Combining Data from Satellite Images and Reindeer Herders in Arctic Petroleum Development: the Case of Yamal, West Siberia

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Abstract: The aim of the study is to assess the capacity for satellite imagery in detecting different natural and anthropogenic land cover types in the vicinity of a modern petroleum extraction development in the Russian Arctic. The Yamal Peninsula in northwest Siberia contains some of the largest untapped deposits known in the world. It also serves as the homeland of the Yamal Nenets, who have exploited first wild and then domestic reindeer in the region for at least 1000 years. Their annual migration from the treeline to the northern tundra brings them into contact with a number of impacts associated with gas exploration and production. These range widely and include physical obstructions from roads, railways, and pipelines, as well as direct and indirect ecological impacts, such as changes in vegetation, soils and hydrology due to e.g. drilling, infrastructure development, and seismic surveys. Some of the effects are relatively small-scale, only a few meters across, while others cover several hectares. Nenets' perceptions of the spatial aspects of their territories encompass changes in both quantity and quality of terrestrial habitats, rivers, lakes and campsites that have been used seasonally for centuries. Even high-resolution imagery was unable to detect things like trash (rusted metal, broken glass), drilling muds and petro-chemicals that can strongly affect the overall quality of reindeer pastures. To properly assess the overall ecological impacts of petroleum development requires a combination of state-of-the-art remote sensing coupled with detailed ground-truthing. These efforts must embrace both scientific and local knowledge from indigenous herders and also non-indigenous gas field workers.
Key words: Nenets, reindeer migration, indigenous knowing, remote sensing, arctic tundra

Introduction

Russia is becoming more important as a producer and supplier of oil and gas to European and eventually North American markets. The Iraq war and post-war chaos have partly increased world market price of oil barrel to its record. Meanwhile Russia has invested in pipelines across eastern and central Europe and tanker traffic via the Northern Sea Route. Among the main sources are the giant oil fields of the Nenets Autonomous Okrug (NAO), Khanti-Mansisk Autonomous Okrug (KMAO), and the super giant gas fields of the Yamal-Nenets

Autonomous Okrug (YNAO). Russian production has an image of being more stable and safe from political crisis than some of the big middle Eastern producers. It has once again become a powerful trading partner, in particular as a major source of energy for the global market. At present Russia supplies 25% of the world's natural gas, which makes it the No. 1 producer. Some 90% of this production comes from West Siberia. As for oil, Russia recently also took over the leading position in world production from Saudi Arabia (Mosnews 2006). 60% of Russia's oil is from West Siberia. Overall EU dependency on both oil and gas from Russia is high and increasing, relative to European sources like Norway and the declining export capacity of the UK. In 2005 the European Union received 25% of its oil (30% of all imports) and 25% of its gas (50% of all imports) from Russia. Dependency on Russia among individual EU countries, however, varies greatly. For example, Finland relies 100% on Russian gas sources, whereas France with its traditional ties to Algeria imported only 24% from Russia as of 2004.

As petroleum industrial infrastructure expands rapidly throughout Russia's north, it has profound implications for the environment and region's economies and local people, in particular indigenous groups practicing traditional livelihoods like herding domestic reindeer (*Rangifer tarandus*), hunting and fishing. The building up of the Russian empire has affected these indigenous groups over the last 500 years. Up until the 19th century the main resource produced from these northern regions was fur, whereas from the mid-20th century onward petroleum products became the central focus.

The exploration and exploitation phases of northern areas like YNAO and NAO were launched in the 1960's with extensive resource prospecting. Geological surveys searched through the tundra zone with heavy drilling equipment and left clear imprints on the permafrost landscapes. Surveys mapped the oil and gas deposits and drilling was first started in boreal and subarctic areas with easiest access from the south, such as existing railways and roads. Surveys and drilling further north in truly arctic areas required enormous amounts of infrastructure for example building of pipelines, expanded road and rail networks and accommodation facilities. Supply of remote arctic exploration sites has been difficult with winter road networks, helicopter, aeroplane and also by ships via the Northern Sea route. In the post-Soviet period, oil and gas have become a vital source of profits to the overall Russian economy. The exploration and exploitation phases of petroleum development result in benefits and wealth but also, at the same time, in a large number of direct and cumulative impacts on ecosystems and cultures all along the route from the source to the market (Forbes 2004; Stammler & Wilson 2006). New drilling sites and oil and gas fields have been connected to transport networks to export oil and gas to world markets. This of course has increased impacts on the environment and local indigenous communities.

In the YNAO indigenous lifeways of the Nenets, Khanty, Komi-izhemtsy and Sel'kup fishermen, reindeer herders and hunters - for the many of whom are still nomadic or semi-nomadic – are comparatively well-preserved. While use of reindeer reaches back to at least 1200 years, the large scale herding of domestic reindeer has developed in the 1600's. In YNAO on Yamal Peninsula reindeer herding survived intact from the Soviet period with the least amount of damage compared to other indigenous cultures elsewhere in Russia (Stammler 2005).

Satellite images have been used successfully in the detection of marine and coastal oil spills. Especially radar satellite images are suitable for detection of oil spills (Benelli & Garzelli 1999; Espedal & Johannessen 2000; Jones 2001; Solberg & al. 2003). Oil spill detection from terrestrial drilling sites is more difficult, because the size of spill is an important factor that defines its potential for detection. In detection of impacts not only spills should be detected. Impacts should be studied holistically, all possible impacts on environment and other land use forms. Also impacts on the herding community must be studied, and several authors have argued for a shift in the focus of impact studies from spill response and impact and damage compensation to prevention of spills, minimising negative impacts and development plans for local populations (Meschtyb & al. 2005; Stammler & Wilson 2006).

Impacts of industrialisation in the northern Russian mining towns of Vorkuta and Noril'sk have been studied with Landsat TM data (Toutoubalina & Rees 1999; Virtanen & al. 2002). Tømmervik & al. (2003) studied effects of air pollution on vegetation in the Norwegian-Russian border area by using multitemporal Landsat MSS/TM data. Stow & al. (2004) reviewed the possibilities of change detection studies in arctic areas with available remote sensing data. Rees & al. (2003) studied land cover change in NAO with Landsat TM and ETM+ images, they also attempted to incorporate indigenous knowledge of Nenets reindeer herders to land cover change interpretation, although this formed only a very small part of their analysis. One problem associated with such attempts is that indigenous knowledge is highly situative, very detailed, learned and enacted by people moving through the land. Prominent scholars have therefore questioned the compatibility of "indigenous knowledge" with natural science knowledge that can be put into databases and treated as body of information independent from its context, whereas indigenous ways of knowing are culturally embedded sets of practices (Ingold 2005; Stammler 2005). Landsat MSS/TM/ETM+ data are too coarse to detect small-scale impacts that are common in most cases. Very high resolution images like IKONOS-2 and Quickbird-2 have a resolution of less than 4 meters and they have the potential for very detailed impact detection. In the Arctic there have been few studies where IKONOS-2 images have been used to study lichen pastures of reindeer (Allard 2003; Kumpula 2006).

There is a critical need to minimize conflicts between arctic grazing systems and industrial development, particularly in Russia which remains in a state of drastic and rapid transformation (Klein 2000; Krupnik 2000). There is strong evidence that these impacts are reaching a critical threshold in YNAO, where the withdrawal of lands for industrial infrastructure has pushed a steadily increasing number of animals onto progressively smaller areas of tundra pastures (Zen'ko 2004; Stammler 2005). This is leading to desertification in places and a serious decline in the quantity and quality of the remaining upland tundra suitable for reindeer pasture (Forbes 1999; Jernsletten & Klokov 2002). At the same time, the indigenous Nenets population has been exposed to a number of new health and demographic problems directly related to the industrial development (Pika & Bogoyavlensky 1995).

In the project *Environmetal and Social Impacts of Industrial Development in Northern Russia* (ENSINOR) we focus on a multidisciplinary analysis of the social and environmental consequences of energy development. We combine state-of-the-art Western scientific technologies with the indigenous or local perceptions of processes of change by Nenets reindeer herders. This method of co-producing knowledge can be expected to yield results which are both highly relevant to local and regional needs and practical for policy implementation. The immediate objectives are to characterize the effects of 2-3 decades of industrial development of petroleum on traditional livelihoods and the supporting society in YNAO and NAO. In this article we are studying the impacts that can be detected from the different resolution satellite images. We also discuss the significance of field surveys and local knowledge in enhancing the interpretation of satellite images.

Research area

The Yamal-Nenets Autonomous Okrug (YNAO) belongs to the West Siberian economic region and the Ural Federal district. YNAO is an independent unit of the Tyumen Oblast and lies in the extreme north of the West Siberian lowland, which encompasses the largest wetland (technically a peatland) in the world. With a territory of 750 300 km^2, the length of YNAO from north to south is 1200 km and from east to west 1130 km. In the Nenets' own language, "Yamal" means "the end of the earth" or "land's end". Ice-rich permafrost is widespread and is susceptible to thermokarst erosion from both natural and anthropogenic disturbance. As a result, much of the terrain is considered moderately to extremely unstable for purposes of engineering and infrastructure developments (roads, bridges, pipelines, etc.). The forest-tundra transition zone covers a broad band coincident with the southern portions of Yamal and Taz Peninsulas and most maps depict the latitudinal treeline as running approximately through the city of Salekhard on the Arctic Circle (lat. 66°33'N). For the indigenous Nenets, their needs are met mainly by reindeer. South of the Ob River delta, sparse lichen woodlands of Siberian larch (Larix sibirica) give way to more or less closed forest in the southernmost parts of YNAO. On the shores of lakes, rivers and bays, subsistence fishing is of major importance too. Substantial populations of terrestrial wildlife still exist, although some fur-bearing species are subject to hunting and trapping, both licit and illicit.

Today the YNAO is numerically the world's most productive reindeer herding region with 556 000 domestic reindeer, herded by approximately 13 000 nomadic Nenets and to a lesser extent Komi and Khanty families. While successor enterprises of Soviet state farms, sovkhoz dominate the institutional landscape in reindeer herding, private clan communities dynamically develop in the North of the okrug and hold more than half of the reindeer population. At the same time, the gas deposits discovered here are the largest worldwide. Large-scale industrialisation since the 1970's has led to an influx of people from the south, which is why today the indigenous share of the overall population is less than 7%.

This paper focuses on the vast Bovanenkovo gas field in the northwestern part of the Yamal Peninsula (Fig. 1). The gas field is located in the area to which the Yarsalinski reindeer sovkhoz holds the principal land title. Bovanenkovo is on the migration path of two major Yarsalinski reindeer brigades. These brigades reach Bovanenkovo from south in early-mid July on the way to the Kara Sea coast where reindeer are taken to for insect relief and high quality forage. Brigades return through Bovanenkovo in mid-late August when they start migration towards winter pastures on the south side of the Ob river. In addition, at least a dozen private reindeer herding camps use the larger Bovanenkovo area as reindeer grazing grounds. In comparison to the brigades, their herds are smaller in size, their migration routes shorter, and their presence in Bovanenkovo area longer, reaching from early summer until October-November. Very little is known about the exact migration patterns of these private herders. However, their number has been increasing after the fall of the Soviet Union, and their herds as well as their families probably outnumber those of the officially registered herding brigades today.

Materials and methods

Field surveys

Two field expeditions to Bovanenkovo gas field and to its surroundings were made

Figure 1. Reindeer herding in northern Fennoscandia and Siberia. Bovanenkovo gas field in Yamal Peninsula is marked with a black circle (lat. 70° 20’N long. 68°30’E). (Map: Arctic Centre, University of Lapland)

during the summers 2004 and 2005. A few hundred field sites were surveyed for image classification. Vegetation types were defined and special attention was placed on the signs of human impacts. Brigades migrating through the area were interviewed and also gas workers from Bovanenkovo were interviewed. Valuable information about Bovanenkovo's history and exploration were gained from both reindeer herders and gas workers. Herders from two brigades were accompanied during their migration through the gas deposit, and explained the migration history, their relations with the gas workers, changes and especially effects of gas exploration on everyday reindeer herding and reindeer pastures. Printouts of satellite images and topographical maps were used in interviews. Information from herders was also obtained during participant observation and in depth unstructured interviews that provided deeper insights about the relations of herders to the land, including its spiritual significance and the impact that the presence of industry has on these relations.

Remote sensing and GIS data and methods

Satellite images with different spatial resolution were used to compare the visibility of the different impacts. The very high resolution remote sensing data used in this study was Quickbird-2 (dated 15.7.2004). The spatial resolution of Quickbird-2 multispectral channels is 2.5 meters and on the panchromatic channel it is 0.61 cm. Quickbird-2 has 4 multispectral channels of blue, green, red and infrared. Data are stored in 11 byte format. High resolution data used were ASTER TERRA with 15 meter resolution (4 channels) (dated 21.7.2001), Landsat TM with 30 meter resolution (7 channels) (dated 07.08.1988), and Landsat MSS with 80 meter resolution (4 channels) (dated 28.7.1984) (Table 1).

GIS data with adequate accuracy were not available. Road network, sand quarries and drilling sites were digitized using Quickbird-2 and ASTER TERRA images. Visibility of different impacts on satellite images was compared between the images using field sites, ground photographs and photographs taken from helicopter. Reindeer herders' migration routes and brigadiers' notes were digitized from satellite image printouts. The aim was to produce a map depicting the total area of disturbance around the Bovanenkovo. Impact area estimation was produced by using field sites, photographs taken from helicopter and by visual interpretation of ASTER TERRA and Quickbird-2 images. Estimation was carried out by outlining the furthest visible signs of industrial impacts from around Bovanenkovo gas field. The area outlined in the ASTER TERRA image encompasses all visible signs of disturbance, such as roads, off-road vehicle tracks, quarries, etc.

Results

Detecting the impacts

From the remote sensing point of view it is always easier to detect the surface characteristics when trees and their canopy and shadows are absent. The detection of impacts from both the satellite data used

Table 1. Spectral characteristics of the satellite data used.

Spectral band	Quickbird-2 Wavelength (μm)	ASTER TERRA Wavelength (μm)	Landsat TM Wavelength (μm)	Landsat MSS Wavelength (μm)
1 (blue)	0.45 - 0.52	-	0.45 - 0.52	0.5 - 0.6
2 (green)	0.52 - 0.60	0.52 - 0.63	0.52 - 0.60	0.6 - 0.7
3 (red)	0.63 - 0.69	0.63 - 0.69	0.63 - 0.69	0.7 - 0.8
4 (NIR)	0.76 - 0.89	0.76 - 0.86	0.76 - 0.90	0.8 - 1.1
5 (NIR)	-	-	1.55 - 1.75	-
6 (TIR)	-	-	10.40 - 12.50	-
7 (NIR)	-	-	2.08 - 2.35	-
Panchromatic	0.45 - 0.90	-	-	-

and the field surveys is presented in Table 2. Contamination of the soil because of oil and various chemicals is difficult to detect even in the field if the contaminated area is small or if accidents have occurred some time ago and have since revegetated. Only a few possible sites were found where there were some sign of oil spills but which must have been leaked from a vehicle or an oil barrel (Bovanenkovo is a gas field). In satellite images there were no visible signs of oil or chemical contamination.

The removal of top soil and vegetation takes place in areas that have been used as building sites, vehicle storage areas, drilling sites activity etc. They usually extend over some acres or hectares and can be detected even from coarse resolution Landsat TM images. Larger quarries where sand is mined for road and other building purposes are detectable also from Landsat MSS images. This is because the spectral reflectance of bare ground is significantly different compared to the reflectance of vegetation.

Garbage is unfortunately difficult to detect. In the field there can be piles of leftover wood and metal gathered together that is possible to detect from panchromatic Quickbird-2 imagery. Wood remaining on abandoned drilling sites is of high value to reindeer herders who have to cope with a scarcity of wood for cooking and other purposes. Herders also make extensive innovative use of other leftovers on former industrial facilities and by doing so contribute to the recycling of waste to a certain extent (Stammler 2002). When metal and glass waste is sparsely distributed,

Table 2. Capacity to detect different impacts of petroleum exploration in Bovanenkovo. Scale is –not visible, x visible with effort, xx quite visible, xxx clearly visible.

Capacity to detect Impact	Field survey	Quickbird-2 Panchromatic	Quickbird-2 Multispectral	ASTER TERRA VNIR	Landsat TM	Landsat MSS
Soil contamination, oil & chemicals	x	-	-	-	-	-
Removal of top soil and vegetation	xxx	xxx	xxx	xx	x	x
Quarries	xxx	xxx	xxx	xxx	xx	x
Garbage						
- metal	xx	-	-	-	-	-
- glass	x	-	-	-	-	-
- concrete	xxx	x	x	-	-	-
- wood	xxx	x	-	-	-	-
Pipelines	xxx	xx	x	-	-	-
Power lines	xxx	xx	x	-	-	-
Roads	xxx	xxx	xxx	xxx	x	x
Off-road vehicle tracks	xx	xxx	xx	xx	x	x
Winter roads	xx	xx	xx	xx	x	-
Drill towers	xxx	xxx	xx	x	-	-
Barracks	xxx	xxx	xx	x	-	-
Trucks/Vehicles	xxx	xx	x	-	-	-

detecting them in field survey can be difficult. Garbage can partly or completely be covered with vegetation. This kind of garbage is one of the most harmful to reindeer according to herders. Reindeer can injure their hooves from glass or sharp metal and hence be exposed to infections that may in the worst scenario lead to death.

Pipelines and power lines are reasonably detectable in multispectral Quickbird-2 imagery. Roads, winter roads and off-road tracks are just barely visible in Landsat MSS image. Drill towers and barracks can be detected with ASTER TERRA imagery. Vehicles can also be seen from multispectral Quickbird images.

Field survey was the most useful way to identify different impacts. Some objects like revegetated old tracks, some seldom used off-road tracks and areas that have been revegetated completely were easier to detect and outline from multispectral Quickbird-2 image. Noticeable is that some tracks were impossible to detect in the field before we checked the satellite image printout.

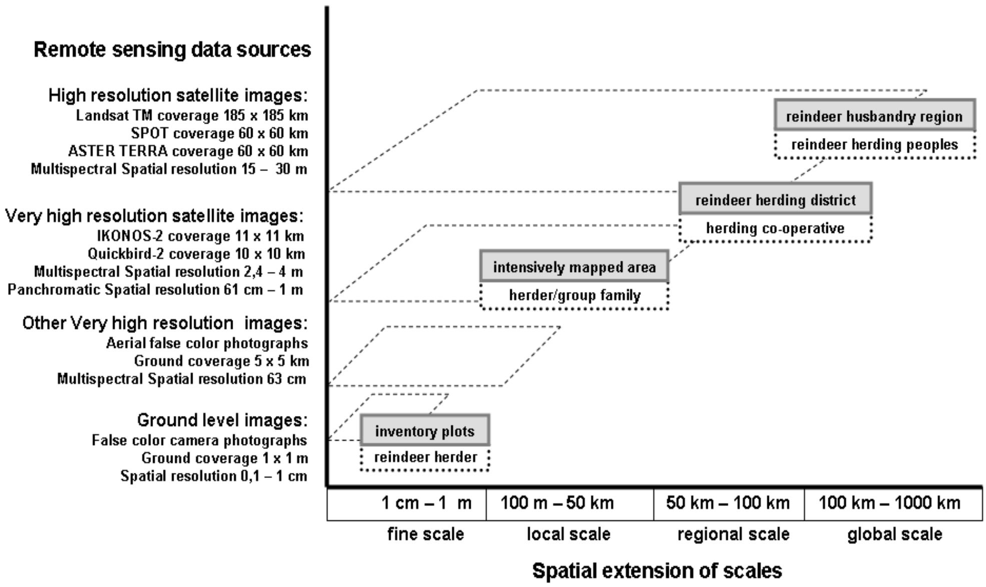

Figure 2. Scales of investigations and relevant remote sensing data sources (Timo Kumpula & Benjamin Burkhard).

Scales of investigations

When investigating environmental impacts, the data resolution has to be suitable for research purposes. For example pipelines cannot be detected from Landsat TM images accurately. Size of the research area is another factor determining the data to be used either in terms of data size (megabytes) or data costs. In the case of Bovanenkovo, where the total area is 35 * 10 km, ASTER TERRA is the most cost efficient data source to study impacts of the whole gas field. But if more detailed study is planned, Quicbird-2 image is a very good choice. Quickbird-2 multispectral image enhanced with panchromatic image provide the best data to detect impacts around drilling sites. Most impacts are detectable in this image combination (Fig. 2).

ASTER TERRA images are worthy of attention from among the larger scale sources of satellite data. Landsat TM covers a larger area and has better spectral resolution with 7 channels, but ASTER TERRA’s 15 meter resolution and lower price increases its overall utility to detect environmental impacts.

Area of disturbance

Total area of disturbance was calculated by outlining inside Bovanenkovo the areas that had signs of human disturbances visible in ASTER TERRA and Quickbird-2 images (Fig. 3). The area of disturbance covers 317 km^2. Inside this buffer there are visible changes compared to the original vegetation cover. Inside this area there is also a significant amount of relatively undisturbed vegetation. Permanently lost pasture-land includes roads and infrastructure areas. The active road network totals 79 km and it covers 143 ha, by calculating an 18 m wide buffer around road network. Although roads are only approximately 18 m wide, the actual affected zone around them is much broader due to the cumulative impacts of blowing sand and dust and altered hydrology. Significant changes in soil moisture, pH and plant chemistry are detectable at least 35 m from the edges of roads within four years of their construction (Forbes 1995). Infrastructure (drill sites, barracks, storage areas) covers 203 ha and quarries 373 ha. However, we are aware that besides these detectable impacts on satellite images, reindeer herders are heavily impacted by the social and economic consequences of industrial infrastructure: for example, a road opens up larger areas of the tundra for open access by industrial workers. Besides for working purposes, they may use roads for going on hunting, fishing (poaching), recreational trips or trading. Being untrained for the interaction with herders and herds, they might not behave in an appropriate way in the vicinity of herders and herds. Therefore, roads are significant for herders beyond the immediate corridor of impacted pasture.

Herders' and workers' interpretation of satellite images

Interviewing reindeer herders was essential to understanding the impacts of petroleum industry on reindeer and their herders. Information on the history of exploration

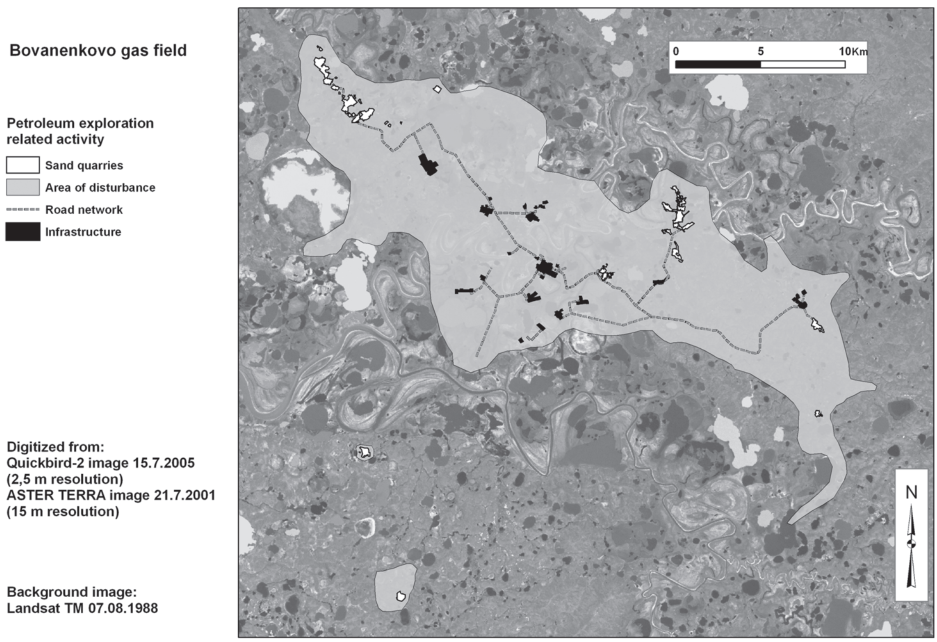

Figure 3. Area of disturbance around Bovanenkovo gas field.

which has taken place in the area would have been extremely difficult or totally impossible to gain from other sources. Many herders were able to interpret satellite image printouts extremely efficiently (Fig. 4). False colour composites did not cause problems to identify lakes, rivers, campsites and migration routes with their exact locations. Herders through their perception of the migration route and the industrial area added an important level of historical depth and detail to our understanding of recent changes in the area. Gas workers also provided a lot of information about the area and history from their point of view. They also provided information concerning the future of the petroleum exploration in the area. Interviews and participant observation with both groups of workers in the tundra impressively revealed the various mental maps of people with different interests in the area. The mental map of most herders consists of a complex set of migration routes, pastures, fishing grounds, camp sites presenting a detailed image of the on-surface resources. The gas workers' mental map in the Bovanenkovo area was also very detailed and in many cases reached back decades, consisting of a complex set of drilling sites that provide access to different layers of the gas under the permafrost, and of pipelines, roads, and camps dispersed across the whole territory of the gas deposit. Gas workers also had developed throughout the decades an intimate knowledge of the rivers and lakes, some of which they have been using for fishing for a long time, and some of which are now being heavily impacted by new road constructions leading right through the water bodies.

Figure 4. Brigadier Vasili Serotetto explaining migration routes, campsites and pastures with false-colour composite of ASTER TERRA imagery. Photo: Timo Kumpula 14.7.2005.

The technology of building bridges by blocking off small rivers or lakes completely for the duration of the road works has been heavily criticised by herders. As a result, larger areas around these blocked rivers can become flooded and turn into extreme wetlands that are not suitable as reindeer pasture or migration routes anymore. These flooded areas as well as drained lakes can also be detected on satellite pictures and herders added historical depth and detailed descriptions of events for these areas.

Discussion

The preliminary results in detecting the impacts of oil petroleum exploration on reindeer herding were promising. It seems that combining different scale remote sensing data results in impacts detection can be achieved. Usually drillings sites are spatially quite small and like Bovanenkovo the whole gas field is 35 * 15 km. This allows pinpointing the special area of interest and to acquire expensive very high resolution data like Quickbird-2 or IKONOS-2. Then detailed research on impacts is possible to conduct.

During the field survey the limitations of human eye were once more clearly demonstrated. We noticed that in the field it was difficult to notice revegetated vehicle tracks and the edges between once disturbed and untouched vegetation. In satellite image printouts different intensities of infra-red signatures were very clear. Also detecting old vehicle tracks from ground level was much more difficult than from helicopter and Quickbird-2 images.

Local and indigenous peoples' assessment was crucial in understanding current development and impacts of petroleum exploration. In general, they add a different level of interpretation to changes on the tundra by ranking events, development and changes and evaluating them in terms of their positive or negative impact on their livelihoods. Thus, satellite images and biological ground truthing provide an important factual basis and information about their significance for the lives of humans and animals on the tundra. Herders are able to provide qualitative data (testimony from active and retired herders) on the degree of environmental and socio-economic change during past decades. They provide information on the current variation in the vegetation and reindeer habitat types and how they are ranked according to quality. They can also estimate what proportion of the habitat has been lost because of the petroleum industry and how the herders and reindeer have adapted to this. Herders also have a good idea where areas of potential or likely future degradation may occur (e.g. desertification from heavy grazing, melting of frozen ground). Herders' expectations or scenarios for the future under petroleum development are important factors that should be considered in research question development. Nenets developed strategies for mitigation of predicted negative changes and scenarios of future reindeer management in conjunction with petroleum development.

What are more difficult or impossible to detect on satellite images are the potential and actual positive social and economic impacts of industrial development on reindeer herders. During fieldwork, participant observation with them revealed that in principle the presence of industrial workers and their facilities is welcomed by herders of the area, and their perception of the negative effects is balanced by the benefits, for example of the workers' settlements as a source of staple food to resupply, the use of roads for the supply of herders, the settlements as a market for reindeer meat, the helicopters of the gas company as means of transport and as means to collect velvet reindeer antlers to be sold on far eastern markets for cash (Stammler 2004). In the case of the private herding camps not belonging to officially registered reindeer brigades, the gas company has become the most important trading partner.

The further processing of satellite data focuses on the extent and rate of tundra ecosystem change during the past 20 – 30+ years. Landsat MSS and TM are the main data sources when studying the situation in the 1970's and 1980's but also CORONA spy satellite images can be used in change detection. The aim is to estimate how large a fraction of the habitat has been affected within the current range of reindeer habitats. GIS and risk assessment of potential future degradation in expanding drilling sites will be conducted.

Together the applied results from these assessments will provide a potentially powerful tool for regional planning and policy development. The results will be of interest to scientists in several disciplines (e.g. anthropology, geography, biology/ecology, political science, international relations, conservation biology), as well as to indigenous groups elsewhere in other arctic and subarctic regions.

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