Chapter 8
Impacts of Arctic Climate and Land Use Changes on Reindeer Pastoralism: Indigenous Knowledge and Remote Sensing

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Abstract Eurasian indigenous reindeer herders have developed an important initiative to study the impacts of climate change and to develop local adaptation strategies based upon their traditional knowledge of the land and its uses – in an international, interdisciplinary partnership with the science community – involving extensive collaborations and co-production of knowledge to minimize the impacts of the various changes. This unprecedented reindeer herder-led initiative is the IPY EALAT Project, "EALAT, Reindeer Pastoralism in a Changing Climate". This chapter provides an overview of the EALAT initiative, with an emphasis on how remote sensing, Geographic Information Systems (GIS), and other scientific data are being combined with indigenous knowledge to "co-produce" datasets to improve decision-making and herd management; some early results; and a description of the EALAT/Monitoring data integration and sharing system and portal being developed for reindeer pastoralism to integrate traditional indigenous knowledge together with remote sensing and other scientific data to enhance early warning and management for change responses and adaptation.

8.1 Introduction

8.1.1 Reindeer Pastoralism and Arctic Changes

The Arctic is home to many indigenous peoples, including those who depend on reindeer herding for their livelihood, in one of the harshest environments in the world. For the largely nomadic peoples, reindeer not only form a substantial part of the arctic food base and economy, but they are also culturally important, shaping their way of life, mythologies, festivals and ceremonies. Reindeer pastoralism

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or husbandry has been practiced by numerous peoples all across Eurasia for thousands of years and involves moving herds of reindeer, which are very docile animals, from pasture to pasture depending on the season. This means herders lead either a nomadic life living in a tent on the arctic tundra year-round as a family unit, or a semi-nomadic life, having permanent residences for parts of the year and having fewer family members herding on a daily basis. Thus, herders must adapt on a daily basis to find optimal conditions for their herds according to the constantly changing conditions.

Having learned over generations to live with uncertainties in an arctic environment, indigenous societies that practice traditional reindeer husbandry are good examples of sustainable human communities that are highly interconnected with the ecosystems in which they live, also reflecting the American Indian concept of the "power of place" described by Deloria and Wildcat (2001). Climate change and variability plus rapid development are increasingly creating major changes in the physical environment, ecology, and cultures of these indigenous reindeer herder communities in the north, and climate changes are occurring significantly faster in the Arctic than the rest of the globe, with correspondingly dramatic impacts (Oskal 2008).

In response to these changes, Eurasian reindeer herders have created the EALÁT project, a comprehensive new initiative to study these impacts and to develop local adaptation strategies based upon their traditional knowledge of the land and its uses – in targeted partnership with the science and remote sensing community – involving extensive collaborations and co-production of knowledge to minimize the impacts of the various changes. This unprecedented new reindeer herder-led initiative has resulted in the development of an international, interdisciplinary collaboration with scientists through the International Polar Year (IPY) EALÁT Consortium (IPY Project # 399 "EALÁT, Reindeer Pastoralism in a Changing Climate") that directly addresses the herders' need for additional data and information for responding to the global and environmental changes through a variety of different projects.

The EALÁT initiative is considered unique because the study was conceived and implemented by indigenous reindeer herders who continue to lead a large multidisciplinary group of invited scientists and other collaborators in this complex study of the multiple challenges facing arctic reindeer herding communities. In addition, the EALÁT study sites are located in areas where reindeer pastoralism has been practiced over thousands of years, and, thus, this wealth of traditional knowledge provides a special perspective similar to that articulated by Deloria for American Indians, who stated that "Traditional knowledge enables us to see our place and our responsibility within the movement of history as it is experienced by the community" (Deloria 2001).

This Chapter provides background on climate and development challenges to reindeer husbandry across the Arctic and an overview of the EALÁT initiative, with an emphasis on indigenous knowledge, remote sensing, Geographic Information Systems (GIS), and other scientific data to "co-produce" data sets for use by herders for improved decision-making and herd management. It also provides a description

of the EALÁT monitoring data integration and sharing system and portal being developed for reindeer pastoralism. In addition, this Chapter provides some preliminary results from the EALÁT project, including some early remote sensing research results.

8.1.2 Reindeer Pastoralism Across the Arctic – Background and Challenges

Reindeer husbandry has a long history in the Arctic. There are more than 20 different indigenous peoples in the Arctic who are reindeer herders. Reindeer husbandry is practiced in Norway, Sweden, Finland, Russia, Mongolia, China, Alaska, Canada and Greenland. This livelihood involves some 100,000 herders and approximately 2.5 million semi-domesticated reindeer, which graze approximately 4 million km^2 in Eurasia (Fig. 8.1). While reindeer husbandry is spread across the Arctic and across many cultures, its organization is remarkably similar everywhere, consisting of a nomadic livelihood with family-based working communities and a typical indigenous way of life. For hundreds of years, reindeer herders have managed vast barren circumpolar areas of land that hold little value for others. Herding represents a model for sustainable management of these areas that has developed through generations. In recent years, however, as noted earlier, arctic reindeer herders increasingly face major challenges, such as climate change, loss of grazing land due to development by humans, and effects of global change in their local societies (Oskal 2008).

Reindeer/caribou are the very base of the traditional economy for many indigenous northern peoples across the Arctic. *Rangifer tarandus*, called reindeer or caribou, is the most common large land mammal of the Arctic and sub-Arctic, gathering in large herds of tens to hundreds of thousands of animals on their calving grounds during the arctic summer, and scattering widely in smaller groups for the remainder of the year (Hall 1989). In Russia, the total number of domesticated reindeer in the region has decreased significantly within the last 100 years with particularly marked change from approximately 2.5 million in 1969 to 1.2 million in 2000 (Jernsletten and Klokov 2002). This decline in numbers of reindeer in northern Russia, which has by far the largest share of pasture lands (87%) and about 67% of all reindeer, is causing a serious decline in the reindeer husbandry industry, and, in turn is directly affecting the health and well-being of the indigenous peoples associated with reindeer husbandry (Jernsletten and Klokov 2002; Nuttal et al. 2005). This decline is not only causing poverty in the Russian indigenous communities associated with reindeer herding, but also, because reindeer husbandry is the very core of their traditional way of life, the decline is causing serious damage to the ethnic traditions and to the families of nomadic reindeer herders (Abrjutina 2003; Jernsletten and Klokov 2002; Glazovsky et al. 2004; Nuttal et al. 2005; Klokov 2000).

In Norway, reindeer husbandry is one industry in which the number of people involved has increased over the past 50 years (Eira 2001). However, while approximately 40% of mainland Norway is designated reindeer pastureland, there

Fig. 8.1 Reindeer peoples of Eurasia. Location of Eurasian indigenous peoples who are reindeer herders, involving approximately 100,000 herders and 2.5 million semi-domesticated reindeer, which graze about 4 million km^2 in Eurasia. Adapted from and reproduced by permission of the International Centre for Reindeer Husbandry

are serious threats to those lands from not only climate changes, but also loss of pastures by increasing encroachment from development, tourism, damming of rivers, cultivation, oil and gas development, and roads and power lines, accompanied by similar impacts as are observed in Russia (Eira 2001). In Finnmark, which is the northernmost, largest and least populated county in Norway (Fig. 8.2), there are approximately 2,000 registered reindeer owners which represent 73 and 75% of semi-domesticated reindeer and Sami reindeer owners in Norway, respectively (Tyler et al. 2007).

In recent years, a number of studies have been published on historical and future challenges which relate directly to reindeer herding in Eurasia including, as a few examples, Eira et al. (2008), Nuttal et al. (2008, 2005), and Klein et al. (2005), a diverse collection of multidisciplinary articles summarizing results from the RENMAN Project ("The challenges of modernity for REiNdeer MANagement: integration and sustainable development in Europe's subarctic and boreal regions" by Forbes et al. 2006), the ENSINOR Project (Stammler and Burgess 2007;

Fig. 8.2 Saami reindeer herd near Kautokeino, Norway (photo by I.M.G. Eira)

Chapter 9, this volume, Jia et al. 2003; Tommervik et al. 2004; Hinzman et al. 2005; Kitti et al. 2006; Kumpula et al. 2006; Tape et al. 2006).

8.1.3 Reindeer, Climate Change and Development

As mentioned in Chapter 1, this volume, in the Arctic climate change is happening faster than in any other region of the world. The changes in snow and ice cover and increases in temperature have already impacted reindeer husbandry and will continue to do so both directly, for example through changes in food availability, and indirectly such as through changes in human land use (Oskal 2008). Temperature changes have begun to cause some rivers to freeze later in the autumn and melt earlier in the spring, resulting in challenges for the annual migration of reindeer between different seasonal pastures. Warming-induced changes in freeze-thaw cycles are also creating problems. For example, as river and lake ice thaws earlier in the spring along migration routes, newborn calves can no longer cross the ice surface, but have to attempt crossing open waters, and large numbers of calves have been swept away by currents (Klein et al. 2005, Nuttal et al. 2005). Another change that has already been observed is increasing climate variability at a local level (Fig. 8.3). This is especially true during the critical wintertime, where, increasingly, periods of mild weather accompanied by rain will be followed by colder periods, form ice layers in the snow and block the reindeers' access to food on the ground. As reindeer live only on natural pastures, this often represents a "worst-case scenario" from the reindeer herders' perspective. Increasing precipitation in the

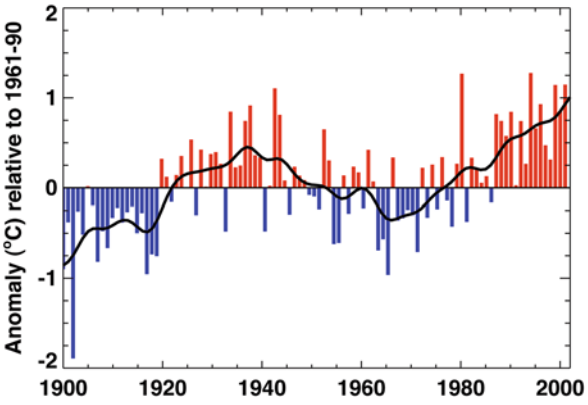

Fig. 8.3 Climate variability in the Arctic. Annual anomalies of land-surface air temperature variations in the Arctic (60–90° N) for the period 1900–2003. Data sets document a statistically significant warming trend during this period and, while general features of the arctic time series are similar to those of the global time series, decadal trends and interannual variability are greater in the Arctic. Reproduced by permission of Arctic Climate Impact Assessment Team (ACIA 2004)

form of snow can add to these challenges, while warming would shorten the period of snow cover in any particular year (Oskal 2008).

A deeper snow pack in winter can also make the reindeer more vulnerable to predator attacks (e.g., wolves) because the lighter wolves can travel on thinner snow crusts where reindeer sink through (Brotton and Wall 1997). Increased insect harassment, accompanying warmer temperatures, is a second major factor shown to interfere with foraging (Kitti et al. 2006). The outcome of this harassment is increased energy requirements, and results in a significant decline in body fat and lactation, and decrease in calving success (Walsh et al. 1992, Brotton and Wall 1997, Gunn and Skogland 1997). One example of recent climate impact is the unusually warm winter of 1996–1997, which was associated with a deep snow pack and icing, and which caused about 10,000 reindeer to die of starvation on Russia's far northeast Chukotsk Peninsula (Malcolm 1996, Nuttal et al. 2005).

Reindeer herders have also observed major changes in biodiversity. A significant example of this is repeated occurrences of certain species replacing others, such as the spreading of shrubs into the barren tundra-areas (Jia et al. 2003, Hinzman et al. 2005, Tape et al. 2006). Shrubs contribute to a hard packing of snow during the tough winter months, thus making access to food a challenge for reindeer. In addition, important food resources for the reindeer, such as lichens and reindeer preferred species of grasses, in time may disappear partially if not fully due to this shrub encroachment. Changes and/or increases in insect populations could also change reindeer behaviour during the summer by not allowing them to feed long enough in summer pastures due to increased harassment (Oskal 2008; Kitti et al. 2006).

Indirect effects of climate change are also being observed, with major implications for reindeer pasture availability and migration routes (Kitti et al. 2006). Due to the sea ice melting and longer summers, increased accessibility of the Arctic regions for human activities is a growing threat to reindeer herders. Human development and activities represent disturbances with negative effects for the semi-domesticated reindeer herds (Kitti et al. 2006) and irreversible loss of marginal pasture resources – a serious challenge for reindeer husbandry. In particular, female reindeer and calves will stay away from humans, physical installations and general human activity. In the last 50 years, for example, approximately 25% of the reindeer pastures of the Euro-Arctic Barents region have in effect been lost due to human development (Tyler et al. 2007).

Of particular relevance today is the fact that the Arctic is estimated to contain approximately 25% of the world's remaining undeveloped petroleum resources. For instance, Yamal in western Siberia holds about 90% of Russia's gas reserves, while also being the largest reindeer herding area of the world. Activities to access these resources would reduce the grazing lands, and are viewed as another human activity in the Arctic contributing to the reduction of the "available room for adaptation" for reindeer husbandry (Nuttal et al. 2005). In fact, industrial development (e.g., pipelines, oil and gas infrastructure) has increased across reindeer migration routes in northern Russia, blocking pathways to summer pasturelands (Forbes et al. 2006; see also Chapter 9, this volume).

It is also expected that there will be a sharp increase in the near future in oil and gas development, mining, and other forms of development in northern Russia – accompanied by infrastructure, pollution, and other manifestations of human presence – which will increase future pressure on available pasturelands for the reindeer and the indigenous communities associated with them (Forbes et al. 2006; Jernsletten and Klokov 2002, see Chapter 11, this volume). Furthermore, future reductions in sea ice from global warming recently projected are very likely to increase the amount of marine traffic and general access to the Arctic and, as a result, significantly increase development as well as serious problems related to sovereignty, social, cultural and other environmental issues, which will directly impact the indigenous reindeer herding community (McCarthy et al. 2005).

8.1.4 Socioeconomic, Political and Other Pressures

Parts of the Arctic are unique in terms of the political settlements and land claims that have been achieved over the last 30 years or so. The extent of vulnerability and resilience to climate change not only depends on cultural aspects and ecosystem diversity, but on the political, legal, and institutional rules which govern social-economic systems and social-ecological systems (Nuttal et al. 2005, 2008). On the one hand, climate change has the potential to enhance economic development, but with further climate change (Fig. 8.4), the climate in the Arctic is predicted to become more variable and extreme weather events more frequent and severe,

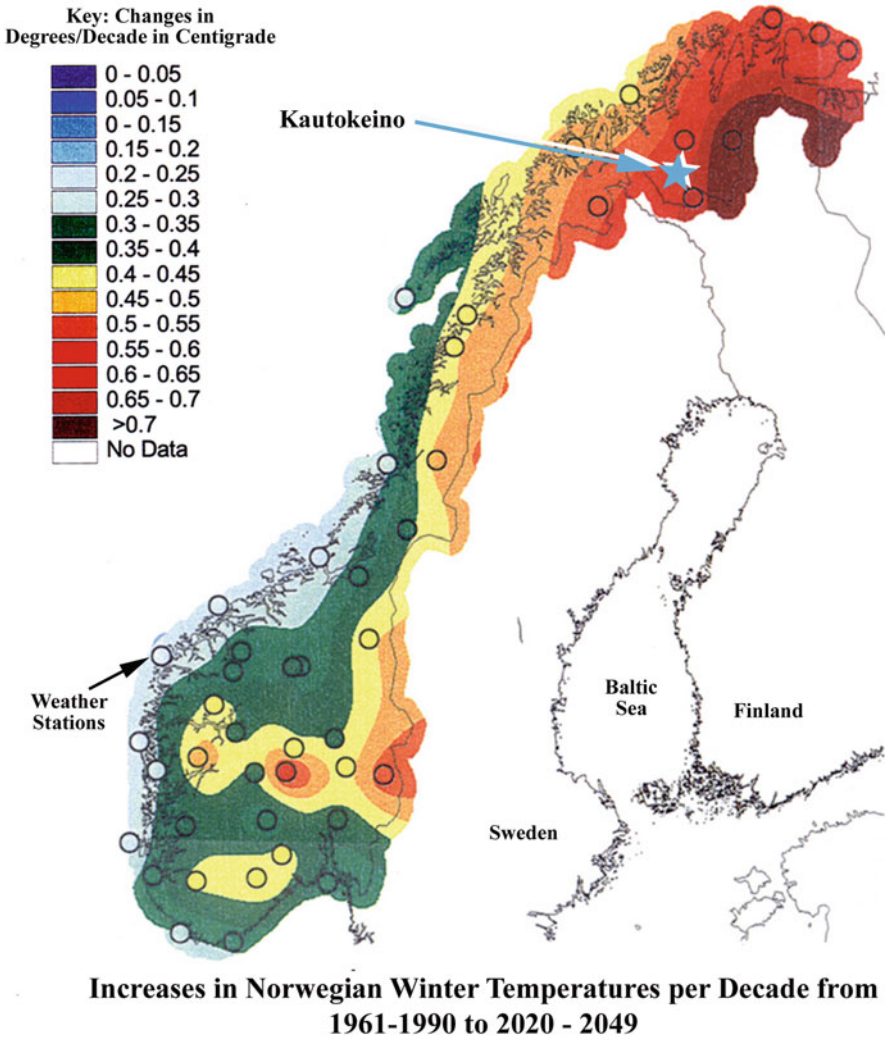

Fig. 8.4 Future warming in Norway showing increased future temperatures in the north and east in regions important for reindeer grazing in winter. Reproduced by permission of Arctic Climate Impact Assessment Team Hanssen-Bauer et al. 2003

which, on the other hand, can undermine economic activities. Thus, it seems particularly important that attention be given to the management of resources and to the effectiveness of governance institutions, and critical questions must be asked as to whether they can create additional opportunities to increase resilience, flexibility and the ability to deal with change (Nuttal et al. 2005).

Compounding the problem for the reindeer herding community in Russia, the transition of Russia to a market economy has, over the past few years, resulted in

considerable disorder in many parts of the supply and transport systems in remote northern areas. This has resulted in serious disruption of any system of goods, services, and health care to northern Russian indigenous peoples (Nuttal et al. 2005; Abrjutina 2003; Jernsletten and Klokov 2002; Klokov 2000). Basic commodities such as paraffin lighting, fabrics, and vegetables or other foods are no longer easily available. The reindeer herders have also been cut off from any health care services at all, and, as a result of these factors combined, health and living conditions are rapidly deteriorating in the reindeer herder communities, with growing death rates and serious health impacts (Nuttal et al. 2005; Abrjutina 2003; Jernsletten and Klokov 2002; Klokov 2000).

For all of these reasons, the Arctic Council has called for the full attention of the international community to the situation in the reindeer herding industry and the critical state of the indigenous peoples of the north in Russia. The 2nd World Reindeer Herders' Congress (2003) reported that there is a "real threat of the complete loss of reindeer husbandry in large parts of eastern Russia" and "indigenous peoples connected with reindeer husbandry here face an ethnic disaster". These concerns were echoed once again at the 3rd World Reindeer Herders' Congress in March 2005. Since that time, the reindeer herding communities have increasingly continued to develop new partnerships and organizations to improve their collective abilities to respond to the challenges of climate change and development. Indeed, as a result, the interdisciplinary multiparty EALÁT Project was successfully launched by the Association of World Reindeer Herders in partnership with the Russian Union of Reindeer Herders, the Sami Reindeer Herders Association of Norway, and the Sami Council. The project was established to address these numerous threats to reindeer herding through collaborative efforts to help prepare reindeer herders in Eurasia, their societies, institutions, and management for change, and accordingly, begin to reduce their vulnerability to these changes.

8.2 IPY EALÁT Project: "Reindeer Pastoralism in a Changing Climate"

8.2.1 EALÁT Overview

Developed under the leadership of indigenous reindeer herders, the IPY EALÁT Project ("Reindeer Pastoralism in a Changing Climate") is an inter-disciplinary, inter-cultural study that is assessing the vulnerability of reindeer herding – a coupled human-ecological system – to changes in key aspects of the natural and human environments, actively involving reindeer herders, linguists, remote sensing scientists, meteorologists, lawyers, anthropologists, biologists, geographers, philosophers (the ethical dimension) as well as indigenous institutions and organizations, relevant industrial enterprises and management authorities. The name of the project, EALÁT, which comes from the word "pasture" in the Sámi language, reflects the emphasis of the project on the close connection these cultures have to the environment

in which they live. It focuses on the adaptive capacity of reindeer pastoralism to climate variability and change and, in particular, on the integration of reindeer herders' knowledge with scientific research and analysis of their ability to adapt to environmental variability and change (http://www.EALAT.org).

The IPY EALÁT Project was initiated by the Association of World Reindeer Herders (WRH), a circumpolar indigenous peoples' organization with observer status in the Arctic Council. The project leaders believe that valuing traditional and scientific knowledge equally and, hence, integrating herders' experience and competence within the scientific method will enable it to contribute towards reducing the vulnerability of reindeer husbandry to the effects of climate change, which are likely to be pronounced over reindeer pastures in the north (Fig. 8.5). *The EALÁT-Network* study has adopted a multi-cultural approach in a multi-disciplinary field that includes monitoring, research, outreach and communication.

To accomplish the goals of the EALÁT Project, there are seven core "Work Packages", which are self-contained areas of research and investigation that cover the wide range of issues that EALÁT addresses. They are:

1. dentification of local climate conditions important for reindeer herding and development of basic climate scenarios
2. Customization of pasture conditions for reindeer pastoralism
3. Reindeer herders' knowledge: codifying and communicating coping mechanisms
4. Social and economic adaptation – institutions and governance as constraints and opportunities
5. Reindeer: consequences of climate variability and change
6. Reindeer welfare and nutrition: herders' observations and scientific data
7. Synthesis: assessing vulnerability

Fig. 8.5 Saami reindeer husbandry activity (photo by I.M.G. Eira)

EALÁT-Outreach has as its objective to communicate Arctic reindeer herders' traditional knowledge and scientific knowledge related to climate change to herders and the mainstream society in the Arctic. *The Reindeer Portal* (http://www.reindeerportal.org) is a multiplatform web portal into the world of reindeer husbandry. Developed by the International Centre for Reindeer Husbandry in Kautokeino, the goal of the Reindeer Portal is to be a one-stop-shop information site for reindeer herders, students, administrators, politicians, indigenous people, business interest, the general public and anyone that is remotely interested in reindeer and the peoples that herd them.

In the IPY EALÁT Consortium, *EALÁT-Monitoring* is already endorsed as a future expert monitoring network in the Circumpolar Biodiversity Monitoring Program of the CAFF (Conservation of Arctic Flora and Fauna) Working Group of the Arctic Council. The data collected in IPY will be the start of a future place-based monitoring system of reindeer herders' pastures and societies, while at the same time representing a unique opportunity for validation of satellite imagery in cooperation with the US National Aeronautics and Space Administration (NASA) Land Cover Land Use Change (LCLUC) program.

The legacy of IPY EALÁT will be continued through a UArctic Institute for Reindeer Husbandry (UArctic EALÁT) hosted in Kautokeino, Norway, as a pilot institute for research, outreach and education. For detailed information on EALÁT, the reader is referred to http://www.EALAT.org.

8.2.2 EALÁT Goals

The primary goals of the IPY EALÁT Project are to assess the vulnerability of reindeer herding – a coupled human-ecological system – to climate and other changes in key aspects of the natural and human environments and to build optimal adaptive strategies through the integration of indigenous reindeer herder knowledge with scientific data and analyses. The IPY EALÁT project partners believe that it is critical to empower indigenous peoples in Eurasia with the best technologies available to combine with indigenous knowledge for achieving a truly sustainable development of the Arctic. The EALÁT team also believes it is important that indigenous peoples' traditional knowledge must be a critical component of the future management and monitoring of the reindeer pastures and their societies. Therefore, another important goal of EALÁT is to build competence locally about land cover/land use change, including tools such as remote sensing observations and GIS as one important factor which could increase future adaptive capacity locally in Eurasian reindeer herding societies. Thus, developing training programs as well as EALÁT monitoring systems for Eurasian reindeer herders, which will extend well beyond the duration of the IPY are a high priority.

For adaptation questions, *EALÁT-Research* uses a vulnerability framework to assess the degree to which reindeer pastoralism is likely to experience harm as a result of exposure to multiple and interacting forces of change. The goal of the *EALÁT-Outreach* component of the project is to communicate arctic reindeer

herders' traditional knowledge and scientific knowledge related to climate change to herders and the mainstream society in the Arctic.

In recent years, traditional knowledge has increasingly become an integral part of scientific studies and a number of projects have included indigenous scientists and reindeer herders as full participants in project planning, implementation and dissemination of studies based on indigenous knowledge of modern reindeer management (Kitti et al. 2006; Magga 2005). However, the EALÁT project is considered unique because indigenous reindeer herders have organized and are leading this complex, interdisciplinary, intercultural study, inviting scientists and other colleagues to collaborate. In this effort to inform the Arctic nations both about the changes to which they are subjected and give some concrete examples how herders' traditional knowledge relates to adaptation to changing conditions, another important goal of the study includes the challenge of taking reindeer herders' knowledge into action for sustainable development of the Arctic.

8.2.3 EALÁT Study Sites

The IPY EALÁT project has research, information, and outreach activities in five different reindeer herding societies across Eurasia: Nenets, Yamal-Nenets and Chukotka Autonomous Areas and Republic of Sakha (Yakutia) in Russia, as well as Saami in Northern Europe (Fig. 8.6). Researchers will concentrate initially

Fig. 8.6 Map of five EALÁT study sites. The five primary IPY EALÁT sites include: (*1*) Saami area of Norway, Finland, Sweden, Russia (initial emphasis on Norway), (*2*) Nenets Autonomous Area, (*3*) Yamal-Nenets Autonomous Area, (*4*) Republic of Sahka (Yakutia), and East Chukotka Autonomous Area. EALÁT researchers are concentrating initially on site 1 in the Norwegian county of Finnmark and site 3 in Yamal-Nenets Autonomous Area in Russia. Adapted from http://www.EALAT-information.org. Reproduced by permission of the International Centre for Reindeer Husbandry

on the two largest reindeer herding cultures in the world: the Sámi, who inhabit Northern Europe and the Kola Peninsula in northwestern Russia, with a focus on the Norwegian county of Finnmark, and the Nenets, focusing in particular on herders in the Yamal-Nenets Autonomous Okrug in Russia. Future research in the other regions where IPY EALÁT has carried out information activities, will be implemented as part of the IPY EALÁT legacy.

8.3 EALÁT Studies

8.3.1 EALÁT Results from Early Studies: SAR Studies for Pasture Quality

This section describes some results from Reindeer Mapper, an early EALÁT pilot project of the NASA Land Cover Land Use Change Program, to investigate the possible use of SAR (Synthetic Aperture Radar) for characterizing pasture quality as an alternative to sensors relying on the visible part of the electromagnetic spectrum and the resulting problems due to low illumination and cloud cover in the Arctic (Maynard et al. 2005; Yurchak and Maynard 2005). This work, part of a larger study called Reindeer Mapper, preceded the EALÁT program as a pilot for the EALÁT project to study remote sensing technologies for reducing the threats to reindeer husbandry from climate and land changes by creating a source of usable, timely satellite data that could be combined with traditional, local and other data and information for improved decision-making (Maynard et al. 2003, Maynard and Yurchak 2003, Maynard et al. 2004). Based upon discussions among Reindeer Mapper team members from within the reindeer husbandry community, including discussions and publications such as the Yakutsk Declaration from the Third World Reindeer Herders' Congress in March 2005, a preliminary list of the highest priority environmental measurements for remotely sensed data was generated. These requirements constituted the primary elements determining pasture quality and state, the most important overall set of parameters for reindeer herders (Fig. 8.7).

This preliminary study of the use of SAR for characterizing the quality of reindeer pasture was initiated because SAR does not rely on the visible part of the spectrum and, therefore, has the ability to provide data regardless of weather or light conditions (Yurchak and Maynard 2005). These early studies focused initially on the highest priority measurements/data products identified by the reindeer herders on the team. The applications of SAR for characterization of vegetation and measuring snow parameters are not as well-developed as optical sensors. Initial studies of seasonal changes in SAR backscatter from different kinds of land features in two locations, Anadyr River Research Area (ARRA) and Vaegi Village Research Area (VVRA) in Chukotka, Russia, were carried out for the four seasons of the period between the years 2000 and 2004. Site selection was done based on data availability from the Alaska Satellite Facility (ASF) and on the location of typical tundra

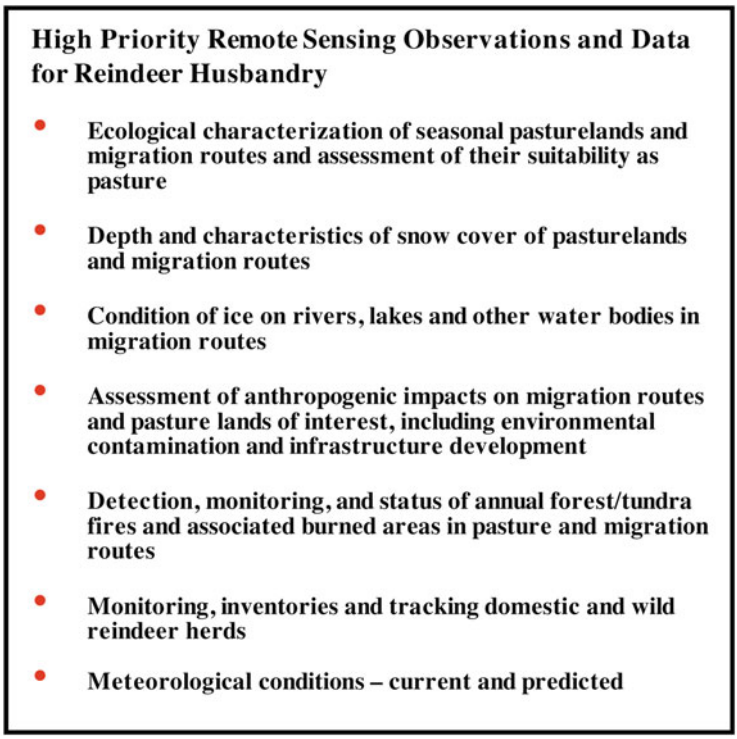

Fig. 8.7 Highest priority remote sensing measurements/data products identified by EALÁT reindeer herders during NASA LCLUC Reindeer Mapper study for characterization of pasture quality for pastures and migration routes. Reproduced from Maynard et al. (2005)

landscapes on reindeer pasture areas. Based on these criteria, two sites within the Anadyr district of Chukotskiy Autonomous Okrug (ChAO) were selected. The first site is a nature conservation area north of "Krasnoe" lake along the Anadyr river (Anadyr river research area – ARRA); the second site, a fire risk area south of Vaegi Village (Vaegi Village research area – VVRA) (Maynard et al. 2005, Yurchak and Maynard 2005).

Results from the study showed that the SAR data detect fire scars very well and could be used for fire scar inventory mapping in conjunction with other systems such as the Moderate Resolution Imaging Spectroradiometer (MODIS) Rapid Response System. An analysis of tundra lakes' radar properties suggested the possibility for remote assessment of the depth of lakes (Yurchak and Maynard 2005). It was also possible to observe the snow masking effect (Ulaby et al. 1984) and wet snow (Bagdadi et al. 1997). Studies showed the capability of SAR to delineate different types of tundra species as well as demonstrate seasonal changes in radar backscatter from tussock and mountain tundra in time series studies. The sensitivity of SAR

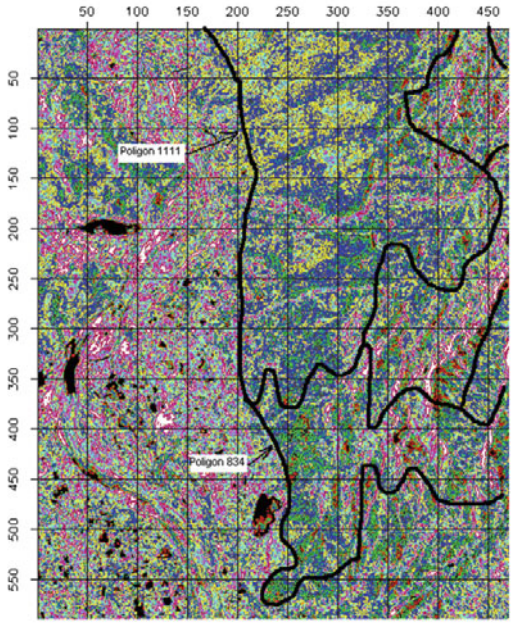

Fig. 8.8 A classified part of a SAR low resolution image of the Anadyr River Research Area (ARRA), Russia, based on comparison with geobotanical map (courtesy of A. Polezhaev). 28 July 2003. Image center: 65° 35′ N, 174° 08′ E. Reproduced from Maynard et al. (2005)

data to vegetation and snow cover over plains and mountain tundra is demonstrated in a time series study of a selected area in the north of ARRA (Figs. 8.8 and 8.9a, b).

The results showed clear seasonal changes in tundra radar backscatter. For tussock tundra the backscatter was higher in summer months and dropped to the lowest value in the fall due to decrease of soil (vegetation) moisture because of freezing. The subsequent backscatter increase in the winter could be related to snow cover impact. For mountain tundra, summer backscatter behavior is opposite to that of tussock: it is the lowest. Also, the range of winter-summer decrease is rather high: ~60 Digital Numbers. The reason for such behavior, probably, is different local incidence angles for tussock tundra (~ 23°) and for the mountain slope (~0°). Further field validation work was planned for this study. In addition, SAR data were shown to be capable of delineating detailed geobotanic polygons. SAR data were compared with ground-based geobotanic maps and were found to provide a higher resolution set of polygons than aerial surveys. These preliminary results suggested that further development of the methodology as well as its validation and calibration may result in a reliable method for SAR applications to these important environmental parameters.

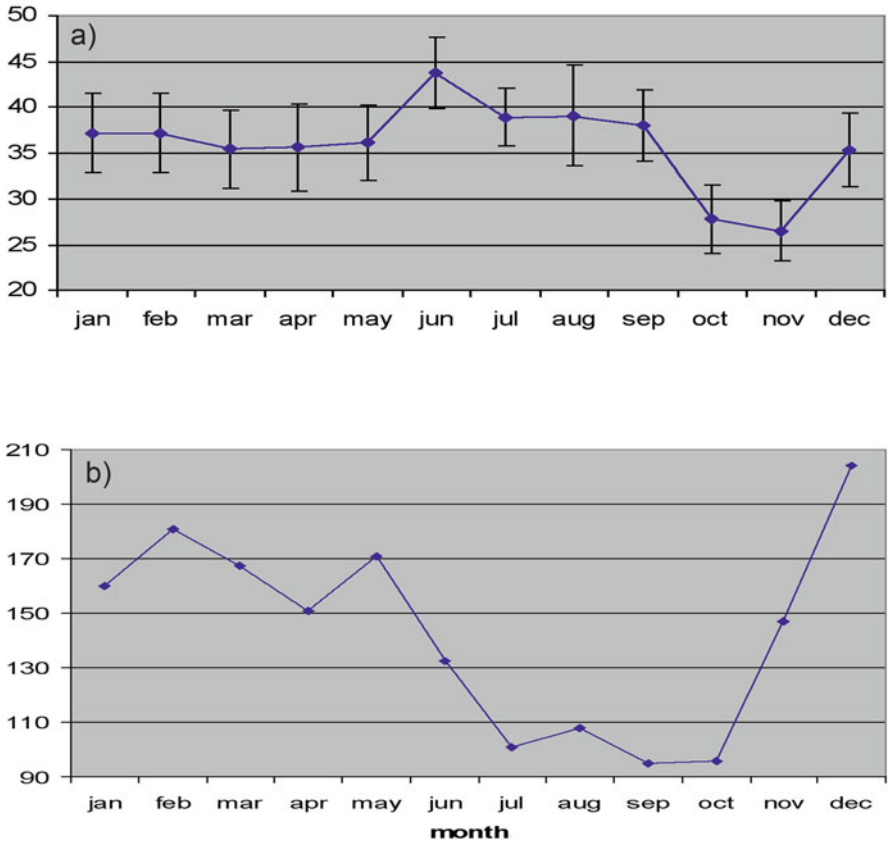

Fig. 8.9 Time series of SAR backscatter from (**a**) plains tussock tundra and (**b**) mountain tundra within Anadyr River Research Area, Russia (ARRA). Reproduced from Maynard et al. (2005)

In summary, the study showed that SAR data can detect fire scars very well and could be used for fire scar inventory mapping in conjunction with other systems such as the MODIS Rapid Response System. Studies showed the capability of SAR to delineate different types of tundra species as well as demonstrate seasonal changes in radar backscatter from tussock and mountain tundra in time series studies. In addition, SAR data were shown to be capable of delineating detailed geobotanic polygons. SAR data were compared with ground-based geobotanic maps and were found to provide an even higher resolution set of polygons than aerial surveys. An analysis of tundra lakes' radar properties suggests that SAR may provide a useful means of remotely assessing the state of lakes. As temperature increases cause earlier melting of lakes along migration routes in springtime, this technique for lake assessment could prove to be very valuable for herders on a real-time basis.

8.3.2 EALÁT On-Going Studies

8.3.2.1 Indigenous Linguistics Studies of Reindeer Herding Language

One of the main objectives within the IPY EALÁT project is documenting indigenous knowledge about snow conditions and indigenous perceptions about how they are adapting to changing conditions. A great deal of insight can be gained from centuries-old knowledge within reindeer herding societies such as the Sáami and the Nenets. With the declining numbers of those from traditional reindeer herding communities following more traditional ways of life, it is important to document this knowledge as much as possible while it still exists. The study of the language itself is important because it is through language that traditional knowledge becomes available and, particularly, through specific terminology.

Some early results from an EALÁT project on the language of reindeer husbandry have recently been summarized by Eira et al. (2008) and they demonstrate the importance and the richness of the use of all kinds of information and knowledge to address the dramatic changes occurring in the Arctic today. This EALÁT study is focusing on how to empower indigenous reindeer herders with the best information – indigenous knowledge as well as scientific/technical knowledge – for addressing the increasing challenges from climate change and loss of grazing lands. Language is a very important part of this and one of the main objectives of the overall EALÁT project is to document indigenous knowledge about reindeer herding, with the traditional language of reindeer herders in the key role structuring their knowledge and knowledge-sharing.

In the EALÁT linguistics study, one of the key early investigations has been the collection and analysis of the existing linguistic concepts that are used in Saami reindeer herding language. There are, for example, in the dialect of Guovdageaidnu/Kautokeino over 1,000 individual terms describing reindeer and especially their appearance, including 50 words describing the shape of the antlers (Magga 2005, Eira et al. 2008). This early investigation has been studying techniques for the use of language in communicating traditional knowledge about reindeer herding among reindeer herders as well as to non-indigenous scientific and the broader world communities. Results are being documented and publications prepared at this time (Eira et al. 2008).

8.3.2.2 Indigenous and Scientific Snow Studies

A joint indigenous and scientific snow project now underway addresses a key EALÁT objective to document knowledge about snow conditions and how reindeer herders are adapting to the changing conditions in relation to snow and pasture availability and mobility of the herds. As noted earlier, for indigenous peoples of the north, a clear understanding of real-time snow, precipitation, and ice in their area has been critical to their survival. Current EALÁT studies are focusing on Saami snow terminology and herding strategies during the winter to find the best forage

for the herd. Section 8.3.2.1 describes a key EALÁT indigenous linguistics study of reindeer herding language, which highlights centuries-old knowledge from herder societies. In addition, historical observations are being documented which include oral histories and stories from parents, grandparents and other elders about extreme snow events and other phenomena.

The study described in this section is a joint observational study by EALÁT and NASA indigenous and scientific collaborators, which is a data collection project with a focus on climate and development changes (snow and vegetation especially). The study is being led by a reindeer herder and PhD student at the Sami University College and Co-PI of EALÁT (Eira et al. 2008). She is coordinating the collection of a comprehensive set of observations in northern Norway, by six reindeer herders over several years, each of whom provide a detailed set of observations of snow, vegetation, meteorological conditions, herd behavior, and other data as they traverse their seasonal migration routes throughout complete seasons. The study area is located across the Saami migration pastures of northern Norway in EALÁT Study area #1 (Fig. 8.10).

This project includes continued data collection with the EALÁT-NASA thermochrons which was initiated in 2007 (see Section 8.3.2.3). Each reindeer herder is recording on special data log sheets the GPS location/time/date of their daily observations data on eleven weather parameters (e.g., wind, cloud cover, precipitation, temperatures), Saami snow terms, physical measurements of snow depth, type, and description, herd behavior, snow conditions as they pertain to the ability of the reindeer to reach the lichens beneath the snow, and thermochron location data.

The herder observations will also be supported by remote sensing and meteorological data from the same time period wherever possible. Remote sensing data to be combined with the herder archives are presently being inventoried for land cover/land use change assessment information including Landsat, MODIS,

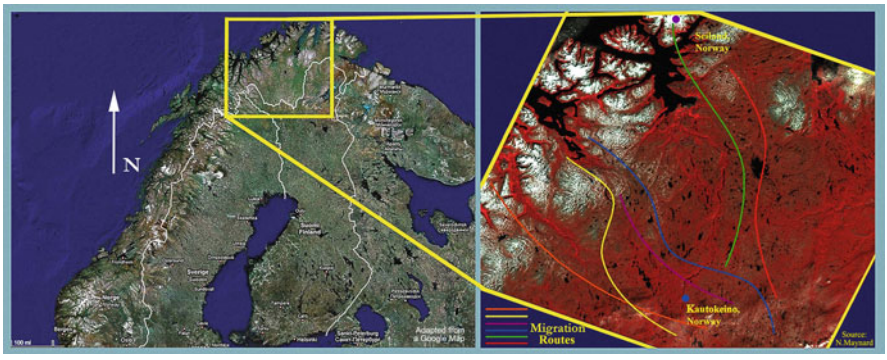

Fig. 8.10 Location of EALÁT-NASA Project Site 1 in Northern Norway and approximate locations of Saami reindeer migration routes where reindeer herders are collecting multi-year, detailed data on snow, vegetation, meteorology, traditional Saami observations of snow and herd behavior and forage availability for reindeer vulnerability studies to be combined with NASA and other data. Source: N.G. Maynard, I.M.G Eira

Advanced Microwave Scanning Radiometer-EOS (AMSR-E), and high resolution commercial satellite imagery. A series of cloud-free Landsat scenes between 1972 and 2007 over the field areas of interest have been obtained and these will be combined with Eurasian GIS data layers, meteorological data, in situ field data, and indigenous knowledge described in other sections of this chapter.

8.3.2.3 Indigenous and Scientific Studies of Pasture Icing or "Lock-Out"

The increasing temperature variations which are accompanying climate change in the Arctic are causing more freeze-thaw-freeze cycles, resulting in icing of the lichens or ice layers within and on the snow pack in reindeer pastures and pasture "lock-out". EALÁT Project members are carrying out field research to obtain indigenous and scientific data that can improve the capability of reindeer herders to predict and adapt to these adverse weather conditions and climate changes, especially with climate change making weather conditions more variable and less predictable than before.

For example, the traditional practice of the Sáami reindeer herders in northern Scandinavia was to allow their reindeer to graze on the tundra in coastal areas during the summer months, where they can graze on abundant grasses, bushes, mushrooms and daffodils. However, these traditional practices have been disrupted somewhat due to the presence of modern national borders, development, and climate changes. After the annual slaughter and the first snowfall, the herders bring their reindeer to over-wintering pastures in the mountains and tundra in the interior part of upper Scandinavia, where reindeer dig through the snow to get to lichens, the primary staple of the winter diet of reindeer (Fig. 8.11).

However certain meteorological conditions can sometimes create conditions that "lock out" winter grazing pastures. If a warm period that partially melts the snow

Fig. 8.11 Reindeer in over-wintering pastures of Scandinavia digging through snow to reach lichens, the primary staple of the winter diet. Increasing temperature variations which are accompanying climate change in the Arctic are causing more freeze-thaw cycles, resulting in icing of the lichens or ice layers within and on the snow pack, making it impossible for reindeer to access their primary food source (called pasture "lock-out") (photo by I.M.G. Eira)

is followed by rain and then the temperature drops below freezing, this can create a thick coating of ice in the winter pastures that makes it impossible for reindeer to access their primary food source. This can lead to illness and starvation for the reindeer, which translates into serious losses for herders.

Accordingly, the IPY EALÁT project is developing a new adaptive strategy for "lock out" prediction to avoid this increasingly difficult problem. Researchers are using indigenous knowledge together with scientific data to better predict when and where adverse winter grazing conditions might occur so that eventually a service could be set up that would help herders know where winter pastures with bad grazing conditions are so they can avoid them. Meteorologists from the Norwegian Meteorological Institute in Oslo are providing data for models that try to predict snow conditions in Finnmark by looking at temperature gradients throughout the snow pack.

These models are being combined with real-time field observations by herders to verify the predictions the models make, including, the use of some NASA technologies. Starting in October 2007, a team of researchers from the Sámi University College placed NASA thermochrons (small data recorders that take temperature readings at regular intervals) along several reindeer migration routes at various depths between the ground and the top of the snow pack (Fig. 8.12). In May 2008, the team removed the first set of thermochrons and temperature data is being analyzed and compared with Norwegian Meteorological Institute (NMI) model predictions. Observations are being compared with remote sensing data from NASA and the European Space Agency (ESA) and data shared with collaborators in the NASA Global Snowflake Network (GSN) and History of Winter (HOW; http://education.gsfc.nasa.gov/how/). This process is being repeated for four successive winters in order to get an adequate data set to compare with the model.

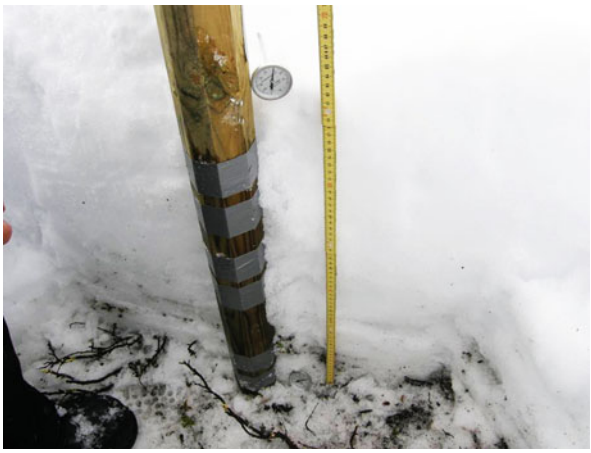

Fig. 8.12 NASA thermochrons at Saami snow station (photo by I.M.G. Eira)

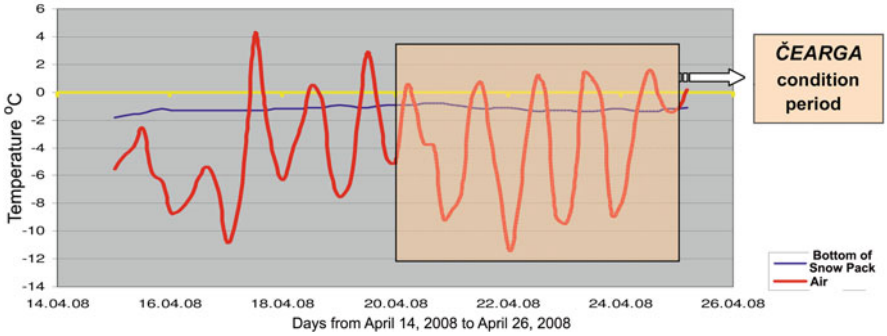

Fig. 8.13 Thermochron temperature measurements. Temperatures (ºC) measured by EALÁT-NASA thermochrons at one of the reindeer herder observation stations in April 2008, during formation of *Cearga* conditions (creating pasture "lock-out"). Temperatures were measured on the ground (at the bottom of the snowpack) and in the air (at 1.5 m above ground). *Cearga* in Saami means snow pack which is so hard that it bears the weight of the reindeer. Source: I.M.G. Eira

Figure 8.13 shows the temperatures (°C) measured by NASA thermochrons in one of the reindeer observations stations. The temperatures were measured on the ground (at the bottom of the snowpack) and in the air (at 1.5 m above ground). The thermochron data show rapid changes in temperature during this period. According to daily observations recorded by the reindeer herders, the snow conditions became worse and *cearga* conditions were formed from April 20 (*Cearga* in Saami means snowdrift which is so hard that it bears the weight of the reindeer, i.e., a very hard snow pack). Prior to April 15, cold temperatures and strong winds developed the conditions conducive to formation of the *cearga*. On April 18, frequent temperatures above 0°C created even worse grazing conditions during this period. This snow condition could be characterized as a kind of "lock-out" condition because it prevents the reindeers' access through the snow to the vegetation.

New data sets will be produced for snow type and distribution as a result of the thermochron study, which include NASA remote sensing data such as MODIS and AMSR-E as well as in situ data from the Norwegian Meteorological Institute and US National Oceanic and Atmospheric Administration/National Center for Environmental Prediction (NOAA/NCEP) and integrated into indigenous knowledge and observations for that area.

The Polar View Consortium, which runs a variety of Earth-observation services for its end-users all over the world, will also be contributing to the study by providing researchers with snow maps created using satellite data. These maps help in giving an overview of the amount of snow cover and snow cover type in the regions being studied in the EALÁT project. These observations will provide useful information on the snow temperature from the ground to the surface of the snow pack because the influence of the temperature of the ground on the snow above is not fully-understood. Researchers are also examining historical meteorological

data taken over the past several decades as well as satellite data, concentrating in particular on years when many pastures were "locked out" due to ice cover.

The combined set of observations will help to better understand what happens to the snow above if warming occurs on the ground. Will the snow get wetter or will it get drier? The answers to these questions will aide in understanding how the energy exchange occurs between the ground and the snow above.

Data from the snow study will be integrated by Saami reindeer herders into a system which will become part of a special service to be produced by the combination of all observations and a model to predict whether certain pastures will be locked out due to ice in the snow pack, so that herders can avoid these areas. This information will constitute a unique data set for the land-use and land-cover studies for this part of Eurasia and the first "adaptation early warning system" created by and for reindeer herders. All data such as these will be distributed through the International Centre for Reindeer Husbandry as part of this special service to reindeer herders.

8.3.2.4 Indigenous and Remote Sensing/GIS Pasture Studies

A remote sensing/GIS pasture study, based upon earlier EALÁT and Reindeer Mapper studies, has recently been initiated. NASA and university colleagues are starting to obtain and process satellite and GIS data and information to combine with indigenous knowledge to document changes in vegetation and infrastructure. The team has obtained Landsat and GIS data for two sites, including EALÁT study sites #1 and #2, set priorities for data requirements, and have begun analyzing and classifying data sets. The team is creating a specific qualitative and quantitative assessment of multi-spectral information from remote sensing combined with indigenous data into a GIS environment where impacts of global warming, climate change and infrastructure development can be shown and mapped as it directly impacts reindeer pastures and migration routes in these areas of northern Norway and Russia. These direct observations and data will be integrated with indigenous historical knowledge and recent observations from herder's daily data logs. Higher resolution imagery will be obtained and processed as funding becomes available. Emphasis of the study is on spatial and temporal changes in vegetation, water bodies, and infrastructure together with variations/changes in weather and climate. One of the issues of interest mentioned earlier is the identification of possible shrub area increase from 1987 to 2007. An increase of shrub land area in reindeer grazing lands makes food access increasingly difficult, so classification of changes in precise locations of these shrub land areas is planned. Other GIS data layers including roads, oil and gas infrastructure, railways, drainage areas, utility lines, urban development, dwellings, water bodies are being obtained and will be validated with GPS ground-truthed field data from reindeer herder data sets. Discussions are under way among EALÁT team members to establish joint data analyses through student/faculty exchanges and data exchange programs between the UArctic Institute, Saami University College and US university students and NASA. Data products will be distributed through web sites, locally-appropriate means, and the International Centre for Reindeer Husbandry.

8.4 EALÁT Monitoring and Information Integration System – Adaptation and Planning for the Future

To achieve optimal adaptation strategies for reindeer husbandry, it is imperative that governments, local reindeer herders, management, policy, and decision-makers include reindeer herders and their traditional local and scientific knowledge in future decision-making which impacts the herding community. To enable the efficient, timely collection and integration of their data into these decision- and policy-making processes, EALÁT Project reindeer herders are developing their own system to monitor changes based upon traditional knowledge and modern technologies. This new system is based on the principles of the United Nations (UN) Convention of Biological Diversity Art 8, UN Agenda 21 Declaration Ch 26, ILO-169 Convention on Rights of Indigenous Peoples, UN Declaration concerning the rights of Indigenous Peoples 2007, the United Nations Educational, Scientific and Cultural Organization (UNESCO) Convention on Protection and Development of Cultural Diversity, and the Yakutsk Declaration from Third World Reindeer Herders Congress in 2005. In fact, the Yakutsk Declaration explicitly stated that reindeer herders should develop their own system to monitor changes of the arctic natural resources, based on traditional knowledge and modern technology.

EALÁT-Monitoring is developing an observation program or monitoring system for reindeer pastoralism in place-based studies in the Saami area (Norway, Sweden, Finland, and northwestern Russia) and Yamal-Nenets Autonomous Area, and, later possibly, Nenets Autonomous Area, the Republic of Sakha (Yakutia), and Chukotka Autonomous Area. The EALÁT/Reindeer Mapper System, being developed at the International Center for Reindeer Husbandry, is a data integration and sharing system to integrate traditional indigenous knowledge together with physical, scientific, and technical data into a common GIS database for improved decision-making and herd management. An early EALÁT pilot project of the NASA Land Cover Land Use Change Program called Reindeer Mapper developed a preliminary concept for this type of system (Fig. 8.14), designed to bring remote sensing, ground measurements, and information technologies together with indigenous traditional and local knowledge for herder use in management of Northern Eurasian reindeer herds (Maynard et al. 2003, Maynard and Yurchak 2003b, Maynard et al. 2004, 2005).

This EALÁT georeferenced data sharing system will use secure Intranet connections for data collection, management, transmission, analysis, access, and dissemination. The system will function as a portal to link data from a variety of sources and provide that information to multiple herders. Observations and information are being integrated into a central GIS data base so that data from all sources such as NASA products, reindeer herder knowledge, observations and maps, ground-based measurements and observations, herd movements can all be put in, managed, transmitted, accessed, and disseminated in real time for herd management. The EALÁT-Reindeer Mapper Information System will assist in the ongoing analysis of trends and detection of emerging events and conditions, which affect humans, agriculture, and the environment to enhance early warning and management of responses and adaptation.

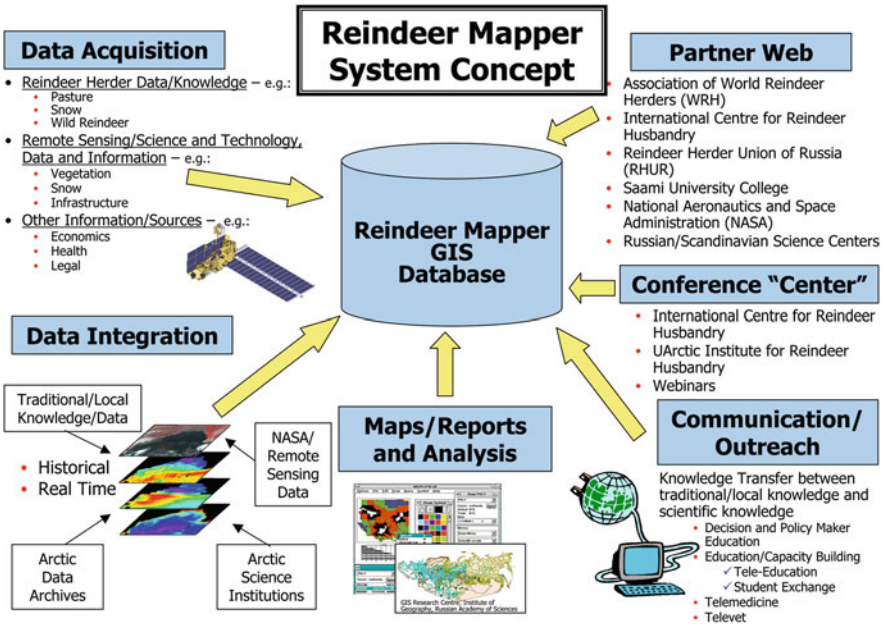

Fig. 8.14 Reindeer Mapper System concept. Reindeer Mapper concept was originally developed to bring remote sensing, ground measurements, and information technologies together with indigenous traditional and local knowledge for herder use in decision-making and management of Northern Eurasian reindeer herds (Maynard et al. 2003)

It is intended that EALÁT will be able to provide reindeer herders with an efficient tool for managing the real-time movements and migrations of their herds. This is accomplished through improved efficiency in linking different members of the herder settlements or communities and by providing real-time local, satellite or other data (e.g., ice melt in lakes and rivers, weather events), thus enabling realtime adjustments to herd movements to avoid problems such as changing weather/climate conditions, freeze-thaw "lock-out" problems, or to take advantage of availability of better pasturelands along migration routes (Fig. 8.15). The system is being designed to incorporate local data to allow users to bring their own data into the system for analysis, in addition to the data provided by the system itself. With the local information of the population, up-to-date environmental data and habitat characteristics, the system could generate maps depicting important features of interest for reindeer managers.

One of the products derived from the planned system will be a web-based graphic display that allows analysts to quickly pinpoint areas of interest such as those with large concentrations of reindeer, and provide surrounding environmental information. The system could be automatically updated with near-real-time information such as hourly precipitation and snowfall rate and accumulation, daily surface and air temperatures, and vegetation cover conditions. The system could bring attention

Fig. 8.15 Dangers of early ice melt (photo by S.D. Mathiessen)

to the proximity of human and animal populations as part of the need for control response. A local GIS will bring these many layers together with several supporting models, showing only a straightforward graphic of the real-time situation in the field. Because the proposed system will be operating in the Internet environment, it should be virtually accessible from any network computers and wireless remote access from the field. The International Center for Reindeer Husbandry in Kautokeino, Norway, is providing regional and international coordination of and access to data sets and expertise, and will act as overall clearinghouse for EALÁT information.

8.5 Reindeer Pastoralism and the Future: UArctic International Institute for Reindeer Husbandry

For a sustainable future, reindeer herders themselves are now have to define and anticipate risks related to rapid change in their local communities and plan for optimal adaptation strategies. Reindeer herders in Eurasia from the Bering Strait in the east to the Atlantic Ocean in the west will face many challenges related to changes in their grazing lands and their societies due to climate variability and change, and arctic industrial development. Reindeer herders therefore have to prepare themselves, their societies, and management authorities to reduce their vulnerability to change, including empowering themselves with new technologies to monitor their local communities based on the best knowledge available.

The most recent development in direct response to these needs is the initiative from the Association of the World Reindeer Herders (WRH) and the International Centre for Reindeer Husbandry in collaboration with Saami University College to the establishment of the UArctic Institute for Reindeer Husbandry ("UArctic EALÁT") to ensure EALÁT has a legacy after the IPY years. As stated by the International Centre for Reindeer Husbandry:

> The new UArctic Institute will be hosted in Kautokeino, Norway, as a pilot institute for research, outreach and education within the objectives of the UArctic Strategic Plan 2008–2013, in accordance with the Yakutsk Declaration (2005) from the Third Congress of World Reindeer Herders and in agreement with the Fairbanks Declaration from the Eighth conference of Parliamentarians of the Arctic Region, Fairbanks, the United States of America, 12–14 Aug 2008.

The Fairbanks Declaration states:

> Further build capacity in Arctic communities to adapt to climate change, including the development of new education programmes and skills training initiatives, to allow. Encourage the University of the Arctic to build practical capacity in the north to address the challenges of adaptation to climate change, and to solve the Arctic's needs for energy, from technical, cultural, economic as well as environmental perspectives, and to provide further education of health care personnel with special focus on Arctic conditions.

The UArctic EALÁT Institute will provide a unique opportunity in building competence locally in reindeer herders' society not presently available in the UArctic. The EALÁT network is today responsible for the UArctic thematic network: Adaptation to globalization of the Arctic. The EALÁT network is based on the unique cooperative network established by the Association of World Reindeer Herders (WRH) through the Eurasian North.

The institute is a very significant vehicle for building the capacity of arctic countries and, in particular, indigenous peoples, to adapt to climate change, industrial development, and globalization across the Arctic as well as to reduce their vulnerabilities through empowerment with the best indigenous, scientific and technological knowledge available – including, remote sensing.

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