3.4. Land Use Interactions: Societal-Ecosystem Linkages

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3.4.1 Background

Northern Eurasia has a diverse land cover and land use with over 20% of the world's arable lands and 24% of the world forests. The Eurasian grasslands constitute the largest contiguous grasslands in the world. The region also has a large extent of rich soils to support productive agricultural systems. However, the semiarid agriculture, both croplands and pastoral systems, are limited by availability of reliable water resources. The sustainable land use is dependent on the appropriate water and land resource management. Pastoral systems in the region can account for as much as 30 to 40% of the GDP in certain regions of the countries. Forestry is a major employer in the region. In much of the region, the rural service economy is poorly developed, has greatly eroded during the past decade, and are only slowing recovering (IBRD 2002). Northern Eurasian ecosystems present challenges to social and ecosystem scientists assessing the human dimensions of land cover and land use change. The social forces that underlay these complex vegetative changes are also unique to the region, which has experienced profound institutional change and an abrupt insertion into a globalized economy over the past decade. The emergence of a market system, changes in governance and property regimes, the onset of international capital flows, and accelerating population movements have all impacted the region's resources and land use. Developing models to explain and predict land cover change in Northern Eurasia will require new approaches that allow for complex interactions of social processes.

Some of the key characteristics of the NEESPI region related to land use are:

- Change in land use intensification related to water use, nitrogen fertilization rates, and grazing affecting agricultural production, and forest and crop management systems;
- Change in economic policy and land-use; and
- Degradation of land productivity, including loss of soil fertility, increase wind and water erosion.

The NEESPI Human Activities science strategy represented in the following sections of this chapter is consistent with the focus of the IGBP and IHDP Global Land Science joint research agenda for land-centric research – people, biota, and natural resources (cf., NRC 1998; Box insert 3.4.1). The focus in all programs is the emphasis on the linkages and changes in the coupled human and environmental system associated with land sustainability.

Box insert 3.4.1. Human Dimensions Imperatives from: "Human Dimensions of Global Change" prepared by the U.S. NRC Committee on Global Change, Board on Sustainable Development (NRC 1998).

- Understand the major human causes of changes in the global environment and how they vary over time, across space and between economic sectors and social groups.
- Determine the human consequences of global environmental change on key life support systems, such as water, health, energy, natural ecosystems, and agriculture, and determine the impacts on economic and social systems.
- Develop a scientific foundation for evaluating the potential human responses to global change, their effectiveness and cost, and the basis for deciding among the range of options

- Understand the underlying social processes or driving forces behind the human relationship to the global environment, such as human attitudes and behavior, population dynamics, and institutions and economic and technological transformations.

3.4.2. Land Use in Transition

The Eurasian region consists of a broad range of ecosystems and associated land uses. During the past decade, most of the land use management in these countries has changed and are transitional economies. These countries are among the most vulnerable in terms of their economic, political, and environmental systems. Interactions between and among policies, human responses, and Earth system function cannot be decoupled. Transition economies are characterized by a combination of a) volatile markets, b) policy reforms, and c) unclear and uncertain land tenure systems. It is not any single factor, but rather the combination of all three, that makes these systems and peoples vulnerable in a number of different capacities.

The past two centuries have seen the world's largest decline of forests and grassland areas from the Eurasia region (Grubler 1994). Croplands have increased in the region with the peak land area occurring in the late 1980s. In the northern regions of Eurasia, a decrease in the agricultural land areas started after World War II (Golubev et al. 2003). Land degradation has become a serious environmental concern in the region due to overgrazing, cropping marginal lands, and increased frequency of fires resulting in desertification, increased dust storms and erosion soil losses, salinization, and increased aerosol loading due to burning. Liberalization has eroded the state institutions through which the socio-economic system was organized and in the absence of alternative social and market-based institutions households have been left to face the risk of a natural calamity alone. As a result, the effects of natural disasters upon the pastoral economy are likely to be far more severe than they have been.

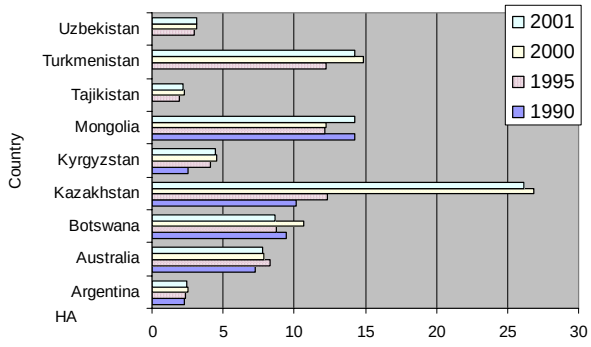

Figure 3.4.1. Permanent pasture per livestock unit (FAO data). For Kazakhstan, a twofold increase in this parameter during the 1990s means (unfortunately) not an increase in the pasture area but a collapse of large collective farms and decrease in livestock.

Transition from centrally governed pastoral systems to free market economy brought very different consequences for livestock industry in countries of east and central Asia during the last decades. While the switch to the market economy was relatively successful in China and Mongolia, it had a detrimental affect in Central Asian states such as Kazakhstan, Tajikistan, and Kyrgyzstan (Kerven and Lunch 1999; Behnke 2001; Kerven 2001). The Institute of Geography of the Russian Academy of Sciences estimates that these ecological problems characterize nearly 16 % of the territory of the former Soviet Union. The human-environmental system in these regions is under greater stress, since over 48% of the former Soviet Union population lives within the region of affected lands. This disproportionate reliance on these lands will further stress the land resources given the concentration of human population around these ecologically fragile lands.

Studies are needed to analyze the nature and extent of the impacts of the varied and different governmental policies, politics, markets, and changes in governance in addition to climate change on nomadic pastoral and sedentary systems, livestock management, grazing patterns, cropping systems, large-scale conversion of natural lands to crop lands, and,

especially, the indigenous peoples of the Russian North. Studies should be done to determine ways to reduce the vulnerability of target populations against these forces.

Studies are needed to analyze the interconnections between the impacts of climate and social/political changes and their combined effects on land use land cover change and on the productivity of the land as well as effects on ecosystem services.

Studies are needed to determine the impacts of the post-Soviet reduction in basic social services (e.g., health care, education, drought mitigation) on human populations and the impacts of the resulting poverty and abandonment of agriculture on the different ecosystems. Studies should be done to determine ways to compensate for loss of these basic social services.

3.4.3 Land Conversion and Driving Forces

Land conversion has taken place throughout the region from northern areas where forestry, mining, and oil and gas development have significantly altered the landscape in these regions to more temperate regions where agricultural development has been extensive during the past century. The agricultural output of Eurasia has been one of the most productive in the world. High soil fertility, good, but variable climatic conditions, and an industrious human resource base have all contributed to the rich agricultural production. Contributing to this increased productivity of croplands is the increased use of synthetic fertilizers, intensification of agricultural practices as evidenced by the number of tractors being used today, and increased number of livestock produced. The human activities, which have significantly altered the environment and, in turn, impacted the people of each region, are described in the following section by ecosystem type.

Far East Asia

Due to an increasing population, industrialization, and urbanization, the demand for land resources has been growing in Far East Asia. During the past century, natural ecosystems such as forest, grasslands, and wetlands have been encroached by farmland and other man-made ecosystems on a very large scale. Estimates of Chinese land cover for 1992 indicate that farmland; forest, grasslands, and desert comprise 0.96, 1.33, and 3.19 million km^2, respectively. During the same period, land degradation has also been very serious, resulting in a shortage of land resources, leading to environmental problems such as desertification, deforestation, and soil and water erosion affecting the sustainable economic and social development of the region. Rapid development of industrial economy and expansion of urbanization in the North China Plain have reduced cropland areas. This has also generated a tremendous demand on water resources, which has caused a further shortage for agricultural irrigation, resulting in a decline of irrigated land since the late 1970s (Xu 1996, Zuo and Xu 1996).

Studies are needed to assess the relationships between climate variations and climate changes - including, natural disasters such as floods, droughts - and rapid development, population growth, urbanization, industrialization, and government policies as well as their combined resultant impacts on agriculture, livestock management, and water availability.

Studies are needed to assess results of the policy decisions to move large populations of non-indigenous peoples into the lands formerly inhabited by indigenous peoples, including loss / change of indigenous culture, traditional land use practices, and subsequent impacts on the land.

Far North (Arctic coastal zone, tundra)

Climate changes in the Far North are the largest and most rapid since the beginning of civilization and are dramatically impacting humans, societies, infrastructure, and ecosystems. Indigenous peoples are especially vulnerable to climate change due to dependence upon

subsistence hunting, herding, and fishing as well as often isolated existence in small rural communities with little infrastructure support (Box insert 3.4.2). Climate change is accompanied by other environmental and social changes including pollution, increased UV radiation, habitat destruction, urbanization, development, and tourism (Corell 2004). The ecosystems at the northern extreme of the continent have been already quite vulnerable due to the extreme weather conditions. Now many oblast'[26] are affected by industrial development. The extraction of minerals in the North has the greatest impact on the environment and human health and of all of the mining enterprises, the coal industry has the most negative ecological and economic impact[27].

A comprehensive scientific assessment of the impacts and consequences of environmental changes across the Arctic region is presented in The Arctic Climate Impact Assessment (ACIA 2004). Coordination with the ACIA recommendations will be important for NEESPI program development. *Taking into account the ACIA Assessment findings, studies are needed on the impacts of climate variability and change and increased UV radiation on the people and ecosystems of the NEESPI region; and studies are needed on the vulnerabilities and capacities of human and ecosystems to adapt to these changes.*

The Arctic Monitoring and Assessment Program (AMAP) in assessing the Arctic pollution issues, concluded that there is a general lack of specific data about contaminant levels in the Russian Arctic and initiated a special project "Persistent Toxic Substances, Food Security and Indigenous Peoples of the Russian North" (AMAP 2002). Further studies are needed to better define the sources, fate, and effects of the contaminants from the different sources of contamination – both in ecosystems as well as human populations. Health effects on local populations, including indigenous peoples, is a high priority research area. The effects of climate change on the sources, fate, and effects of these contaminants should be also investigated.

Box insert 3.4.2. Reindeer in Russia: An Example of Social-Ecosystem-Climate Linkages and the Impacts of Land Use Transitions. Reindeer husbandry in Northern Russia is an economic activity with a special cultural dimension of utmost importance to the indigenous peoples (AMAP 2003). Approximately 60,000 people, including 20-25 different groups of indigenous peoples, are employed in reindeer husbandry that is very sensitive to changes in the environment (Jernsletten and Klokov 2002). Climate changes with warmer temperature are creating significant problems now in the Arctic for the reindeer herds (Anisimov and Fitzharris, 2001; Fancy and White 1985; Cameron et al. 1992; Malcolm 1996). In addition to the impacts from climate change, industrial development (e.g., mining, pipelines, oil and gas infrastructure) has increased across reindeer migratory routes in Northern Russia, blocking pathways to summer pasturelands and reducing usable pasturelands (Forbes, 2000). The recent transition of Russia to a market economy has resulted in complete disorder in most parts of the supply and transport systems in remote northern areas. This has resulted in nearly complete disruption of any system of supply of goods, services and health care to northern Russian indigenous peoples. As a result of these factors combined, there are rapidly deteriorating health and living conditions in the reindeer herder communities, with growing death rates and serious health impacts (Jernsletten and Klokov 2002).

Boreal Forest Zone

The boreal forest ecosystems have come under extensive fire threat in the past decades with catastrophic fires covering approximately 200,000 hectares annually in Russia alone (3.1; Korovin and Zukkert 2003). In addition to the more natural disturbances, timber cutting

[26] Oblast' = province; Krai = large boundary provice in Russia that may include some "oblast'" as its part.

[27] For example, the mining of 1 million tons of coal is accompanied by a discharge to the open water reservoirs of 3.22 million cubic m of polluted industrial waters, removal and dislocation of 1.5 million m^3 of stripped and enclosing rocks, disturbance of 10.2 hectares of land plots, and emission of about 3.0 thousand tons of harmful substances to the atmosphere.

(over 1 million hectares of forest lands annually) continues to be active in these ecosystems. The quality of forest resource products have declined and the area of high-grade timber has declined markedly, though pressure for wood products does not seem to be declining. Another impact associated with indirect effects of mining and industrial activities is the decline in forest productivity due to increased pollution levels (hundreds of thousands of hectares on the Kola Peninsula, Urals, southern Siberia, Norilsk and other). At the same time, during the last several years, agricultural lands were overgrown with forests – the area covered with forest increased by 36.2 million hectares.

Studies are needed on the effects of the extensive fires, which have taken place over the past decade across Northern Eurasia on the area's ecosystems, human health and well-being, and forest-related products and services. Studies should include the effects of climate change on the frequency and intensity of fires in forests, peat, and other ecosystems.

Studies are needed on the effects of pollution from mining, oil and gas development, and other industrial activities on forest productivity, the forest ecosystem, and the human populations that depend upon the forest environment, including health effects.

Studies are needed to assess the rate and specific features of forest restoration after felling and the relationship to human activities.

Areas of intensive agriculture development (steppe, forest, steppe, and forest zones)

Agricultural development is located at a key intersection between industrial modernization and preservation of natural resources (Fuelner 2001). On the one hand, ever-increasing needs of humans put pressure on the quantity and rate of food production, while on the other hand, food production itself depends largely on healthy ecosystems. Because agriculture is a major land use/change activity in Northern Eurasia, it is important to increase awareness of the consequences of associated desertification, deforestation, reduced biological diversity, limitations of fresh water, and degradation of lands (Fuelner 2001). Climate change and elevated CO_2 will affect agro-forestry systems, productivity, altering local food and fiber supply, thus affecting the magnitude of land carbon fluxes and their spatial distributions. Impacts will depend on the severity of climate change as well as on the adaptation capacity of regional systems (Rosensweig and Tubiello, 2004). All of these forces must be part of any research program for assessing the success, impacts, and future sustainability of agriculture in the Northern Eurasian region.

One of the main factors affecting the state of the environment in Northern Eurasia is the change of area and structure of agricultural lands. Highly cultivated regions have tended to grow except for the cultivated chernosem areas. Thus, levels of agricultural cultivation attained by 1980-90 had reached their maximum extent for practically all areas of the European territory (Table 3.4.1). During 1990-2001, in all the oblasts of the European territory, a reduction of agricultural lands took place.

Existence of fertile soils in Northern Eurasia (e.g., in many regions of chernozem – one of the most fertile soils in the world) has historically predetermined the development of agriculture. Located in these zones is the main grain belt of Ukraine, Russia, and Kazakhstan. Thus, steppes and forest steppes of the Russian plain, occupying 6% of the Russian territory, give 40% of its agricultural productivity (Steppes…, 1994). Droughts and soil erosion are the most powerful factor of crop capacity formation in all grain- producing oblasts of the former USSR[28]. Decrease of soil fertility and soil erosion have led to reduction

[28] For example, oblasts with a possibility of drought of over 25% along with dry and arid regions include a significant part of Moldova and Ukraine south of Russia and Trans-Caucasus, whereas oblasts with a possibility of drought of less than 25% include the more northern territory, up to the latitude of Saint Petersburg in the European part of the Region (60° N), part of south of Siberia, and even Central Yakutia. Agricultural lands in

of productivity of arable land by 30-40%. Deficiencies in projects, construction, and exploitation of irrigating systems led to the fact that, out of 5 million hectares of irrigated lands in Russia, 739 thousand hectares (or 15%) are in an unsatisfactory state. The present sowing area over these regions amounts to 1.028 million hectares which is 5.3 million hectares less than at the time of maximum cultivation (1990).

Table 3.4.1. Land Use Characteristics for Russia, Belarus, and Ukraine (IBRD 2002)

Indicator \ Country	Russia	Belarus	Ukraine
Land Area (10^6 ha)	1690	20.7	57.9
	Land Use (%)		
Arable Land	7	30	57
Permanent Pasture	5	14	13
Other Agricultural	0.1	0.6	1.7
Forest and Woodland	45	35	16
Other	42	20	12
Irrigated Cropland (%)	3.9	1.8	7.2
Fertilizer Use (kg/ha)	13	119	27
Agricultural % of GDP	7	13	14

Research work is needed to improve the description and quantification of the impacts of climate variability and change on agricultural and forestry productivity, as well as to describe how management and land use changes feed back on the regional climate and carbon cycle, and, in turn, how feedbacks with social, economic, political and governmental policies affect practices, management, and land use changes.

It is necessary to improve current biophysical descriptions of agricultural and managed forestry systems within existing ecosystem models, focusing on plant growth and yield as a function not only of climate, but also as a function of genetic and management factors such as crop and cultivar characteristics, irrigation and fertilization schedules, rotation types, soil management, as well as influences of policies and social factors.

There is need to close the gap among site-level crop modeling studies, land use dynamic, and terrestrial carbon modeling, including critical linkages with climate modeling. *Strong interdisciplinary collaborations should be developed among researchers with expertise covering crop, ecosystem modeling and carbon cycle, as well as climate change impacts land and water resources, adaptation and management strategies, social and economic forcing, and vegetation-climate interactions within regional and general circulation models*. Such expertise should include ground-truthing of data, models, and scenarios using field, statistical, and satellite data. Integration of research and education at the local to international level needs to be an essential component of this effort.

Pronounced observed and projected patterns of warming in the Eurasian region over the coming decades may be associated with high impacts on ecosystems, land use and management, greatly affecting carbon cycle dynamics and the sustainability of societies. *Therefore, a general modeling framework linking crop, land use and ecosystem models, socio-economic factors, and climate, to investigate key research questions within the areas of intensive agriculture development of Northern Eurasia is a must.*

Arid and semiarid zones

Arid semi-arid and dry sub-humid regions occupy a considerable part of the CIS countries (Table 3.4.2) China and Mongolia. The area of dry arid regions with a ratio of

Russia impacted by water erosion equal an area of 300,000 km^2 and lands damaged by wind erosion equal 79,000 km^2. The area of eroded lands grows by 4-5 thousand km^2 each year and lands impacted by secondary salinization of irrigated lands grows by about 7.7 thousand square km a year.

precipitation to potential evapotranspiration of less than 0.65 amounts here to over 4.6 million km (Glazovsky and Orlovsky, 1966; Glazovsky 1997). Over 70 million people live in this territory within the CIS and more than 100 millions in Northernmost China and Mongolia. In semi-deserts and deserts, only 15-20% of the pastures are in satisfactory condition, 30-40% are moderately worn out pastures, 30-40% are strongly worn out, and 15-20% are withdrawn from agricultural use and transformed into worn out sands and bad lands. Within the limits of sand pastures, the area of open and mobile sands increased from 5-10% to 20-30%. In these semiarid and arid regions of Eurasia, drought and desertification affected areas are widespread. The increase in drought and desertification has caused an important new source and mechanism for potential health problems as well as ecosystem impacts – the transport of airborne desert soil dust (often in large amounts) that is lifted and carried by the winds over significant distances. Dust and dust storms from the arid areas have been increasing due to drought, agricultural and other land activities, and population growth. Recent studies have shown that dust in the atmosphere may present a serious set of health issues. Dust events can cause significant impacts from the dust itself, as well as accompanying contaminants, salt, and other inorganic and organic materials, including pathogenic microorganisms (Maynard 2004; 3.6.3). The damage to humans and ecosystems from desertification and dust storms is exemplified by the Aral Sea story, a combination of human and natural forces working together to create a dramatic ecological disaster.

Table 3.4.2. Area of dry and arid regions, thousand square km (with the ratio of precipitation to evapotranspiration less than 0.65)

COUNTRY	AREA	COUNTRY	AREA
Azerbaijan	40	Russia	610
Armenia	12	Tajikistan	95
Georgia	6	Turkmenistan	488
Kazakhstan	2627	Uzbekistan	440
Kyrgyzstan	145	Ukraine	136
Moldova	13		

Studies are needed to assess the present state of impact of human activity on ecosystems and human societies in arid and semi-arid regions and projected future trends given current social, economic, climatic and developmental projections. Studies are needed on the relationships between human activities, ecosystem changes, climate changes, and the initiation of the large dust storms in Northern Eurasia.

Studies are needed to determine lessons learned from past land use practices and ecosystem responses in arid and semi-arid regions and to develop more sustainable natural resource management practices.

Studies are needed to assess the impacts of extreme desertification and dust events on human and ecosystem health, including the effects of the dust and contaminants, salt, and microbes on downwind populations, livelihoods (e.g., agriculture), and ecosystems. Related studies are needed on possible ways to mitigate these effects and improve land management practices.

Urban and industrial development

Rapid urban growth and industrial development stemming from the promise of perceived improvement in economic opportunity and quality of life have resulted in often extreme concentrations of people accompanied by significant impacts on surrounding

ecosystems as well as adverse feedbacks to the urban dwellers themselves and populations nearby. Factors such as poor sanitation, congestion, lack of social and physical infrastructure, poverty, pollution of the air and water by municipal and industrial waste, and imprudent use of water combine to contribute to degradation of the environment and to health problems in local populations. Demands on the surrounding regions are large so the linkages between urban/industrialized areas, local ecosystems and humans are increasingly important. Human interactions with hydrological and biogeochemical cycles and geological processes are especially strong in urban areas. This may create serious problems[29].

Studies are needed on the effects of urban and industrial development on global and local land use and change patterns in Northern Eurasian regions, especially, as they reflect the changing policies, governance, and economic realities of the post-Soviet era. These studies must take into account the effects of climate and environmental changes.

Studies are needed to devise tools to detect the effects of human-related structural changes to land surface characteristics and ecosystem properties in urban and industrial areas in Northern Eurasia and the ramifications for human and ecosystem health.

Studies are needed to document lessons learned in current industrialized regions and urban areas and to devise more sustainable strategies for future development practices.

3.4.4. Natural and Anthropogenic Hazards

The Northern Eurasian region is subject to a complex mix of serious hazards from both natural environmental forces (including climate change) as well as anthropogenic causes. In the first place, the region is characterized by extreme weather-related events such as strong winter storms, high winds, low temperatures, floods, landslides, snow, sleet, ice and heavy rain storms, severe thunderstorms, avalanches, landslides, drought, massive dust storms, and coastal erosion, all of which may have enhanced effects from climate and environmental changes in the future. Climate change is already creating unprecedented changes in Northern Eurasia (3.3.4.2). In addition, there are a number of growing, serious anthropogenic influences making dramatic changes to the environment, such as pollution from persistent organic pollutants, heavy metals, radioactivity, munitions waste, hazardous materials dumping, and acidification as a result of mining, oil and gas development, building of infrastructure, road construction, and other forms of industrial development in the Northern Eurasian region – accompanied by infrastructure, additional pollution, congestion and other manifestations of human presence.

Studies are needed to more clearly define the frequency and intensity of extreme events and natural disasters in the different regions of Northern Eurasia as well as the vulnerabilities of the population to these events. In particular, the capability of the peoples to cope with natural as well as anthropogenic disasters should be studied and measures to enhance this capability should be suggested.

Studies are needed to define the additional effect anticipated that could result from climate changes in the region on the severity and nature of the extreme events and natural disasters (e.g., sea level rise, permafrost thaw, ice melt, thunderstorm activity) and their impacts on people of the region. This should include improved efforts to monitor and predict

[29] Examples of these problems are, in Russia, 725 cities (66% of the cities) are subjected to landslides, 301 (28%) to karst, 958 (88%) to suffusion, 563 (52%) to subsidence of loess rocks, 442 (40%) to soil erosion, 734 (67%) to surface and gully erosion, 50 (5%) to reworking of sea shores and water reservoirs, 960 (88%) to floods from beneath, 72 (7%) to cryogenic processes, 103 (9%) to earthquakes, and 746 (68%) to floods. The amount of waste from urbanization and industrial development, production, and consumption, including the toxic waste, is gradually growing. There are already 1.8 billion t. of toxic waste accumulated, their annual increment being 108 million t. Only 15% are rendered harmless. Of the burial sites of the most dangerous toxic waste, 70% do not meet sanitary requirements.

climate conditions and changes – and to feed back that information to people in the region for emergency preparedness.

3.4.5. Impacts on Ecosystem Services

Land use impacts in the region have affected ecosystem services. Ecosystem services, such as, water quality and quantity, air quality, and biodiversity have been greatly affected. The net result has been a lessening of the quality of life in the region with implications on declining human well-being and health in the region. The following sections discuss some of these concerns.

Impact on water quality and quantity

The use of natural waters is one of the most important problems in arid and sub-arid regions of northern Eurasia. The problem is aggravated by the fact that the geographic distribution of water resources is extremely irregular and all the largest river basins are located within the territories of several states. Water issues are also affected by the rapid increase of irrigation development and the water quality changes associated with drainage runoff from these irrigation projects. The Aral Sea as a Case Study for Water Issues is described in (2, 3.3; Box insert A2.1).

Studies are needed to analyze lessons learned from previous water management projects in Northern Eurasia and elsewhere and to find methodologies for integrating these lessons into future planning efforts on water management projects in the region.

Studies are needed to assess the proposed plans to transfer river waters from Siberian rivers to Central Asia, and to assess the impacts of those actions on the ecosystems and people of all effected regions.

Studies are needed to assess the magnitude and impacts of pollutants from both localized sources in specific regions (e.g., industrial development) as well as long-range transport of pollutants from distant sources on quality of water supplies in Northern Eurasia.

Studies are needed on the present and potential impacts of anthropogenic influences and climate change on the sources and pathways of key water supplies of Northern Eurasia which are a resource to major population centers. Studies are also needed on the implications of these changes in supply and quality of water to receiving populations as well as an analysis of possible mitigation measures.

Studies are needed to better understand the societal, governmental, and political/economic factors which cause adverse effects on water supplies.

Impact on air quality

Air pollution from both natural and anthropogenic causes is considered to be one of the most serious world-wide environmental-related health problems, and is expected to become worse with changes in the global climate ((Piver et al. 1999; McMichael et al. 2000; Patz et al. 2000). Populations in large urban settlements are expected to be exposed to increased air pollutants, where health effects could be exacerbated by increases in weather-induced heat waves (McCarthy et al. 2001). This is a particular concern because of the dramatic migration of populations from rural to urban centers and the associated rapid expansion of cities (Parris and Kates 2003). Contaminants, smoke, and pollutants from fires, stoves, motor vehicles, industrial development, and other sources can create significant problems for both city and rural settlement populations. Some of the pollutants of greatest concern are ozone, nitrogen dioxide, sulfur dioxide, acid aerosols, carbon monoxide, lead, and particles (Bernard, Samet et al. 2001). Recent studies have demonstrated an important new source for potential health impacts in airborne desert soil dust that is lifted and carried by the winds over significant distances. Although atmospheric transport of large amounts of dust has taken place throughout geologic time, dust amounts have been increasing in Asia since the 1950s (Kebin

et al. 2002; 3.6.3) due to drought, agricultural and other land activities, and population growth. In addition, air pollution from forest fires is a growing issue due to the increase in the occurrence of fires of both natural and human-caused origin (Korovin and Zukkert 2003). Of special concern are "dirty fires", in which radioactive or other toxic material burns, converting the smoke into an especially serious air pollution problem.

Studies are needed to determine the sources, fates, and effects of emissions of the different kinds of urban, mining, and industrial activities on human health and ecosystems, and their interactions with the water and land ecosystems. In particular, studies should be done to locate, map, and prioritize nuclear and toxic test sites, dumps, spills, and accident sites and then provide environmental, hydrological, and climatological expertise and information to help guide the clean up process.

Studies are needed to better understand the relationships between the social/political forces in Northern Eurasia and the pollution from cities and industrial development. This problem may be divided into three objectives: The inventory of air pollutants emission data over Northern Eurasia, that has a lot of gaps; Qualification of emission rates and total concentration in troposphere of the most important optically active gases (CO_2, NO_2, N_2O, O_3, etc); and finally studies should be conducted to determine mitigating actions might be taken to reduce pollution levels that are harmful for human health.

Studies are needed to better understand the causes (social, political, economic as well as natural), nature, and magnitude of the occurrence of fires including health impacts on populations. This should include the risks associated with "dirty fires" which involve radioactive and toxic materials.

3.4.6. NEESPI Contributions to Biodiversity Science in Northern Eurasia

In terms of practical actions to preserve biodiversity, reasonably anthropocentric approach was recommended (Zagorodniuk, 2000). It includes completion of red lists of endangering species, combined with urgent designing of quasi-natural ecosystems and protection of functionally steady aggregations of species rather than species as such. In scope of this and other approaches following priorities could be proposed:

- *Zoning of the protected territories the most threatened by global climate changes*
- *Management of transboundary protected areas and territories, development of the Northern Eurasian Protected Areas network*
- *Biodiversity and sustainable agriculture*
- *Enhance the application of IT (RS, GIS and Internet)*
- *Migratory species monitoring and conservation.*

The NEESPI expects to contribute to the updating the global biodiversity model (GLOBIO) as well as to the improving scenarios "2010" and "2100" related to biodiversity and support projects that seek to use modern technologies and modeling to better understand and quantify the relationship between biodiversity and land-cover/use change and climate change and their interactions in Northern Eurasia. There are a number of national and international groups (e.g., the Biodiversity Program within NASA, World Resources Institute, Conservation International, World Wildlife Fund, Greenpeace Russia, and other groups in United States, Northern Eurasia, and Europe) whose contribution to the NEESP initiative is highly desirable.

3.4.7. Consequences of land use change for society: Human Health and well-being

To evaluate the health and well-being of humans in the Russian Arctic, it is necessary to address the complex mix of factors which make up the human environment, including physical, chemical, biological, social, and cultural factors - all of which affect people's health and well-being (AMAP 2002). Currently, a significant number of people in the Arctic are

exposed to high level of environmental pollutants. Of particular concern, persistent contaminants, from both local and long distance sources, were found to magnify in animals that are used a traditional foods by the indigenous peoples, thus providing a direct pathway for pollutants to human (AMAP 2003). In general, indigenous peoples of the Russian Arctic reflect a poor health status relative to the general population of Russia as well as to other Arctic indigenous peoples, with life expectancies 10-20 years lower than the average Russian population.

In Northern Eurasian cities, atmospheric pollution is an important health factor, especially in the Siberian and Ural regions. In many cities where the level of pollution is extremely high, it is reflected in high levels of morbidity and mortality. The most recent information about air pollution in Russia was presented in the national report, published by Izrael et al. (2002). Materials of this report list the most polluted Russian cities where short-term (20 min averaged) concentrations of one of the pollutants, monitored in 2001, were higher than the tenfold value of the corresponding Maximum Permissible Concentration (the Russian National Ambient Air Quality Standard) at least once. The values of MPC (usually both, short- and long-term) are established in Russia for more than 2000 species. In 2002, the list of the most polluted Russian cities based on this API sorting included 31 cities with a total population of over 15 million. The impact of high levels of pollution on human health is detrimental, in particular, proven correlation with cancer in polluted regions was documented (cf., Box Insert A3.4.3 in Scientific Background Appendix).

Atmospheric, water, and soil pollution are important health factor in several rural regions in Northern Eurasia. First of all, these are the regions windward and downstream of major industrial areas and regions of ecological and technogenic catastrophes (e.g., areas around Chernobyl, Chelyabinsk, Semipalatinsk, and Aral Sea).

Studies are needed to better understand the links between environment, weather, climate and health problems in Northern Eurasia including factors such as urban, regional, and global air and water pollution; contaminant transport and deposition – through oceans, atmosphere, and ice; UV radiation, water-borne-diseases, thermal stress; and infectious and vector-borne diseases.

Studies are needed to identify relative vulnerabilities of different populations (urban, rural, close proximity to mining and industrial operations) to health impacts from environmental, weather, pollution, and climate factors, and to identify mitigation actions to reduce risk.

Studies are needed to define the governance, social, economic, and policy drivers which have created the sources and pathways of pollutants which are affecting human health, and to find methodologies for feedback of this information to policy-makers and decision-makers for improved policies and actions for the future.

Studies are needed to better define the health impacts of POPs, heavy metals, radioactivity, and acidification on Northern Eurasian peoples, the variations within different settlement types (urban, rural), and possible mitigation actions.

3.4.8. Major Science Questions are grouped in four categories according to *Human Dimensions Imperatives* (cf., Box insert 3.4.1, NRC 1998).

Understand the major human causes of changes in the global environment and how they vary over time, across space and between economic sectors and social groups.

- What is impact of land use structure changes on biogeochemical cycles?
- What is the state of impact of human activity on ecosystems and human societies in arid and semi-arid regions and projected future trends given current social, economic, climatic and developmental projections? What are the relationships between human activities,

ecosystem changes, climate changes, and the initiation of the large dust storms in Northern Eurasia.

- What are the effects of urban and industrial development on global and local land use and change patterns in Northern Eurasian regions, especially, as they reflect the changing policies, governance, and economic realities of the post-Soviet era?
- What are the present and potential impacts of anthropogenic influences on the sources and pathways of key water supplies of Northern Eurasia which are a resource to major population centers? Studies are also needed on the implications of these changes in supply and quality of water to receiving populations as well as an analysis of possible mitigation measures. How can we better understand the societal, governmental, and political/economic factors which cause adverse effects on water supplies?
- What are the vulnerabilities of agricultural, grasslands, and managed forest ecosystems to expected climate and socio-economical trends?
- What is the role of aerosol and gas air pollutants from the industrial centers in Northern Eurasia to climate change processes? From the point of view of air pollution over Northern Eurasia, will the future climate be more favorable or not (increased occurrence of temperature inversion, low wind speed, etc)?

Determine the human consequences of global environmental change on key life support systems, such as water, health, energy, natural ecosystems, and agriculture, and determine the impacts on economic and social systems.

- How will population numbers and density in various regions of Eurasia affect the land use?
- How do human modifications of land cover affect regional Northern Eurasian and global ecosystem functions and ecosystems feedbacks?
- What are the effects of the land uses and land-use changes during the planned economy on Earth system functions (e.g., regional climatology, water resources, carbon and surface energy balance, biogeochemistry, biodiversity)?
- What are the impacts of extreme desertification and dust events on human and ecosystem health, including the effects of the dust and contaminants, salt, and microbes on downwind populations, livelihoods (e.g., agriculture), and ecosystems.
- How do we identify relative vulnerabilities of different populations (urban, rural, close proximity to mining and industrial operations) to health impacts from environmental, weather, pollution, and climate factors and how do we identify mitigation actions to reduce risk?
- How can we better define the health impacts of POPs, heavy metals, radioactivity, and acidification on Northern Eurasian peoples, the variations within different settlement types (urban, rural), and possible mitigation actions (especially, indigenous people)?

Develop a scientific foundation for evaluating the potential human responses to global change, their effectiveness and cost, and the basis for deciding among the range of options.

- What lessons can be learned from past land use practices and system responses of dramatic land-use modifications for sustainable natural resource management?
- What are the lessons learned in current industrialized and urban regions to devise more sustainable strategies for future development practices?
- What are the lessons learned from previous water management practices which could help define improved methodologies for sustainable water management in Northern Eurasia?

Understand the underlying social processes or driving forces behind the human relationship to the global environment, such as human attitudes and behavior, population dynamics, and institutions and economic and technological transformations.

- How will global economic processes affect the land use in Northern Eurasia?
- What are the relationships between climate changes and social, economic, and political drivers of land use change?
- What is the nature and extent of the impacts of the varied and different governmental policies, politics, markets, and changes in governance on nomadic pastoral and sedentary systems, livestock management, grazing patterns, cropping systems, large-scale conversion of natural lands to crop lands. How can the vulnerability of target populations against these forces be reduced? How will climate variability and change affect these systems and interactions?
- What are the best means of quantifying the impacts of climate variability and change on agricultural and forestry productivity, as well as the description of how management and land use changes feed back on the regional climate and carbon cycle, and, in turn, how feedbacks with social, economic, political and governmental policies affect practices, management, and land use change?
- How can we better define the governance, social, economic, and policy drivers which have created the sources and pathways of pollutants which are affecting human health, and to find methodologies for feedback of this information to policy-makers and decision-makers for improved policies and actions for the future?

A separate question is: *What were the initial pre-industrial conditions in Northern Eurasian ecosystems in the past?* If we know the answer on this question, we can try separating (at some extent) natural trends from human induced trends.

In summary, the vast regions of Northern Eurasia – and the broad range of lands, ecosystems and peoples that characterize them - have undergone major fundamental changes resulting from the unprecedented and dramatic transformations of the social, economic, political and technological systems in the countries of the region. There are many questions regarding the complexities of the social-ecosystem linkages and their impacts on land and resource use and management, and, ultimately, the consequences for basic sustainability of the regions. This chapter has provided a brief summary of the state of knowledge of the understanding of the linkages and changes in the coupled human and environmental systems associated with land sustainability in the region as well as a list of research gaps that should be resolved to fully address the following NEESPI questions, which are of special relevant to the Societal-Ecosystem Linkages of Land Use Interactions:

- *What has been the role of anthropogenic impacts on producing the current status of the ecosystem, both through local land use/land cover modifications and through global gas and aerosol inputs? What are the hemispheric scale interactions, and what are the regional and local effects?*
- *How will future human actions affect the Northern Eurasia and global ecosystems? For example, for different scenarios of future greenhouse gas and aerosol inputs, and for different forest clearing, water and agricultural land management, urban, industrial, and oil development projects, how will the ecosystem be changed? And how will changes in these ecosystems feed back to society? How can we describe these processes using a suite of local, regional, and global models?*
- *What will be the consequences of global changes for regional environment, the economy, and the quality of life in Northern Eurasia? And how can science contribute to decision making on environmental issues in the region?*

And to answer the overarching NEESPI science question:

How do we develop our predictive capability of terrestrial ecosystems dynamics over Northern Eurasia for the 21st century to support global projections as well as informed decision making and numerous practical applications in the region?