, Baron Ferdinand von Richthofen (1833-1905) in the late nineteenth century. It was used to describe these multiple routes passing through Central Asia. These routes would develop into a network of constantly shifting paths, usually dependent upon the location of kingdoms, natural barriers, enemies or allies, families, drought, and disease (Christian 2000, 2-4).

During the Bronze Age, and following the passing of the Karasuk Culture, the Eurasian steppe saw the rise of two kindred groups, the Scythian and Saka (Asiatic Scythians) tribes (Bashilov and Yablonsky 2000, 9). These largely nomadic groups occupied the central and northern steppe lands from the Black Sea to the eastern Mongolian plains. During this period, the area south of the Aral Sea to the Volga-Ural region is said to be where the Indo-Iranian language originated (Bashilov and Yablonsky 2000, 9). The Scythians were notorious for their fierce fighting and large burial mounds, known as *kurgans*. Herodotus, known by some as "the Father of History," in 447 B.C. gave us our first glimpse of this culture and their use of fire in battle on the Russian grasslands. While retreating from the army of Darius, the Scythians left "the whole country bare of forage…destroying all that grew on the ground" (Herodotus 1954, 267-269; Thomas *et al.* 1956, 120-121).

Within the Scythian-Saka cultures of the Iron Age was a group known as the Pazyryks, whose burial mounds still are scattered around the Sailugem Mountains and this study area. The most famous of their kurgans was excavated in 1993, in the Ukok Plateau of Russia, which is a mere fifty kilometers west of the study site. The site was dated to the 3rd-4th Century B.C. and documented in the October, 1994 *National Geographic Magazine*. At this site was discovered a mummified woman with blond hair standing 5'6", with various tattoos on her body. Unearthed with her were six horses, ancient rugs, wool and silk clothing, and a brass mirror. DNA testing showed that she was not entirely Caucasian, but also had shared genes and features of Mongoloid descent, highlighting how this area of the world and its numerous trade routes had connected different peoples for sometime.

Eventually, power shifted from Scythian cultures to a Turkol Mongol group known as the Hsiung-nu (Xiongnu). Arising from the eastern parts of Mongolia, this group was largely nomadic, like the Scythian culture, and displayed many of the same customs, traditions, and fighting styles (Grousset 2002, 23). The Hsiung-nu gained control of the old routes of trade, pushing the Indo-European groups and the Chinese back out of Inner Asia and causing the latter to eventually connect and complete "the Great Wall," owing to numerous raids from the inner steppe lands into China (Grousset 2002, 26).

The centuries following saw the rise of several groups that would dominate Inner Asia. The Turks, Uighurs, and Chinese T'ang Dynasty would control larger empires for certain periods, while advances and shorter reigns of smaller Arab and, later, Altay groups would occur until A.D. 1218, when the Mongol armies of Chinggis Khan would overrun Central Asia (Grousset 2002, 236; Gritzner 2001, 129-131). These multiple movements of invading and fleeing groups are thought to have caused considerable destruction to what remained of the steppe farming communities (Thomas *et al*. 1956, 293). From this period of the thirteenth to the fifteenth centuries, the Mongol Empire controlled the lucrative trade routes across Central Asia, until the rise of the Kazakhs (Christian 2000, 17; Gritzner 1995, 131).

The Kazakhs dominated the area until the late seventeenth century, when Russians and other Europeans began their expansion into Central Asia, dispersing this group and many others. They brought with them European land-tenure practices that caused the fragmentation of traditional nomadic pastureland (Gritzner 2001, 132).

Kazakhs, fleeing the Russian expansion in the late 1800s, dispersed throughout Inner Asia, with many migrating into the Xinjiang-Uigar region of China, the Kosh-Agach District of the Altai Republic, and northwest Mongolia (Badenkov 2002, 320). Initially, after the fall of the Soviet Union Empire in 1991, many Kazakhs left Mongolia and returned to Kazakhstan, only to find conditions there unfavorable. They soon returned to Mongolia, creating many problems related to disputed grazing lands which were temporarily abandoned and claimed by others-generally Mongols leaving urban areas (Tumenbayar 2000, 26).

Currently, there are around 92,000 Kazakhs in Mongolia, where they make up around 90% of the population in the Province of Bayan-Olgii, and they are the second largest ethnic group in the Kosh-Agach District of the Altai Republic, residing with the Altai Telengit peoples. Both still practice semi-nomadic livestock breeding (Maroney 2004, 41; Badenkov 2002, 320).

The Telengit of the Altai peoples, a Turko-Mongol group predominately found in the Kosh-Agach District of Russia. According to a 1979 census, the Altaics, known as the Oirot until 1947, when the Oirot Autonomous Region changed its name to Mountain Altai Autonomous Region (Republic of the Altai: 2006). They make up about 29.1% of the population, with a total number of 50,203 in this district.

Pastoralist Culture and Land Use Patterns

In 1991, the fall of the Soviet Union and the attendant dissolution of the socialist collectives (*negdels*) initiated a transition towards a free-market economy. In predominantly rural Mongolia, free-market reforms led to what many have called the "new nomads." Owing to lack of employment, semi-urban peoples began moving into the steppe to raise animals. With little or no work in urban areas between 1992-2000, the number of herder families in Mongolia increased twofold and livestock 18%, while, by 1998, 35% of all households were herders (Johnson *et al*. 2006, 14). Additionally, with Mongolia's land laws, which have always maintained that rangelands are state owned and common property for herders, it is logical that people would return to their historic livelihoods when faced with the transition from a fixed economy to a market-based economy (Johnson *et al.* 2006, 16). However, with the fall of the Soviet Union, institutions regulating herds and lands disappeared, and animals were distributed in 1991 and 1992 to the herders who were part of the collectives, giving them freedom to choose when, where, and how they raised their livestock (Reading *et al*. 2004, 5).

Known as the Land of Five Animals (sheep, goats, cattle [including yak and yak hybrids], horses and camels), Mongolia's nickname could also sum up the livestock found in the herds of the Sailugem area (Phillips 1996, 1). Grazing systems are transhumant, with winter camps which consist of corrals and usually a covered structure for the protection of livestock from severe conditions, as well as *hot ails* (summer camps) with several seasonal moves for herder families and animals (Reading et al. 2004, 4-5; Fernandez-Gimenez 2004, 31-33). Although, pastoral land-use practices have changed and evolved over time, certain key characteristics of pastoral life remain, such as maintaining a flexible and mobile strategy to adapt to the adverse and variable conditions of weather, livestock, or rangelands (Fernadez-Gimenez 2004, 30).

During the last century, from the 1950s to the collapse of the Soviet system, *negdels*, or collective farms, were implemented throughout Mongolia. This brought with it new approaches (good and bad) to herding, such as separating herds by species, building wooden shelters for animal protection, access to veterinary services, and emergency fodder provided for all (Fernandez-Gimenez 2004, 33). Collective farming was a Soviet design, and was implemented throughout the Soviet Central Asian states, including the Altai Republic. During this time, grazing regulation was enforced by the state, and herders continued their *otors*, or moves, from seasonal pastures, while out of season use on winter or spring pastures was punishable with fines (Fernandez-Gimenez and Batbuyan 2006, 144). Other institutions, such as the Buddhist church, also enforced some regulations, while informal regulation was enforced within the local herding communities (Fernandez-Gimenez 2004, 33).

Since the time of Chinggis Khan in the 13th century, rangeland management has been practiced on the steppe lands of this area, and enforced by Mongol nobility (Fernandez-Gimenez 2004, 32-33). By the 16th century, Tibetan-Buddhism had swept across the area and had much influence over the Mongols, with almost all of the herds and pastures controlled and regulated by *lamas* of Buddhist monasteries (Lattimore 1940, 88; Fernandez-Gimenez 2004, 31). There was such a strong connection between Mongolia to Tibet that the fourth Dalai Lama of Tibet (1589-1616) was a Mongol, making him the only Dalai Lama not of Tibetan birth or nationality (Lattimore 1940, 88).

Over the last decade, with no real range-management regulations being enforced, it has been observed primarily in desert-steppe and desert ecological zones that ecological conditions and long-term ecological stability have been greatly impacted, owing to increased livestock numbers, diminished spatial distribution of livestock, collapse of many grazing systems, severe winter storms, and droughts (Johnson *et al*. 2006, 4). With almost 200,000 households (in 2000), and more than a third of Mongolia's population dependent upon animal husbandry, this has serious implications for long-term economic and ecological sustainability (Johnson *et al*. 2006, 14).

In the Kosh-Agach District of the Altai Republic, conditions today are very similar. During the Soviet times, state subsidies accounted for nearly 100% of the local budget for this mountain district. After the fall of the Soviet Union, politicians from Moscow disbanded all collective farms and sold off livestock to wealthy politicians, leaving the Altai Republic with vast impoverishment, rises in criminality and alcoholism, and deteriorating social services (Badenkov 2002, 321-322). Additionally, these groups were much more institutionalized during the Soviet era, with many people forced into a sedentary lifestyle, forgetting their historical practices of pastoralism and now without the means to return (Badenkov 2002, 322). Today, with less demand for livestock products, pastoral practices in the Kosh-Agach District are occurring at a much lower level than experienced during Soviet times and perhaps during the pre-Soviet era.

While a reduction in livestock and pastoralism seems to be the case for the Kosh-Agach District, the exact opposite seems to have occurred across the Sailugem Range in the Province of Bayan-Olgii, as well as in the rest of Mongolia. Livestock numbers, herd sizes, and the number of herding families increased dramatically in the 1990s. With a lack of rangeland-management oversight and concentrated grazing near water holes, roads, population centers, haylands, and seasonal camps, deteriorating range conditions exist in many of these areas (Johnson *et al*. 2006, 15).

Livestock numbers in Mongolia peaked in 1999, with approximately 33.5 million head, but faced with two consecutive years of harsh winters and drought (termed: *zhuds*), the number of animals was reduced to around 26 million by 2002 (Johnson *et al*. 2006, 19; Tumenbayer 2000, 8). Livestock numbers in Bayan-Olgii doubled in the 1990s, from around 50,000 animals in 1992 to 100,000 by 1997, and then, owing to the *zhud* years, dropped to around 80,000 by 2001 (Maroney 2003,11; Bayan-Olgii Office of Statistics, 2002). The human population rose in these areas from around 578 in 1982 to approximately 4615 by 2001 (Bayan-Olgii Office of Statistics, 2002).

Other considerable changes on these rangelands include the species composition on the land being grazed. Since these economies have moved to a free-market system, there have been improvements in the cashmere markets, resulting in a dramatic increase in goats (which are known to increase impacts on grassland conditions) throughout Mongolia and the area of the Sailugem (Johnson *et al*. 2006, 20).

Current Cultural Conditions

In the Sailugem region today, new routes of commerce and trade have been opened, connecting the markets of Kosh-Agach with Bayan-Olgii, as well as the Xinjang region of China, owing to better relations among these nations and their embracement of certain forms of globalization and free trades. It has been noted by Yuri Badenkov, a Russian scientist at the Institute of Geography of the Russian Academy of Sciences, that the Kazakhs seem to be adapting far better than other ethnic groups in this region because of their shared language, culture, and nationality. He also suggests that this could be attributed to the Islamic faith practiced by the Kazakhs, which generally keeps them from the influences of alcoholism and drugs that seem to be plaguing the Telengits of the Altai and other ethnic minorities such as Mongols and Tuvans, who all have populations in these countries (Badenkov 2002, 321; Phillips 1996, 5-8).

Owing to the hard life that these groups faced during this phase of economic transition, it is not surprising that an increase in ethnic tensions is arising. Grazing land disputes between Kazakhs and Mongols in Bayan-Olgii still exist, dating from the initial exodus of the Kazakhs after the collapse of the Soviet Union, and then their subsequent return a few years later, expecting their grazing lands and the winter shelters which they had abandoned to still be there for them (Tumenbayer 2000, 26).

In the Kosh-Agach District, Kazakhs are not recognized as a legitimate minority by the Russian government, unlike the Altaic Telengits (*Federal List of Minorities*, 2000 -

which entitles the latter to various forms of state support). Although many Kazakhs are active in the local and regional governments there, resentment between the two groups is growing (Badenkov 2002, 321). Sadly, these same two groups have lived together peacefully for the past 200 years.

It is rather clear that capitalism and free markets are currently poorly adapted to the cultures and livelihoods of the region. As these groups embrace their pastoral roots in order to survive in this new economic system, the observations of Swedish economist C.G. Wildstrand are instructive: a classic pastoral livestock operation is “not a capitalistic undertaking aimed at producing a marketable surplus,” but rather herds are for regular supply of food for family, for physical survival, social status, and to maximize the chances of survival during adverse periods or times of risk (Tumenbayar 2000, 7).

CHAPTER 5

METHODOLOGY AND ANALYSIS

To understand vegetation conditions and quantify change within the landscape, this study drew upon a series of analyses using multi-temporal satellite imagery provided by the University of Maryland's Global Land Cover Facility (GLCF). Matrix Change and Normalized Difference Vegetation Index (NDVI) analyses, as well as visual comparison overlays utilizing information collected in the field, shed light on this area's current rangeland conditions. There is a strong correlation between the NDVI and above-ground net primary productivity for vegetation (Paruelo *et al*. 2000, Schickhoff 2002, 3, and Lillesand, Kiefer and Chipman 2004, 470).

When studying multi-temporal vegetation and landscape change with satellite imagery, images should be acquired at approximately the same time of year, and, if possible, on the exact date to ensure similar seasonal influences. This is referred to as an "anniversary date" (Lillesand and Kiefer 1994, 621). Using anniversary-date images reduces computational errors that may arise from seasonal differences in plant phenology or changing climatic variables. The change between dates will be depicted by increase or decrease in the extent of each spectral signature class. This type of analysis frequently yields information useful in predicting trends, as well as identifying threats to ecosystems.

Data Acquisition and Processing

Because the study area fell across the seam on the path of the Landsat satellites, two images were necessary to cover this area for each year considered. Two Landsat 4 TM scenes (Path 143 Row 25 and Path 143 Row 26) acquired on September 17, 1989 and two Landsat 7 ETM scenes of the same area (Path 143, Row 25 and Path 143, Row 26) acquired on September 4, 2001 were acquired from the GLCF for this study. All images were in the UTM Zone 45 North projection, with a WGS 1984 spheriod and datum. Although these images are not exact anniversary dates, they fit within the window of acceptability owing to temporal proximity. Furthermore, the cost of new image acquisition on the exact anniversary dates exceeded the budget for this study.

Prior to initiating the analysis, preliminary data processing was conducted on the images. Bands 3, 4, and 5 for each image were converted from the tagged image format (.tif), into an unsigned 8-bit Erdas (.img) format before all four image scenes were "stacked" into four individual multi-band images. Then, using Erdas software, images were merged with one another to form one image from the two 1989 images and one image of from the 2001 images. Next, the images were checked for registration and were found to be within an acceptable range for this study (inside half a pixel).

In this false colored composite 1989 image from September 17th (Fig. 2), snow was discovered in the higher elevations of the Sailugem Range. Although the snow was located in the higher, rocky talus slopes (black in this image), not obscuring any vegetation, when conducting a Matrix Change or NDVI, this bright feature would heavily skew the results. Hence, it was decided to mask or remove this area from the image to make sure the same total area, or "study area," of each image was being compared accurately. This higher elevation area was removed from the 1989 image and the 2001 image, using the "Mask" feature in Erdas.

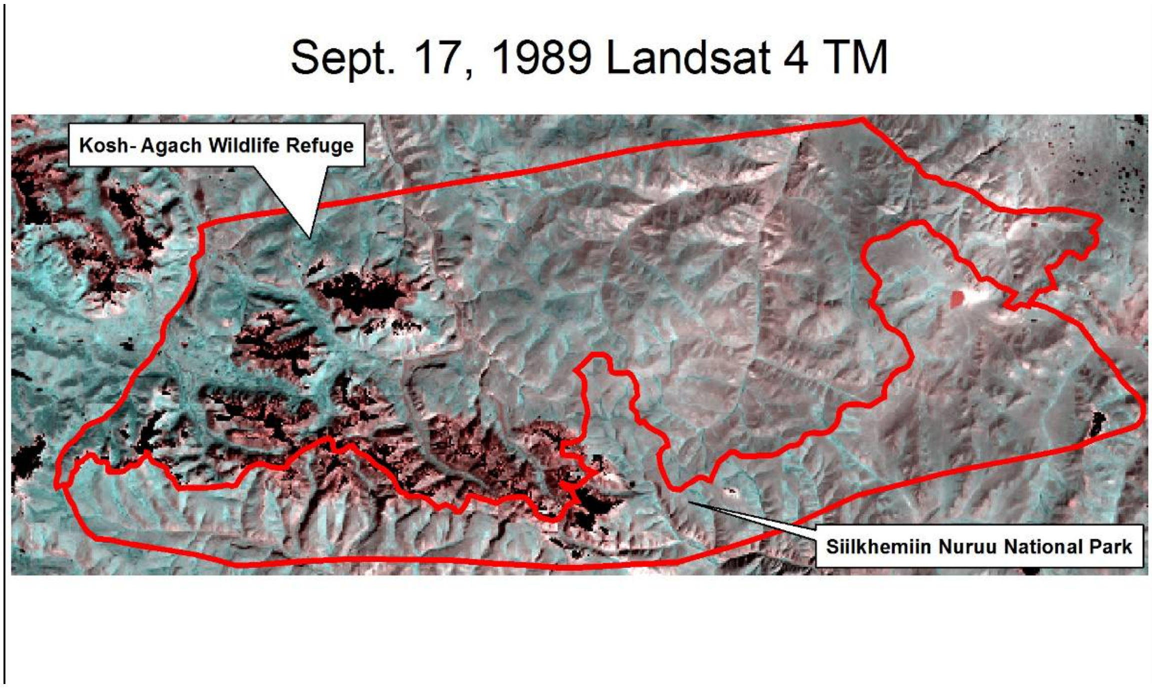

Fig. 2 Landsat September 17, 1989 4TM

Additionally, in the 2001 Landsat 7 image, a faulty sensor caused a defect in one of the bands, causing a streaking or stripping effect. This was discovered in the upper part of the image just adjacent to the study area. Data was processed in Erdas Imagine 8.7 software, and the area of the band/sensor error was removed from the images using the Environmental Systems Research Institute's (ESRI) ArcInfo 9.1 Software. All areas were recalculated using the ESRI software.

To have a better understanding of the landscape and its condition, an unsupervised classification for both the 1989 and the 2001 images was conducted. In essence, an unsupervised classification is a segmentation of pixels into classes based upon natural groupings and clusters that are inherent in the imagery, where the computer uses a complex algorithm to determine similar pixels, and groups them accordingly

(Lillesand, Kiefer, and Chipman 2004, 573). Images were split into six classes each for comparison, based upon these similar spectral classes. This unsupervised classification requires the analyst to determine the identity of these classes by referencing other pre-existing datasets, aerial photography or ground truthing.

Ground-truth data and other field data were collected in August 2004 in Kosh-Agach Wildlife Refuge, Russia and September 2005 within Siilkhemiin Nuruu National Park (Cluster A), Mongolia. Vegetation plots and predetermined spectral classes were sampled in the latter trip in Mongolia using maps of the unsupervised classed Landsat 7 ETM image of the area. Owing to the large area and limited timeframe for fieldwork, it was decided that a random vegetation sample would not to be used. This would better assure that information for all class indices was collected in case an supervised classification was to be attempted, as well as to guarantee a thorough assessment of the entire landscape per its spectral class. Vegetation plots included vegetation class, photo points, and percentage cover.

Analysis

The Matrix Change model was conducted within Erdas Imagine software. This basically utilizes two images, and does a “from-to” analysis, meaning from 1989 to 2001-newer image (2001) pixel values being subtracted from the older image (1989) pixel values giving the difference. Pixels were classified as: (i) no data, (ii) increased, (iii) some increase, (iv) unchanged, (v) some decrease, or (vi) decreased; depending upon the change in their spectral reflectance.

With the NDVI analysis, the Landsat TM and ETM imagery band 3 (red, 630-690 nm) and band 4 (near infrared, 760-900 nm), the NDVI was calculated for these images as: NDVI = (NIR – R) / (NIR + R) where NIR is the near infrared band (band 4) and R is the red band (band 3) (Lillesand, Kiefer and Chipman 2004, 468). Data is displayed in a range from within, but not equal to, –1 and 1. For example, ranges may be (.78 to .56), with negative values being non-vegetation and positive values being vegetation with photosynthetic conducting values. NDVI images for each year will then be compared and analyzed.

Image data in this format are displayed with ramping values and can be hard to visually examine. For better geographical viewing analyses, the NDVI images were run through a binary model with a conditional statement, so that all values less than zero were assigned a zero (non-photosynthetic properties), and areas with positive values (photosynthetic properties) were assigned a one. This image was a 2-bit, thematic image, which helps in understanding the data spatially.

CHAPTER 6

RESULTS

The Change-detection analysis from the 1989 to the 2001 image, saw values in the red and pink decreasing from 1989 to 2001, and yellow and green were increasing. Pixel values were: (i) no data = 0, (ii) increased 369,347 (iii) some increase 2,127,594 (iv) unchanged 381,347 (v) some decrease 824,431 (vi) decreased 241,630

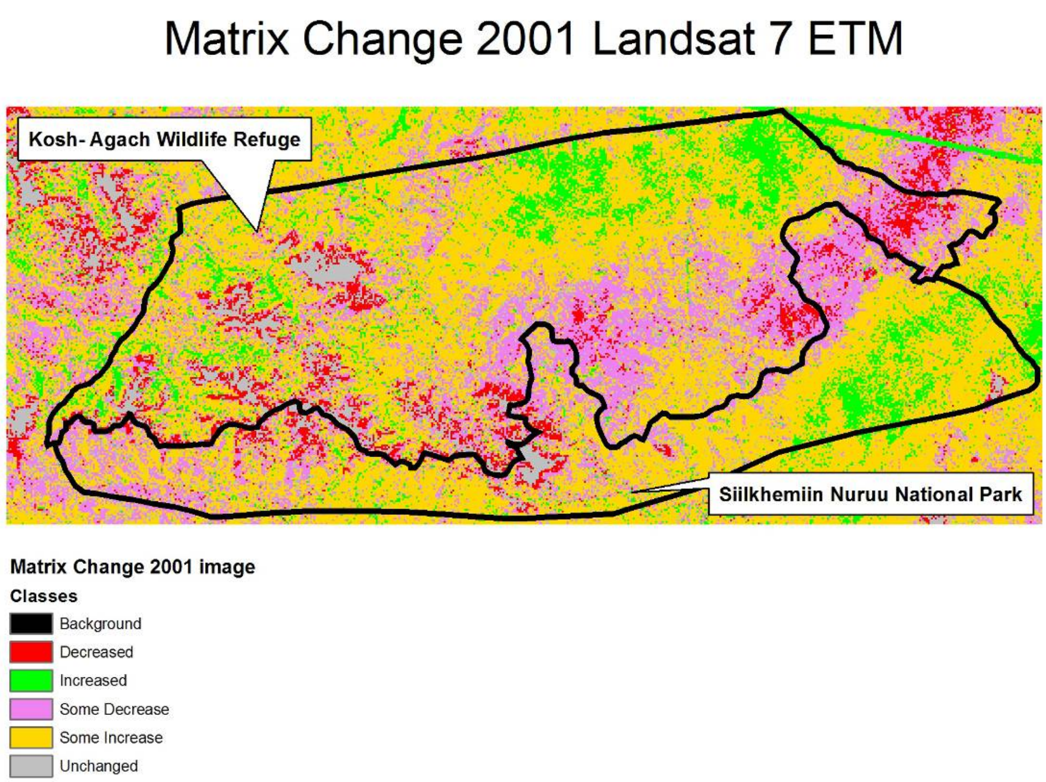

Fig. 3 Matrix Change 2001 Landsat 7 ETM

The NDVI analysis showed significant changes, with 21,295.03 acres of photosynthetic activity occurring in the 2001 image, versus the 1989 image which had 274,581.5 acres of active vegetation or 3% of the land area versus 37% of the total area in respective years. This is an overall decrease from 1989 to 2001 of 93% of the active vegetation.

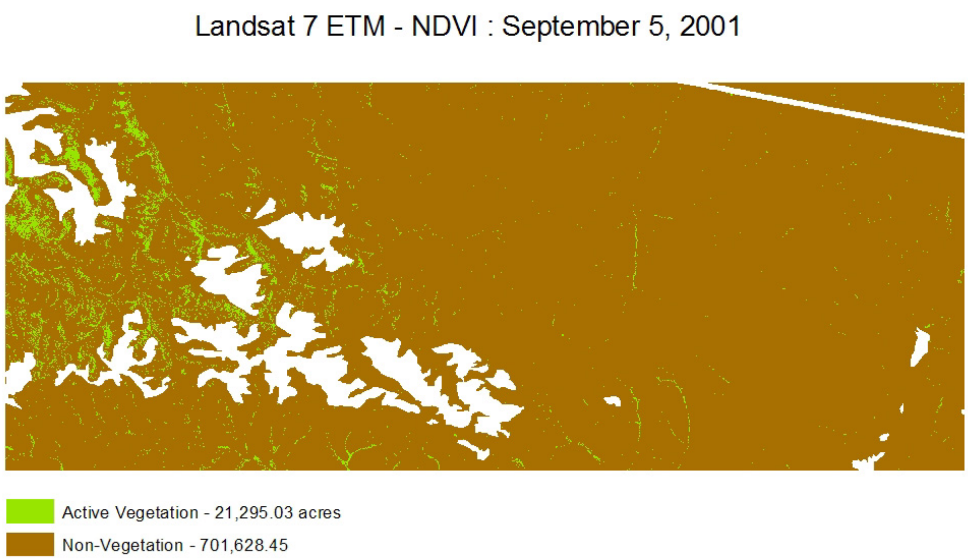

Fig. 4 Landsat 7 –NDVI – September 5, 2001

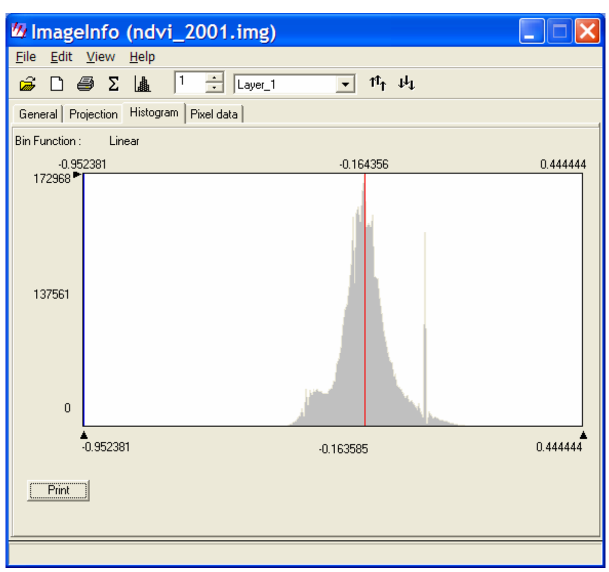

Fig. 5 Landsat 7 – NDVI – Histogram Distribution

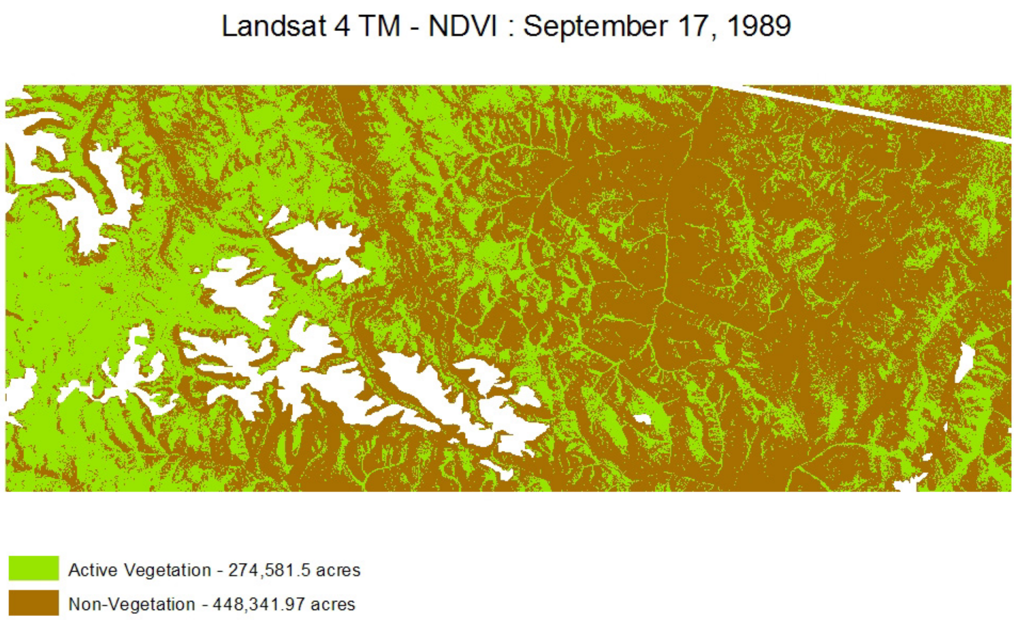

Fig. 6 Landsat 4 –NDVI – September 17, 1989

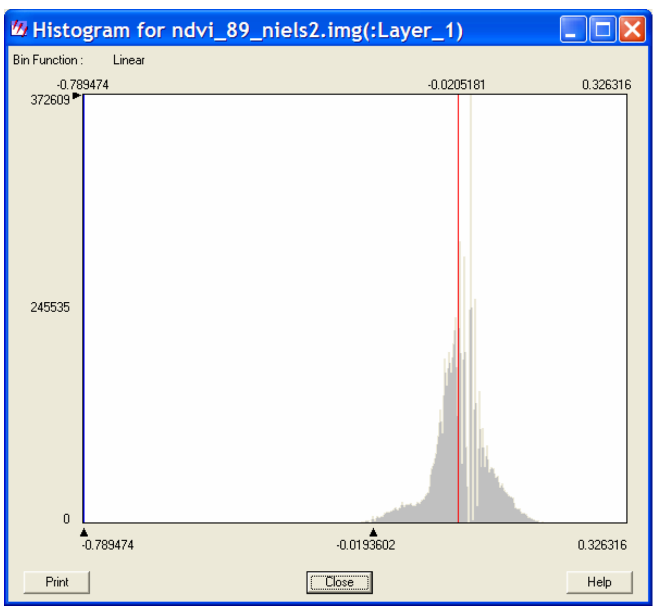

Fig. 7 Landsat 4 –NDVI – Histogram Distribution

CHAPTER 7

INTERPRETATION AND DISCUSSION

The results of the matrix change analysis show a decrease of values (pink/red) in the upper elevation zones closer to the Sailugem Ridge, where higher precipitation levels usually occur, while an a increase in values in the lower elevations can be seen (yellow/green). Looking more closely at the false color composite images of the Khug Nuur area of Siilkhemiin Nuruu National Park in the eastern portion of the study area offers some explanation (Fig. 8-11). These images are of the same area with the matrix change performed.

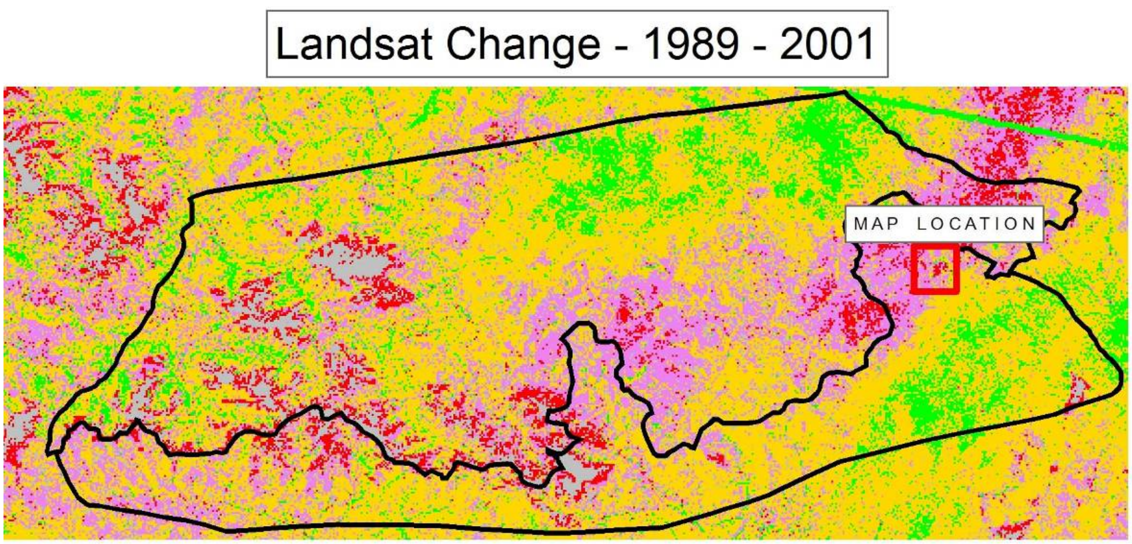

Fig. 8 Landsat 7 Matrix Change – Map Location – Study Area

Additionally overlayed on the images are field sites observed during field studies conducted in 2005.

In the 1989 image (Fig. 8), higher lake levels can be observed, in addition to green vegetation surrounding the lake. Also noteworthy is the large white area in the north-eastern portion of this image. This is a large bare-soil area located on a dry south-

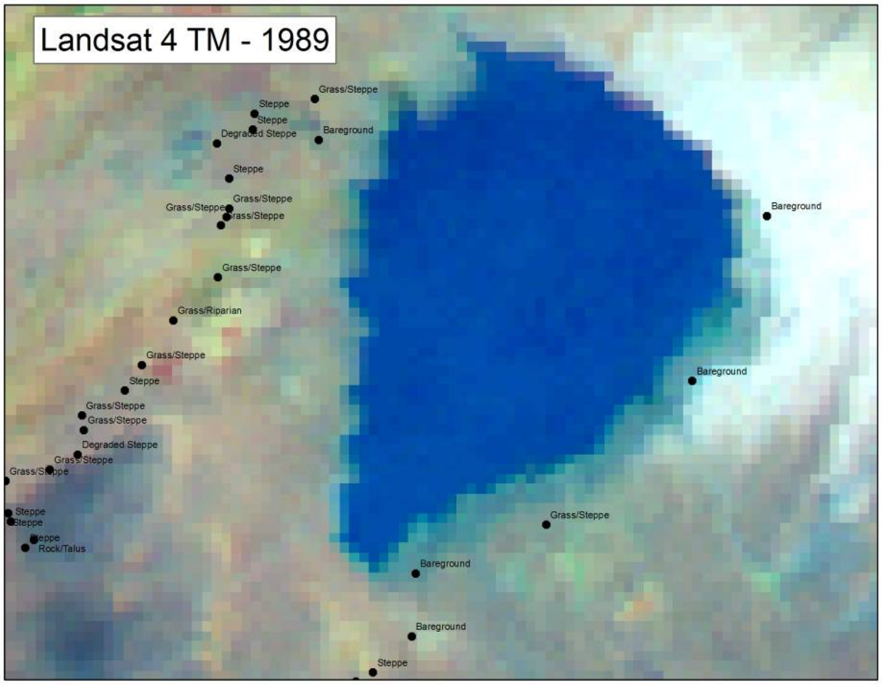

Fig. 9 Landsat 4 – 1989 – False Color Composite (RGB)

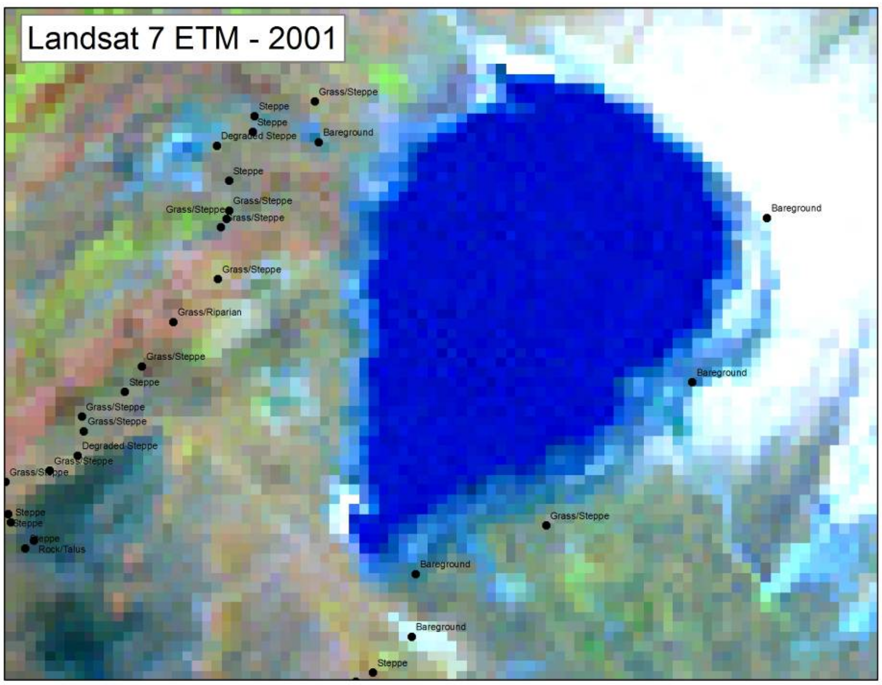

Fig. 10 Landsat 7 – 2001 – False Color Composite (RGB)

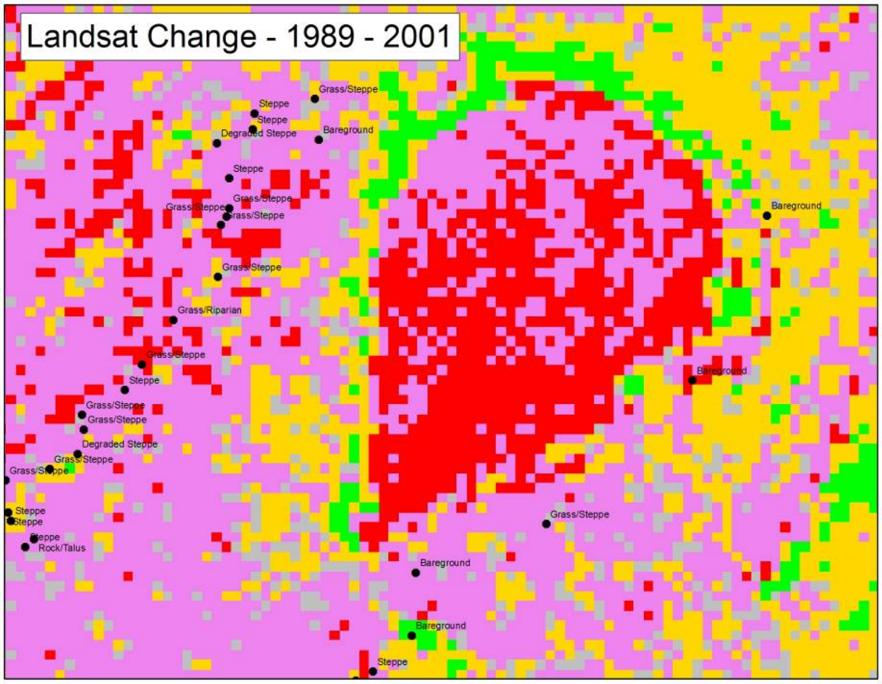

Fig. 11 Landsat 7 – Matrix Change - 2001

west facing slope. Points indicate local conditions, such as (i) bareground (ii) steppe (iii) grass-steppe or (iv) rock-talus. These are vegetation plots where basic classes were identified during field research. Viewing the 2001 image, lower lake levels can be seen when compared with the 1989 image. Also,more exposed ground or bare-soil surrounding the lake can be seen in the 2001 image, as well as in other areas of the picture. This is indicative of the much drier conditions of the 2001 image as well as losses of grasses, soil moisture, and other steppe vegetation.

Also in the upper left or north-west corner of the 1989 image, more lush riparian vegetation, such as sedges and alpine grasses, can be found. Again, this is where elevations begin to rise toward the border. In the 2001 image (Fig. 9), these classes have decreased. All of these changes have been picked up in the matrix change analysis in

Fig. 10, with classes of decrease being pink and red, while classes of increase are yellow and green, with gray remaining the same in both images.

With the NDVI analysis, sharp drops in active vegetation were observed from 1989 to 2001. Although images used in the analysis were twelve years apart, both are from similar seasonal periods (separated by two weeks), making such a large decrease normally unexpected. However, in 2001, this area had just experienced its second consecutive *zhud* year, which is a year of extreme winter storms followed by intense summer droughts (Fernandez-Gimenez 2004, 31; Maroney 2004, 41). Lack of active vegetation would thus be expected, owing to consecutive years of low moisture, vegetative stress, and grazing pressure. All active vegetation in the 2001 image was located specifically in the riparian areas, sumps, creek bottoms and the higher mountains of Russia where greater precipitation generally occurs.

CHAPTER 8

CONCLUSION

Although significant changes were observed in both analyses between these two image dates, there are several potential explanations for these, as previously mentioned. First and foremost would be the *zhud* years, or extreme drought years of 2000 and of 2001 that influenced the later imagery of this analysis. Although the highest stocking densities ever observed in Mongolia occurred in 1999, it cannot be concluded that this contributed to the observed changes in vegetation within this study area. In addition to the vegetation changes, the reductions in water bodies and an increase in bare ground surrounding these areas cannot be conclusively attributed to anything other than the harsh drought conditions experienced in 2000 and 2001.

Secondly, with the matrix change or change detection analysis, there is a probability of reflective properties of the soil influencing the analysis, especially in areas of sparse vegetation (Camacho-De Coca et al. 2004, 3450). Further analysis, such as a supervised classification, would be needed to determine each influence and its contribution to the change.

Lastly, most changes observed occurred in both protected areas of Russia and Mongolia, suggesting a strong climatic influence rather than land management or pastoral practices. It can be concluded that vegetation conditions in the study area had declined within the twelve year time-frame observed, but further analysis is suggested to study on how might any anthropogenic influence may have contributed to this decline.

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