Public Disclosure Authorized

MONGOLIA

The Economic Value of the Upper Tuul Ecosystem

December 2009

THE WORLD BANK

This study was prepared by the Social, Environment and Rural Development Unit (EASER) of the East Asia and Pacific Region, and was funded by the World Bank's Netherlands-Mongolia Trust Fund for Environmental Reform.

Social, environment and rural development issues are an integral part of the development challenge in the East Asia and Pacific (EAP) Region. The World Bank's Sustainable Development Strategy for the region provides the conceptual framework for setting priorities, strengthening the policy and institutional frameworks for sustainable development, and addressing key environmental, social and rural development challenges through projects, programs, policy dialogue, non-lending services, and partnerships. The EASER Discussion Paper series provides a forum for discussion on good practices and policy issues within the development community and with client countries.

The publication and primary data are available online at www.worldbank.org/mn and www.worldbank.org/nemo.

Suggested citation:
Emerton, L., N. Erdenesaikhan, B. De Veen, D. Tsogoo, L. Janchivdorj, P. Suvd, B. Enkhtsetseg, G. Gandolgor, Ch. Dorisuren, D. Sainbayar, and A. Enkhbaatar. 2009. *The Economic Value of the Upper Tuul Ecosystem.* Mongolia Discussion Papers, East Asia and Pacific Sustainable Development Department. Washington, D.C.: World Bank.

Contact details for authors:
Lucy Emerton, Environment Management Group, Colombo, Sri Lanka, lucy@environment-group.org
Erdenesaikhan Naidansuren, Environ LLC, Ulaanbaatar, Mongolia, erdene@environ.mn, www.environ.mn
Bastiaan de Veen c/o Acacia Water, Gouda, The Netherlands, info@acaciawater.com, www.acaciawater.com
Dr. Tsogoo Damdin, Maral Ganga NGO, Ulaanbaatar, Mongolia, tsogoo_damdin@yahoo.com,
Dr. Janchivdorj L., Geoecology Institute, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia, janchivdorj_mn@yahoo.com
Suvd Purevjav, Ulaanbaatar, Mongolia, suvd@gtz-mongolia.org
Dr. Enkhtsetseg Bat-Ochir, Ulaanbaatar, Mongolia, batochir@gmx.de
Gandolgor Gavaa, Sustainable Tourism Development Center, Ulaanbaatar, Mongolia, ganna_gavaa@yahoo.com
Dr. Dorjsuren Chimednyam, Institute of Botany, Academy of Sciences, Ulaanbaatar, Mongolia, chdorj@yohoo.com
Sainbayar Damdinsuren, Ulaanbaatar, Mongolia, oin_ireedui@yahoo.com
Enkhbaatar Altangerel, Geoecology Institute, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia, Enkh_a@yahoo.com

---

Table of Contents

Maps

Figures

Tables

Foreword

The calculation of ecosystem values has been influential in decisions on the management of natural resources around the world. It is a well-established approach which is used to inform a wide variety of development initiatives. It has not however, until now, been undertaken in Mongolia.

The genesis of this innovative piece of work was the high-level environment meeting between the Government of Mongolia and its Donor Partners held in October 2006. This meeting discussed the great values of Mongolia's ecosystems and natural resources, and the Deputy Minister of Finance told the meeting that no valuation was available to help assess the appropriate investment needs for resource protection and management in Mongolia.

The NEMO2* team took the above statement as a challenge. Despite limited availability and quality of data, an attempt was launched to do such an economic valuation. The resulting report now shows that this was the right decision. The work focused on the Upper Tuul valley, arguably the most important ecosystem in the country because it serves as the source of all of Ulaanbaatar's water and as a major domestic and international tourism center. With a combination of household interviews, local government data, primary data collection, computer modeling, and good GIS analysis, a conservative yet considerable estimate of the value of the Upper Tuul ecosystem has resulted. Since the study area is immediately adjacent to Ulaanbaatar and its highest-value resource—water—is something which more than 1 million people use every day, the results and recommendations need the close attention of the national and municipal governments, NGOs, academics and the citizens of Ulaanbaatar.

In an effort to translate the report's findings into action, we intend to support the full dissemination not only of the Mongolian and English versions of the report, but also of the primary data which will be made available through the websites of the World Bank Mongolia office (*www.worldbank.org.mn*) and NEMO (*www.worldbank.org/nemo*). We hope this report will generate a renewed focus and enthusiasm for the active management and protection of the Upper Tuul Valley.

Ede Ijjasz-Vasquez
Sector Manager for Sustainable Development
The World Bank, Beijing

Arshad Sayed
Mongolia Resident Representative &
Country Manager
The World Bank, Ulaanbaatar

* The second phase of the Netherlands-Mongolia Trust Fund for Environmental Reform jointly executed by the Ministry of Nature, Environment and Tourism and the World Bank.

Acronyms and Abbreviations

FUT	Flows under threshold
GEF	Global Environment Facility
GIS	Geographic Information System
ha	Hectare
hh	Household
IDA	International Development Association
MFALI	Ministry of Food, Agriculture and Light Industry
NEMO	Netherlands-Mongolia Trust Fund for Environmental Reform
NPV	Net present value
NTFP	Non-timber forest products
OSNAAG	Housing and Public Services Company
POT	Peaks over threshold
PV	Present value
SEU	Sheep equivalent unit (goat = 0.9 SEU, cow = 6 SEU, camel = 5 SEU, horse = 7 SEU)
Tug	Mongolian Tugrig (US$1 = Tug 1,500 used in study)
USAG	Ulaanbaatar Water Supply and Sewerage Company

Acknowledgments

Enormous thanks are due to the entire team for their diligence and for their innovative approaches to the questions and problems encountered.

The study benefited from the assistance of many people. Thanks are due to Mark Johnstaad who supported the tourism team, Albert Tuinhof who supported the eco-hydrology team, and Stefano Pagiola and Glenn-Marie Lange of the World Bank who served as peer reviewers. Within the Ministry of Nature, Environment and Tourism acknowledgment is made of the close interest and encouragement of the Vice Minister and NEMO2 National Project Director, D. Idevkhten, and the help throughout from the NEMO2 Coordinator for World Bank-executed projects, B. Enkhtsetseg. Many government departments generously provided data, comments and other expert advice to the study.

The work was managed by Tony Whitten, Environment Sector Coordinator (Mongolia), of the Social, Environment and Rural Development Unit of the East Asia and Pacific Region assisted throughout by Judith Schleicher of the same Unit and Erdene-Ochir Badarch, Environment and Rural Development Officer in our Ulaanbaatar office.

Executive Summary

The Economic Value of the Upper Tuul Ecosystem in Mongolia reports on a study carried out under the auspices of the World Bank and the Government of Mongolia. The goal of the study was to improve understanding about the economic value of the Upper Tuul ecosystem for Ulaanbaatar's water supplies and how this might be affected by different land and resource management options in the future.

The study also aims to develop and apply ecosystem valuation methods that can be used more widely in the country, to generate information about the contribution of the environment to the Mongolian economy, and to make the case for improved budget allocations for the conservation of the Upper Tuul.

Integrating eco-hydrological and economic valuation techniques, the study traces through the biophysical effects and socioeconomic impacts of future land and resource degradation, and ecosystem conservation, in the upper watershed.

Water security is key to Ulaanbaatar's economic future

More than one million people, 20,000 industries and businesses, 400 hectares of irrigated farms,

Results overview. The study found that the land and resources of the Upper Tuul currently contribute income and marketed products worth around Tug 28 billion per year in tourism, herding, and forest-based sectors. Meanwhile, the value of water use in Ulaanbaatar is estimated to be worth Tug 90 billion a year at the minimum.

Conservation of the two protected areas that cover most of the upper watershed of the Tuul River, Gorhki-Terelj National Park and Khan Khentii Strictly Protected Area, has a high economic value because it helps to safeguard downstream water supplies to Ulaanbaatar. Overall, improved, conservation of the Upper Tuul ecosystem is estimated by the study to be worth some Tug 1,370 billion in present value terms, through the provision of water, tourism, herding, and forest products.

In contrast, continuing ecosystem degradation and biodiversity loss will prove extremely costly in terms of water and other services lost. Even taking into account the costs of the additional protected area budgets and the losses in value that would be required to bring land and resource uses to ecologically sustainable levels, conservation would give rise to substantial economic gains over a situation where the ecosystem is further degraded. The study shows that if the Upper Tuul ecosystem continues to be degraded, the loss of water, pasture and forest products will cost the Mongolian economy a total of Tug 400 billion over the next 25 years.

Conservation is estimated to generate an additional Tug 76 billion net present value over 25 years as compared to continuing gradual degradation of the watershed, and Tug 125 billion over and above a situation of no protection. As compared to the current situation, the study findings suggest that every Tug 1 invested in the conservation of the Upper Tuul ecosystem has the potential to generate an additional Tug 15 in water, land, and resource use benefits over the next 25 years. By the end of the period modelled, conservation will be generating ecosystem services worth Tug 55 billion a year more than would be the case than if the Upper Tuul was not protected. This figure will keep on rising, as land and resource uses and water availability are sustained (rather than degraded) into the future.

330,000 livestock, and 3 power plants in Ulaanbaatar depend on water supplied from the Upper Tuul. Annual demand for water is in excess of 77 million cubic meters, most of which is supplied by the Ulaanbaatar Water Supply and Sewerage Company. The total value of water use is estimated at almost Tug 90 billion a year. Around two-thirds of this value accrues to domestic consumers.

Groundwater tables in Ulaanbaatar have been showing a marked decline over the last 50 years. Water is being abstracted faster than the rate of recharge. As the city grows, and water demand increases, this problem is intensifying. According to government figures, water use is estimated at 212,000 cubic meters per day and is predicted to reach 286,000 cubic meters in 2010, 438,000 cubic meters in 2020, and 708,000 cubic meters by 2050.

Yet existing wells, even at full capacity, are designed to supply only around 300,000 cubic meters per day. Demand for water is beginning to outstrip the supply of existing wells. Seasonal water shortages are growing ever more common, and various studies warn that sometime within the next 10 years the city will be facing a critical shortfall in water availability.

In response, measures are being set in place to manage water demand, improve water use efficiency, and deal with problems of leakage in the system. On the supply side, the options that are being considered include plans to tap into new groundwater supplies, develop surface water storage reservoirs, increase wastewater treatment and re-use, and apply artificial borehole recharge techniques.

Downstream water availability is linked to the status of the upper catchment ecosystem

The planned actions to improve Ulaanbaatar's water supplies also emphasize the importance of protecting the city's watershed, and developing integrated water resource management in the Tuul River Basin. Watershed conservation alone is going to neither ensure future water security nor abrogate the need to develop additional water supplies. The sustainable management of the Upper Tuul is however an essential (and economic) part of any water sector investment plan, whether it is based on groundwater or surface water or both.

The Tuul River and its main tributary, the Terelj, as well as around 40 other smaller rivers, streams, and lakes are fed by rainfall, snowmelt, and groundwater and drain the southern slopes of the Baga Khentii to the northeast of Ulaanbaatar. The Upper Tuul Basin, where these rivers rise, covers a total area of just over 5,000 square kilometers.

Ulaanbaatar's current and future water supply options depend wholly on the Tuul River. To date the city has been supplied via deep wells that draw on groundwater sourced from an unconfined aquifer that runs along the bed of the river. Future possibilities for augmenting these supplies depend either on tapping the surface water of the river or on exploiting additional alluvial-proluvial deposits from the Tuul's tributaries.

Ecological conditions in the upper watershed have a direct link to the availability of surface water and groundwater downstream. Natural vegetation is particularly critical since it influences interception, runoff, and discharge over the course of the year. The extent and quality of forests, grasslands, and soils affect the Tuul River's mean flow and flow duration, influence the timing and intensity of peak and low flows, and determine the extent and rate of groundwater recharge. They also impact on the silt and sediment loads that are carried downstream.

Most basically, a healthy upstream ecosystem helps to ensure clean, regular, and adequate river flow and groundwater resources for Ulaanbaatar.

Lands and resources in the Upper Tuul are subject to intense and growing pressures

More than three-quarters of the Upper Tuul Basin have been officially designated as two conservation areas: Khan Khentii Strictly Protected Area and Gorkhi-Terelj National Park. Although, at least in principle, a variety of environmental regulations and land and resource use restrictions govern the protected areas and the upper basin, in reality humans heavily utilize large parts of the area. Around 2,600 people and 50,000 livestock live permanently in the Upper Tuul, and each year more than 130,000 domestic and foreign tourists visit its 180 camps and hotels. The dependence and impact by all on the natural ecosystem is heavy. Every year, almost one million tourist bednights are spent in the Upper Tuul; around 170,000 hectares of land are used for grazing; just under 8,500 cubic meters of firewood and 3,300 cubic meters of timber are felled; and almost 20,000 kilograms of fruits, berries, wild vegetables, pine nuts, and medicinal plants are harvested.

Unsurprisingly, the value of these land and resource uses is immense: it is estimated to generate gross income in excess of Tug 28 billion per year. The bulk of this value, 80 percent or more, accrues to the companies and entrepreneurs who operate tourist establishments or who are engaged in the timber and non-timber forest products (NTFP) trade. The Upper Tuul land and resources generate income and subsistence products worth about Tug 4 billion per year for local communities, and contribute around Tug 500 million in revenues to the Erdene Soum and Nalaikh District Administration, and to the protected area authorities.

Human influence is extending into the Upper Tuul, transforming the landscape and exerting severe pressure on the natural ecosystem—and thus on the water services it provides. As each wave of land use change expands into the upper watershed, it is opening up the area (and displacing prior land uses) for further changes. Permanent housing and dense areas of settlement are spreading toward the southern buffers of the Gorkhi-Terelj National Park from the direction of Gachuurt, Ulaanbaatar, and Nalaikh. This in turn is pushing tourist development further and further toward the north of Gorkhi-Terelj National Park and into southern parts of Khan Khentii Strictly Protected Area. Herders, losing their permanent pastures to settlements and tourist developments, are increasingly moving northwards along the Tuul and Terelj Rivers into Khan Khentii Strictly Protected Area. The spread of humans into the upper watershed is being accompanied by ever-greater exploitation of timber and non-timber products as previously unused areas become more accessible and resource demands grow.

There are substantial economic values to be gained from conserving the Upper Tuul for downstream water supplies

The study modeled the hydrological effects of ecosystem change. Three scenarios were projected for the next 25 years: (a) gradual ecosystem deterioration (a continuation of the status quo), (b) rapid resource depletion and land degradation, and (c) conservation and sustainable use. These scenarios were based on different rates and trajectories in the expansion of human influence into the Upper Tuul.

Results show that, as the Upper Tuul ecosystem is degraded and land cover is lost, average runoff will increase and the river's mean annual maximum and low flows will be intensified. Diminished discharge will lead to a further lowering of the groundwater table. Daily water losses would be registered in Ulaanbaatar over time. In contrast, under a scenario of conservation and sustainable use, there would be no appreciable distortion of the Tuul River's base flow, and groundwater levels would not be affected significantly.

Weighing up the gains (sustained water values in Ulaanbaatar) and losses (reductions in the value of land and resource use in the upper watershed, and increased investments in protected area management in the upper watershed) implied by conserving and sustainably using the Upper Tuul shows that this is the most economically beneficial of the three future management scenarios.

The conservation and sustainable use scenario is estimated to yield a present value (PV) of Tug

1,370 billion over 25 years. This is appreciably higher than the present values generated under either a continuation of the status quo (Tug 1,293 billion) or a scenario of rapid ecosystem degradation (Tug 1,243 billion). Looking at the additional water values generated, the study findings suggest that every Tug 1 invested in conserving the Upper Tuul ecosystem would generate economic benefits of more than Tug 15.

Clearly, ecosystem conservation generates the greatest economic gains for the Upper Tuul Basin as a whole—the value of water benefits generated outweighs the costs of any reduction in land and resource uses or additional management expenditures that are required to maintain the ecosystem in a healthy state.

Financing watershed conservation remains a key challenge to be addressed

While the study underlines the substantial economic values that the Upper Tuul ecosystem generates for downstream water supplies and provides a strong economic rationale for its conservation and sustainable use, this is not the end of the story. There are costs to conservation, and these must be covered.

One element of these conservation costs is the additional direct expenditures that government must make on running Khan Khentii Strictly Protected Area and Gorkhi-Terelj National Park. These have a present value of just under Tug 1 billion and Tug 3 billion, respectively, as compared to the scenarios of continuation of the status quo and no protection.

Another element is the opportunity costs that local land and resource users must bear through limiting their activities to ecologically sustainable levels. The study shows that there is a gap in land and resource use values of an estimated Tug 4.5 billion present value between the scenarios of conservation and a continuation of the status quo, and a difference of almost Tug 9 billion as compared to a scenario of no protection.

Although it is clearly in the broader public interest to conserve the Upper Tuul ecosystem and to the benefit of water users in Ulaanbaatar, it is not in the immediate financial interest of the people who use its land and resources. It is neither realistic nor equitable to expect people in the upper watershed to subsidize the provision of water benefits for the inhabitants of Ulaanbaatar.

A key challenge emerges: to generate funds to ensure adequate public investment in ecosystem conservation and protected area management and to set in place sufficient financial incentives to persuade land and resource users in the Upper Tuul to limit their land and resource uses to sustainable levels.

Summary of management recommendations and key messages

Recognize the strong economic rationale to investing in the Upper Tuul ecosystem as a productive and cost-effective part of Ulaanbaatar's water infrastructure.

Alongside measures to construct and operate the physical infrastructure that is required to manage water demand and supplement water supply in Ulaanbaatar, the study makes it clear that there is an urgent need—and a strong economic justification—to invest in conserving and maintaining the "natural" water infrastructure that is the Upper Tuul ecosystem. To not do so would be extremely shortsighted and may ultimately undermine the urban water security goals that so much time, effort and funding are currently being given to achieving.

Pay attention to increasing awareness and understanding of ecosystem values among planners and decision-makers in both conservation and development sectors.

Ecosystem conservation is persistently accorded a lower priority in policies, planning, and budgets as compared to other sectors that are perceived to be more valuable in economic terms or to yield more immediate development benefits. This study presents important information to show that ecosystem conservation is not just a biological or ecological concern but also yields high economic and development returns. There is a need to ensure that this information and a broader understanding of ecosystem values is shared with and understood by the planners and policymakers who control budgets and make decisions about future land and resource use, water infrastructure, and urban development in the Upper Tuul Basin.

Ensure sufficient public budget allocations to enable effective protected area management in the upper watershed.

Khan Khentii Strictly Protected Area and Gorkhi-Terelj National Park receive budget allocations that are far too low to enable even basic conservation and management activities and are disproportionately small when compared with the benefits that they generate. There is a need to carry out a realistic budgeting and financial planning exercise for these two protected areas, which should form the basis of future budget allocations to upper watershed conservation.

Identify and implement measures to cover the local opportunity costs of conservation, and provide financial incentives for sustainable land and resource use in the Upper Tuul.

At least over the short term, most land and resource users in the Upper Tuul can generate more income from continuing their activities as is, even if they are unsustainable in ecological terms. Action is required to address the economic causes of ecosystem degradation in the Upper Tuul and to balance the opportunity costs of conservation, alongside measures to enforce more strictly the penalties and restrictions against illegal activities. There is a need to ensure sufficient financial incentives for land and resource users in the Upper Tuul to carry out their activities in an ecologically sustainable manner.

Identify, scope, and pilot new and additional ways of generating funding that make a direct link between water services in Ulaanbaatar and ecosystem conservation in the Upper Tuul.

The additional funding to cover the direct and opportunity costs of conserving the Upper Tuul will no doubt be substantial although the economic benefits are also immense. There is a need to investigate extra-budgetary mechanisms for raising funds. The high value of water benefits generated—and the fact that water use in Ulaanbaatar is already priced, paid for, and generates revenues—provides opportunities for capturing these values. A variety of methods have been used successfully in other parts of the world. These methods are based on some form of payment being made by water users to the groups who manage natural ecosystems. There is undoubtedly potential to raise significant and substantial funding for upper watershed conservation by transferring a portion of water revenues earned, or other water-related charges and levies, to the conservation of the Upper Tuul, as a compensation or reward for the economic services generated.

Introduction: About the Study

What the study aims to achieve

The Economic Value of the Upper Tuul Ecosystem in Mongolia investigates the economic consequences of different watershed management scenarios in terms of their impacts on the provision of ecosystem water services.

The study's primary objective is:

- Improve understanding of the economic value of the Upper Tuul ecosystem for Ulaanbaatar's water supplies and how different land and resource management scenarios might affect these values.

The study also aims to achieve the following:

- Develop and apply a practical and policy-relevant methodology for the economic valuation of ecosystems for Mongolia, which could be replicated in other watersheds of the country;
- Generate information on the contribution of the environment to the Mongolian economy; and
- Make the case for improved budget allocations and other support for the conservation of the Upper Tuul ecosystem, in recognition of the economically important services it provides.

Why the study took place

The Government of Mongolia and the World Bank initiated the study to better understand the ways in which the natural environment contributes to the economy. At the November 2006 Technical Meeting of the Government of Mongolia and its External Partners, the Ministry of Finance highlighted the need to articulate the broader economic values of natural resources, especially forests, for their watershed and recreation value and how these might be affected by alternative land and resource uses.

During 2007 the Government of Mongolia and the World Bank cooperated on an environmental section of the Public Expenditure Review, and the Bank's Country Economic Memorandum includes innovative work on the natural "wealth" of Mongolia. Together these documents reveal a disparity between the contributions of the environment and natural resources to the economy and budget allocations for their management. Clearly, there is both a need and an interest in finding ways to better incorporate environmental values into economic and financial planning and to reflect the economic importance of the environment in public investment.

The Upper Tuul ecosystem was chosen as a study topic for several reasons. The current and growing water shortages facing Ulaanbaatar are an urgent priority in public investment and decision-making, and a matter of great concern to most sectors of the population. In addition, the World Bank has long been involved in efforts to improve water supplies and sanitation in Ulaanbaatar, most notably through the First and Second Ulaanbaatar Services Improvement Projects. At the same time, the Government of Mongolia has requested the World Bank to prepare an IDA- and GEF-financed project on Forest Landscape Development and Conservation. At least some of the focus of this project will be on the central forest block surrounding Ulaanbaatar, including parts of the Upper Tuul ecosystem.

The study responds to this interest. It also addresses the paucity of information on environmental values in Mongolia and the lack of tried-and-tested methodologies for calculating them. A key aim of the study (as stated above) is therefore not only to generate information about the economic value of the Upper Tuul ecosystem but also to develop and pilot environmental valuation techniques that are appropriate to the specific needs and conditions of Mongolia and could be applied more widely in other parts of the country.

What the study focuses on

The study calculates the economic value of the Upper Tuul ecosystem under different land and resource management scenarios. It models 3 possible future management scenarios for the Upper Tuul over the next 25 years: (a) gradual ecosystem deterioration (a continuation of the status quo), (b) rapid resource depletion and land degradation, and (c) conservation and sustainable use.

On the eco-hydrological side, the study ascertains how the resulting changes in watershed ecology and hydrological processes might impact on downstream water supplies to Ulaanbaatar. On the economic valuation side, it calculates the costs and benefits of these 3 management scenarios overall and for different groups of upper watershed land and resource users and downstream water users.

As illustrated in Figure 1, the study involves answering four questions:

- What are the current and future management scenarios for the Upper Tuul?
- What are the eco-hydrological linkages and impacts of changes in the Upper Tuul?
- What are the economic linkages and impacts of changes in the Upper Tuul?
- How do people in the upper watershed and in downstream areas use and benefit from the Upper Tuul ecosystem under different management scenarios?

The bottom line is to articulate the economic importance of the Upper Tuul ecosystem in terms of its contribution to water supplies in Ulaanbaatar and through the provision of other development benefits.

How the study was carried out

Between September 2008 and March 2009, a team of Mongolian experts carried out the study on natural resources management, hydrology, pasture and herding, tourism and hunting, timber and firewood, non-timber forest products, and GIS. Two international experts in environmental economics and eco-hydrology assisted them.

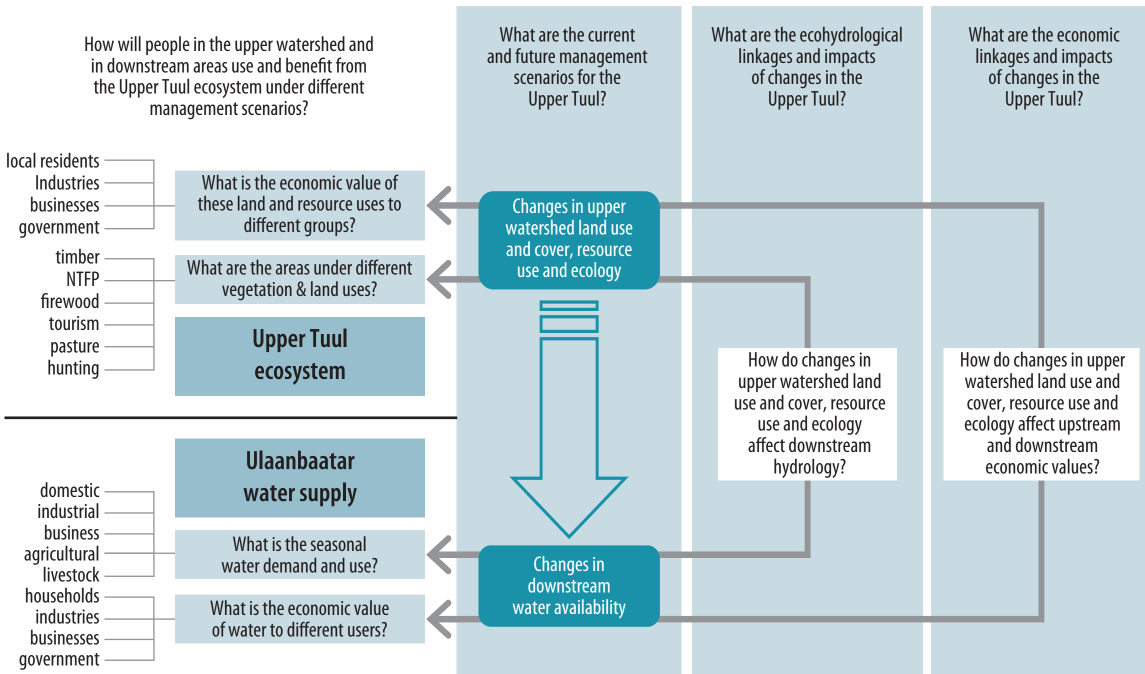
The study was carried out under the auspices of the Government of Mongolia/World Bank NEMO II project. The Netherlands-Mongolia Trust Fund for Environmental Reform (NEMO) was first established in April 2005, and a second phase was initiated in 2007 with funding from the Governments of Mongolia and the Netherlands and the World Bank. The overall expected outcome of NEMO II is strengthening of environmental governance and advancing the environment and natural resources agenda in Mongolia.

Data sources

The study draws on government economic indicators, water use statistics and hydrological/meteorological records, data from peer-reviewed publications and "grey literature", as well as information gathered through consultation with government officers and other experts. Data sources are cited throughout the study.

Primary data were collected from questionnaire-based and participatory field surveys carried out

Figure 1: Scope of the study



by the study team. These dealt with pasture and herding, tourism and hunting, timber and non-timber forest products, and fuelwood in the Upper Tuul ecosystem. They focused on the levels, types, and value of land and resource uses; on the people who are carrying them out; on their environmental sustainability; and on relevant laws and customary practices governing land and resource use. The GIS-based maps were rendered with information collected in the field, as well as from existing data sets for the Tuul Basin. A rapid survey was also carried out on water use in Ulaanbaatar.

Field surveys

The ***pasture and herding*** field study involved a review of published and unpublished literature and a collation of relevant government statistics and maps, as well as meetings with the local administration in the Upper Tuul Basin. Interviews with 27 herders, selected randomly, elicited information about livestock production, sales, prices, and markets, as well as a better understanding of the factors influencing land and resource use in the Upper Tuul. Measurements were made of pasture yields in order to draw conclusions on carrying capacity. Herding areas and pasture conditions were mapped.

The ***tourism and hunting*** field study involved a review of published and unpublished literature and a collation of relevant government statistics and maps, as well as meetings with the local administration in the Upper Tuul Basin. A list of all tourist operators was compiled, and basic data about the operations of 104 of these enterprises was collected. Interviews were held with selected operators to gather detailed information about tourist demand, facilities and activities offered, size and composition of the market, and prices charged. The locations of tourist camps of different types were mapped.

The ***non-timber forest products*** field study involved a review of published and unpublished literature and a collation of relevant government statistics and maps, as well as meetings with the local administration in the Upper Tuul Basin. Based on field observation and interviews with households, detailed information was gathered on species utilized, amount of products harvested, home consumption and sales, types of markets, and prices. The locations and conditions of harvested non-timber forest products were mapped.

The ***timber and fuelwood*** field study involved a review of published and unpublished literature and a collation of relevant government statistics and maps, as well as meetings with the local administration in the Upper Tuul Basin. Based on field observation and interviews with households, detailed information was collected on the levels and types of timber and fuelwood exploitation, species utilized, home consumption and sales, types of markets, and prices. The locations and conditions of different forest types and utilization areas were mapped.

The ***water user in Ulaanbaatar*** study involved a review of government statistics on current water use by different types of consumers, volume of water supplied, projected future demand, tariffs and revenues, and water sector projects. Individual interviews were held with water users to discuss demand, water problems, and responses. The interviews covered domestic, commercial, industrial, and institutional consumers.

Data analysis

The study integrates economic valuation and eco-hydrological analysis. In other words it looks at both the biophysical effects of changes in upper watershed management and their socioeconomic impacts. Key elements include:

- Future ecosystem management ***scenarios*** model the changes in land cover associated with different levels and combinations of human land and resource uses and settlement patterns over a 25-year period. These scenarios and the assumptions about changes in key parameters have been constructed based on actual changes and trends observed in the Upper Tuul Basin.
- The ***eco-hydrological methodology*** is based on a HBV model developed by the Swedish Meteorological and Hydrological Institute. It carries out 25-year daily discharge simulations of the Upper Tuul watershed using inputs of rainfall, temperature, and potential evaporation. Hydrograph analysis is used to assess the impact of land use change on surface and groundwater quantity over time.
- The ***ecosystem valuation methodology*** applies revealed preference, stated preference, and cost-based techniques to value ecosystem land and resource uses and downstream water use. The exercise calculates marginal or incremental values: in other words, it looks at the changes in economic value arising from different watershed management scenarios over and above the current situation. Values are modeled over a 25-year period and expressed as present values using a 10 percent discount rate (based on the Central Bank's prevailing discount rate).

Data constraints and limitations

The development of appropriate hydro-ecological and economic valuation methodologies for the Upper Tuul posed something of a challenge in conducting the study. There is no prior experience in carrying out ecosystem valuation in Mongolia, and both socioeconomic and biophysical data on the Upper Tuul are extremely patchy and often inconsistent between different sources. There was also limited time, funding, and other resources with which to carry out the valuation study.

These constraints, combined with the urgent need to generate practical and policy-relevant information for planning and management purposes, meant that it was necessary to strike a balance between (a) putting together rapid, integrated valuation techniques that were realistic and feasible to carry out in practice (and which would be able to be easily adapted and replicated elsewhere in Mongolia in the future), and (b) applying a methodology that could yield rigorous and credible information to withstand scrutiny and that could also point with some degree of certainty to conclusions and recommendations that would be of utility to planners and decisionmakers.

The resulting methodology should be technically coherent and yield credible information. But at the same time the results should be relatively straightforward and easily applied in situations where data, capacity, time, and funds are limited and where there is a need to generate rapid, practical information that can be used to inform real-world management decisions. Summaries of the eco-hydrological model used in the study and the assumptions used in economic valuation and scenario modeling are provided in the study's Annex.

The study ultimately represents a first attempt to develop and apply ecosystem valuation methods in Mongolia. **Of necessity the study makes many assumptions and simplifications that are often based on incomplete or unreliable data sets. The values expressed are broad indicative estimates based on the best information available at the time of the study and should not be seen as exact figures.** It is however hoped that as more accurate and comprehensive data become available, and as capacity and understanding of ecosystem valuation advances, the study can be updated and extended accordingly.

Particular attention is drawn to the following recognized limitations:

- **Calculations of the returns to water use in Ulaanbaatar are based on the water charges levied on consumption**. Currently, there are insufficient data to enable a more accurate valuation of water. There is little or no information on either the costs of water provision or the returns to water use in different activities (e.g., industry, farming and livestock production). Current tariffs are known to be highly subsidized and thus may be inaccurate indicators of either the marginal value of water to users or the marginal costs of its provision. In the absence of data that would permit more accurate estimates of water value being calculated, the findings of a recent World Bank/Public-Private Infrastructure Advisory Facility (2007) study, which looked at consumers' stated willingness to pay for water, were therefore used as an inflator on current water tariffs. It is worth noting here that if shortages persist, the marginal value of additional water will also increase substantially. The water values presented in the study should therefore be taken as minimum estimates.
- **Valuation does not look at the stock or asset value of the ecosystem, land, and resources of the Upper Tuul**. It looks at the flow of benefits yielded by the Upper Tuul ecosystem: the value of water supplies; tourism earnings; livestock production; and income from timber, firewood, and non-forest product harvesting.
- **Economic values are expressed as gross figures**. They do not net out the costs of labor, or other inputs and factors of production used to generate a final product or income source. In particular, the value of land and resource uses (tourism, livestock, timber, firewood, and non-timber forest products) in the Upper Tuul look at the total flow of income and other marketed products gained from the Upper Tuul ecosystem—not at net value-added, consumer surplus, or producer surplus. Data constraints and the relatively short time available to undertake the study precluded more detailed calculations.
- **The ecosystem valuation exercise is a partial one**. It does not cover each and every element of the total economic value of the Upper Tuul ecosystem or consider all the goods and services it supplies. Notable omissions include those associated with biodiversity and non-water ecosystem services. Analysis of ecosystem water services focuses only on water flow and supply; it does not consider the water quality and flood attenuation services that are also provided by the ecosystem.

How the report is structured

- This Introduction looks at why, how and to what ends the study was carried out. It summarizes the aims of the study and provides an overview of the questions it aims to answer.
- Chapter 1 lays out the issues being addressed in the study: the emerging water problems

in Ulaanbaatar, the importance of ecosystem conservation for downstream water supplies, and the need to use economic and financial instruments to support the sustainable management of land and resources in the Upper Tuul.

- Chapter 2 describes the Tuul Basin and the Upper Tuul ecosystem and defines the boundaries of the study area.
- Chapter 3 details and quantifies the economic value of land and resource uses in the Upper Tuul, including tourism, herding, timber, firewood and non-timber forest products.
- Chapter 4 details and quantifies the economic value of water supplies in Ulaanbaatar, including domestic, industrial and commercial, and agricultural uses.
- Chapter 5 models future management scenarios for the Upper Tuul. It describes the impacts of land and resource use change on downstream hydrology and water availability in Ulaanbaatar.
- Chapter 6 looks at the changes in economic value that would result—overall and for different stakeholder groups in upstream and downstream areas—from different future management scenarios of ecosystem conservation and degradation.
- Chapter 7 draws conclusions on the need for adequate investments for conserving the Upper Tuul ecosystem as an economic part of Ulaanbaatar's water infrastructure, and highlights the necessity of ensuring that adequate financial and economic incentives are provided in support of conservation.
- The Annex summarizes the eco-hydrological and economic methodologies used in the study and lists the assumptions upon which the scenario modeling is based.
- References and notes are found at the end of the study.

1. Background: The Issues to be Addressed

Ulaanbaatar—a growing city

By far the largest city in Mongolia, Ulaanbaatar is the primary hub for commerce and industry and generates nearly 70 percent of national production.[1] Around 40 percent of the country's population lives in Ulaanbaatar,[2] and the number of inhabitants has shown unprecedented rates of growth—rising from just 30,000 in the mid-1940s to 650,000 in 1998, to more than one million in 2009. Between 1990 and 2003, the average annual population growth rate was almost 5 percent (around 3 times the national average).[3] The Master Plan for Ulaanbaatar City predicts that by 2020 the number of city dwellers will have reached 1.62 million.

Water security is key to Ulaanbaatar's economic future

It is obvious that clean and regular water supplies are absolutely critical for the health and well-being of the city's residents, as well as underpinning future urban growth and development. There is however broad consensus that, as Ulaanbaatar continues to grow and as water demand increases, the city's water supply will be placed under severe stress.[4] The water distribution network is now more than 50 years old, and the existing system of wells and boreholes is being stretched beyond its limits. Seasonal water shortages have already become a regular occurrence. According to recent estimates, the city will be facing severe water shortfalls by 2020, if not earlier.[5]

The Government of Mongolia has initiated a range of actions to ensure the city's future water security. Substantial amounts of public and donor funds have been earmarked for addressing Ulaanbaatar's water problems. Programs are being set in place to expand urban water supplies and manage water demand. Although the major focus of these planned interventions is on engineering and technological solutions such as sinking new wells and boreholes, expanding the capacity of groundwater extraction systems, and constructing larger water storage facilities, there is also mention of the need to better manage the water source itself.

Ulaanbaatar's water supplies depend wholly on groundwater drawn from an alluvial aquifer extending along the bed of the Tuul River. The Master Plan for Ulaanbaatar City to 2020 articulates a vision for urban development, which includes protecting the city's upper watershed,[6] while the National Water Program's Water Action Plan for 2002–2006 details plans to develop integrated water resources management in the Tuul River Basin.[7]

1 Zandaryaa, and others (2003).
2 According to government figures released January 2009, the population of Mongolia is 2.7 million, of whom 1,080,000 live in Ulaanbaatar.
3 Basandorj and Davaa (2005).
4 JICA and Government of Mongolia (2007).
5 For example, among others, Zandaryaa and others (2003), and Basandorj and Davaa (2005)
6 JICA and Government of Mongolia (2007)
7 Appendix to the Resolution No. 236 (2002), Government of Mongolia.

Investing in ecosystems as an economic part of water infrastructure

The Government-promoted integrated approaches to water management require paying adequate attention and allocating sufficient funds for managing the source of Ulaanbaatar's water supplies. This is in addition to investing in the physical infrastructure, which is required to abstract, store, treat, and distribute water to the city, and in managing water demand. They are based on a recognition of the key role that natural ecosystems—in this case the forests, grasslands, and mountains of the Upper Tuul—play in ensuring secure, clean, and regular water supplies downstream.

Experiences from other parts of the world show that investing in these "natural" components of water infrastructure can yield substantial pay-offs in economic terms and save considerable costs. For example in Portland, Oregon; Portland, Maine; and Seattle, Washington, it has been found that every US$1 invested in watershed protection can save anywhere from US$7.50 to nearly US$200 in costs for new water treatment and filtration facilities.[8] Through conserving upstream forests in the Catskills range, New York City hopes to have avoided investing an extra US$4–6 billion on infrastructure to maintain the quality of urban water supplies.[9]

Little or no information is available on the economic rationale to investing in natural ecosystems as part of Ulaanbaatar's future water sector development. It is against this backdrop that this study was carried out, aiming to assess the value of the Upper Tuul ecosystem for downstream water supplies. Intentions for the study were to contribute to ongoing efforts to find cost-effective, sustainable solutions to Ulaanbaatar's water supply problems. It also responds to a more general interest shown by the Government of Mongolia and the World Bank in better understanding the way in which the natural environment contributes to the economy.

Meeting the costs of ecosystem conservation

This study shows that there is a net economic gain from conserving the Upper Tuul ecosystem: that the value of water benefits generated outweighs the costs of conservation. From an economic perspective—one that seeks to maximize positive effects for society as a whole—there is a clear rationale to ensuring that the watershed is conserved and managed sustainably, in the interests of downstream water availability. This (together with the many other important biodiversity and ecosystem values of the Upper Tuul) provides the basic economic justification for public sector investment in the two protected areas, Gorkhi-Terelj National Park and Khan Khentii Strictly Protected Area that shelters the source of the Tuul River. Although ecosystem conservation will not singly solve Ulaanbaatar's water problems, it is an essential part of future water investments.

The Government is however not the only group that must bear the costs of conserving the Upper Tuul. In addition to the direct physical expenditures required to manage the protected areas and enforce environmental regulations, there is an opportunity cost to ecosystem conservation. This comprises the foregone income and revenues from land and resource use activities that must be reduced or stopped in order to ensure that the ecosystem continues to generate downstream water benefits. As the study describes, conservation incurs opportunity costs to the current users of Upper Tuul: those engaged in tourist development, herding, timber and firewood harvesting, and non-timber forest products collection.

A paradox arises. Although it is clearly in the broader public interest to conserve the Upper Tuul ecosystem, it is not in the immediate financial in-

1 Reid (2001).
2 Isakson (2002).

terests of the people who use its land and resources. At least over the short term, they can generate more income and other material benefits from continuing their activities, even if these are unsustainable in ecological terms. In addition to an unclear financial rationale, there is little immediate gain to the land and water users for limiting their livelihoods or compromising their business profits in order to generate gains for water users in Ulaanbaatar. Although command and control measures such as regulations and penalties are a core part of any conservation strategy in the Upper Tuul and can go some distance toward addressing illegal and unsustainable land and resource use, enforcement has proved to be difficult and costly in practice. This is one important reason why ecosystem degradation continues largely unchecked in the watershed area. It is also the case that some community members who live in the Upper Tuul lack access to alternative sources of livelihoods and may simply be economically unable to change their current production and consumption patterns.

Demonstrating the economic value of the Upper Tuul for downstream water supplies is therefore not the end of the story. The study findings raise an important question: *How is funding generated to enable adequate public investment in ecosystem conservation and to set in place sufficient financial incentives for land and resource users in the Upper Tuul to shift to a more ecologically sustainable mode of production?* Having recognized the economic rationale for investing in the Upper Tuul ecosystem, a key challenge facing the Government is to find ways of balancing the costs and benefits of conservation so as to ensure that this productive and valuable natural asset can continue to generate downstream water benefits in the future.

2. The Study Area: An Overview of the Tuul Basin

The Tuul River

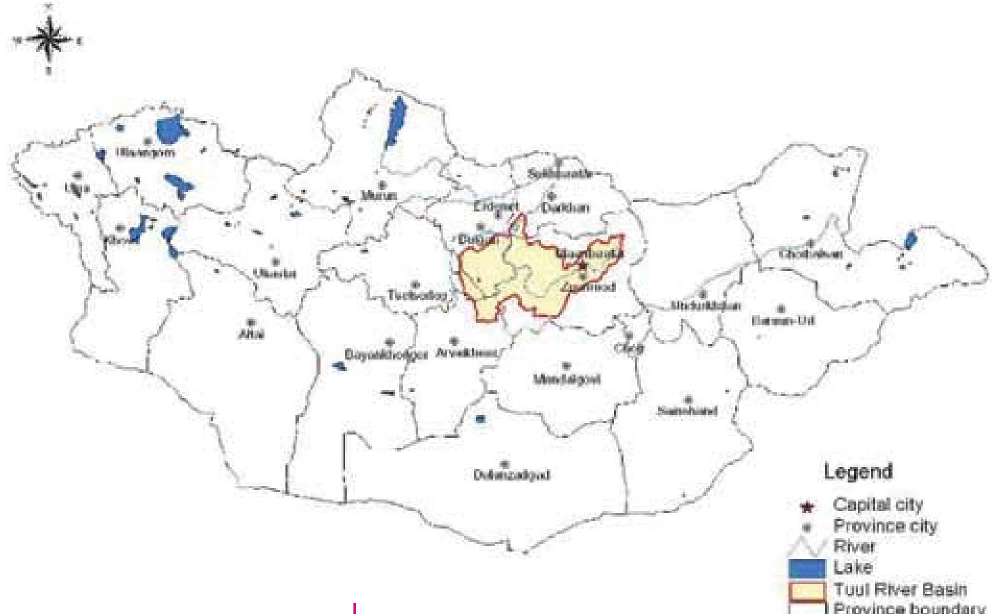
Although the Tuul River Basin covers only 3 percent of Mongolia's land area (Map 1), it contains more than half of its human population. Rising in the Khentii Mountains in the northeast of the country (Map 2), the river has a total length of 704 kilometers and a catchment area of some 49,840 square kilometers.[10] As illustrated in Map 2, the Tuul River flows south-west through Ulaanbaatar, changing its direction several times before merging with the Orkhon River, which then drains to the Selenge River, and ultimately feeds into Lake Baikal in Russia.[11]

The Tuul Basin can be divided into 9 sub-basins: the Tuul-Bosgo, Terelj, Kholiin gol, Uliastai, Selbe, Turgen, Middle Tuul, Lower Tuul and Kharuukh. This study focuses on two of these sub-basins, the Tuul-Bosgo and Terelj, the conflu-

3 Basandorj and Davaa (2005), and Zandaryaa and others (2003).

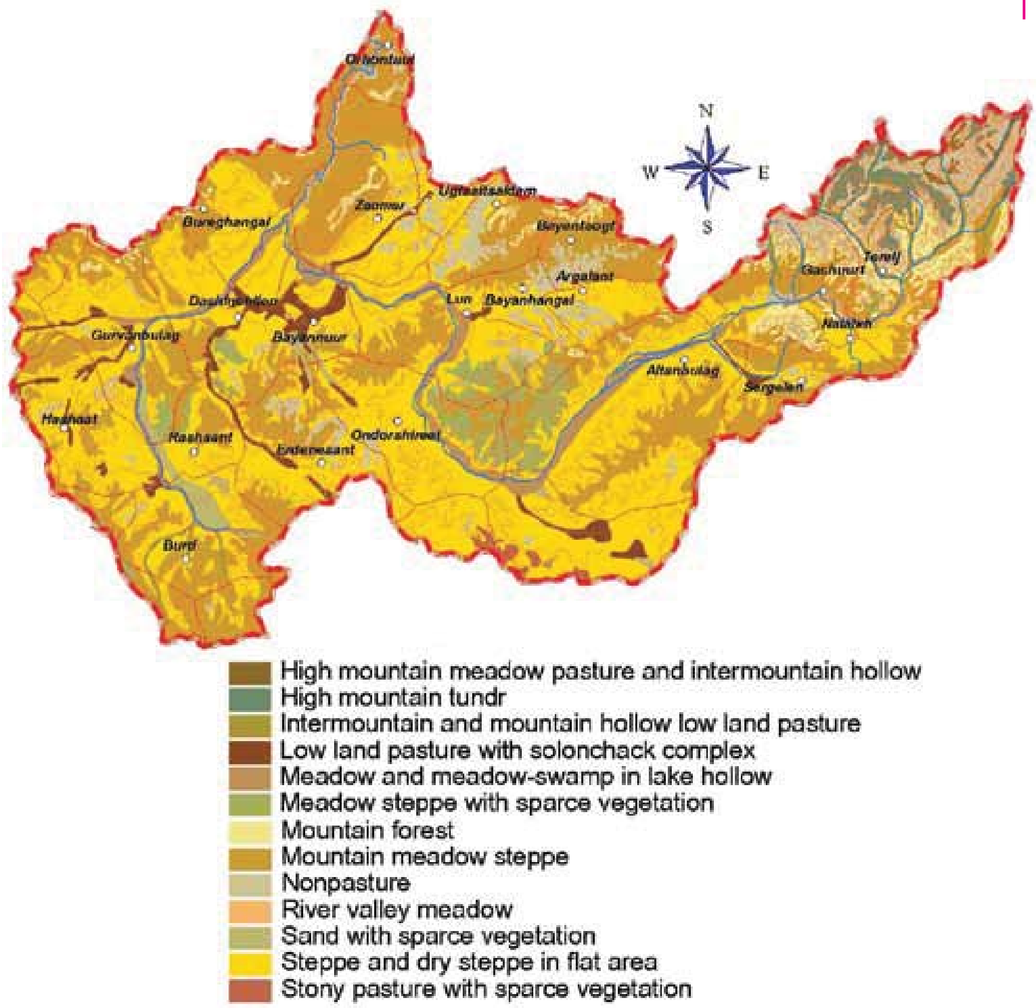
4 Zandaryaa and others (2003).

Map 1: Location of the Tuul Basin in Mongolia



THE RESOLUTION IS FINE BUT THE QUALITY IS VERY POOR

Map 2: Tuul Basin



Source: Basandori and Davaa (2005).

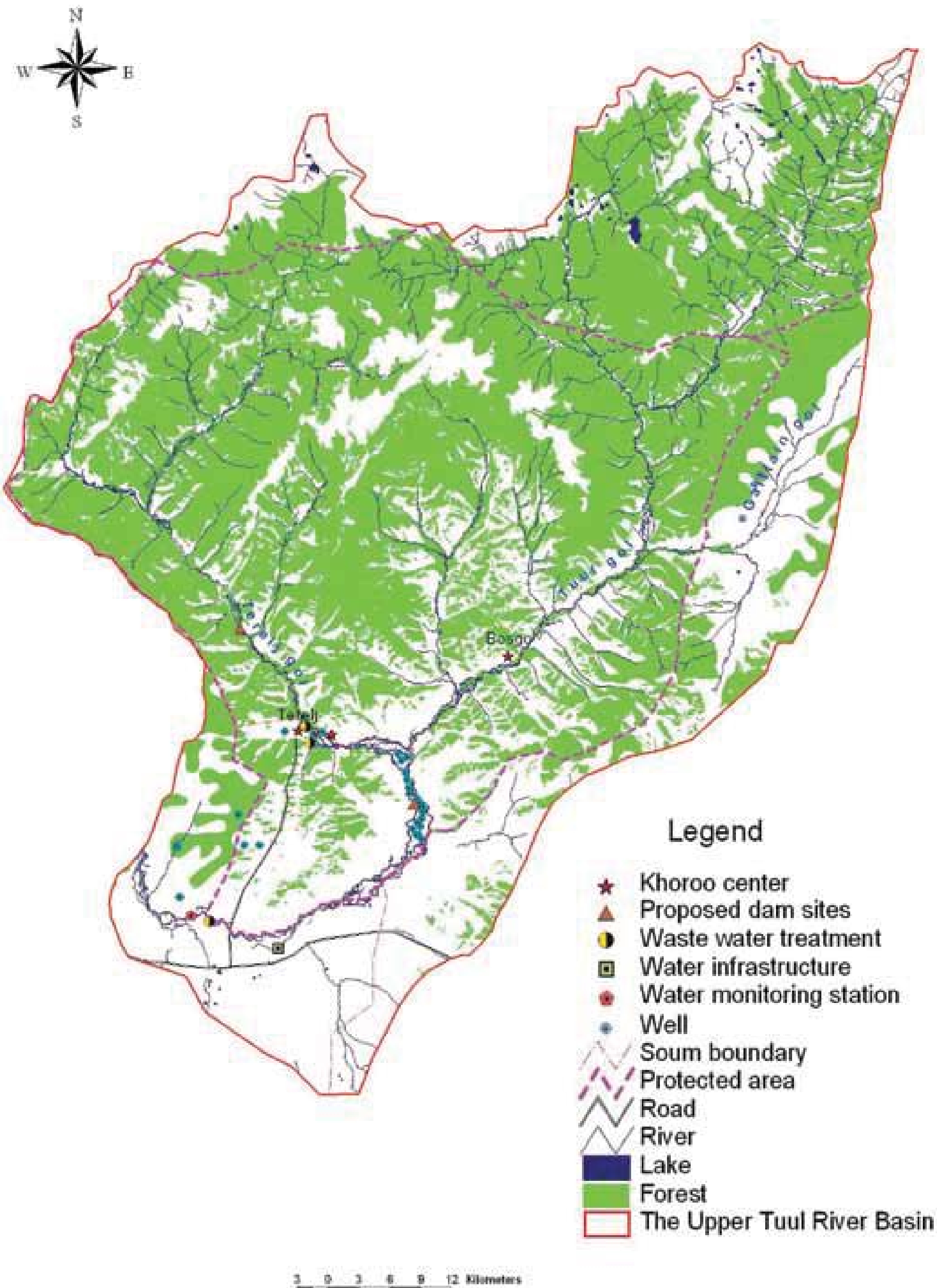
ence of which forms the Tuul River (Map 3) The Terelj is the largest tributary of the Tuul River, draining from a catchment area of 1,380 square kilometers on the southern slopes of the Baga Khentii range. Around 40 other rivers, streams, freshwater lakes, and ponds also feed into the Upper Tuul. Map 4 shows the hydrology of the Upper Tuul Basin.

The study area

The study looks at both the Upper Tuul Basin (the water source) as well as the downstream

Map 3: Sub-basins of the Upper Tuul Basin

Map 4: Hydrology of the Upper Tuul Basin



area (the water users). There are several different interpretations of the boundaries and area of the Upper Tuul Basin in the literature. Zandaryaa and others (2003) for example cite an upper catchment of 7,312 square kilometers.[12] Sugiura and others (2005) delineate 5,512 square kilometers.

5 The Terelj, Upper Tuul, Middle Tuul and Lower Tuul.

And both Basandorj and Davaa (2005) and Davaa and Erdenetuya (2005) give an area of 6,300 square kilometers for the portion of the Tuul Basin from its source to Ulaanbaatar. This study bases its definition on these last two estimates and takes an area of 6,300 kilometers for the upper basin and downstream area. These are defined in Map 5.

Upper basin

The Upper Tuul Basin covers 5,010 square kilometers, encompassing:

- All of Gorkhi-Terelj National Park;
- Most of Khan Khentii Strictly Protected Area;
- West-central portion of Erdene Soum.

Downstream area

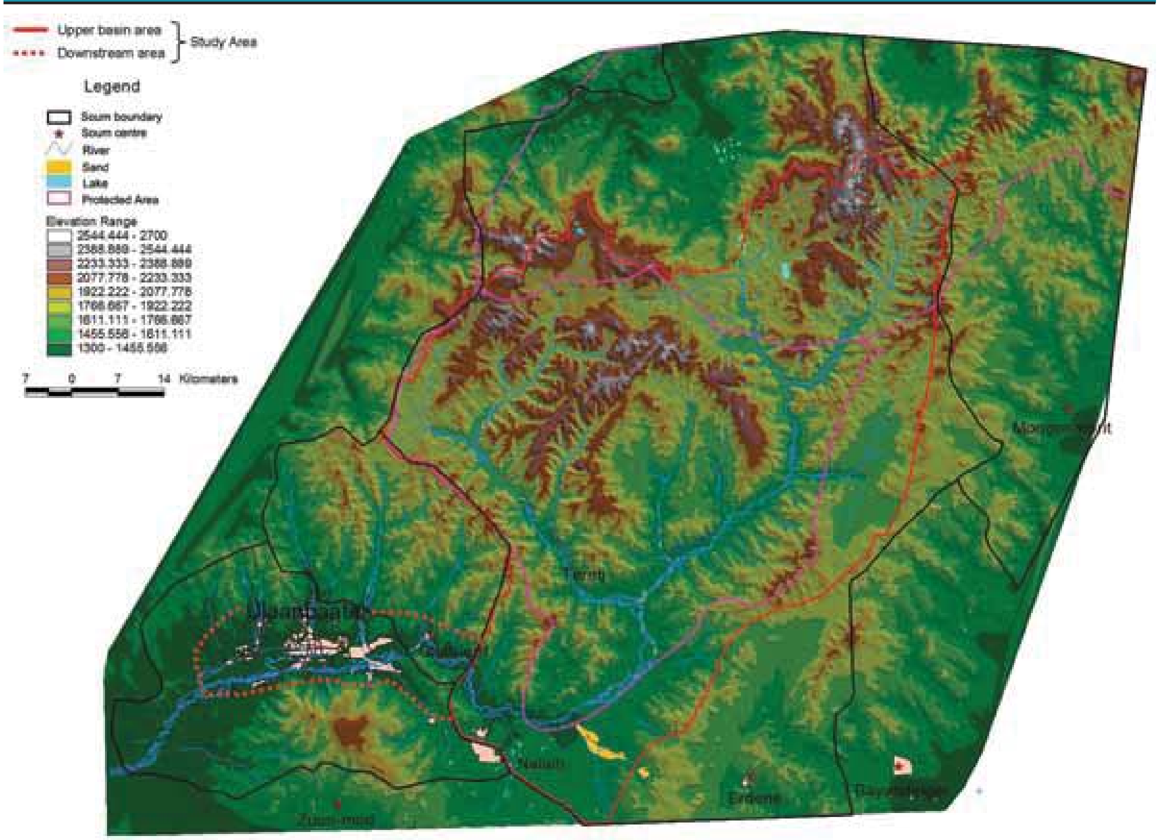
The study designates the downstream area as the strip of land that stretches along the north bank of the Tuul River from Gachuurt to the western boundary of Ulaanbaatar municipality. It covers 1,290 square kilometers and includes households, businesses, and industries that are located in Ulaanbaatar Municipality and peri-urban parts of Gachuurt Khoroo (a built-up area of some 225 square kilometers).[13]

The upper basin area

The elevation of the Upper Tuul Basin ranges from 1,200 to 2,700 meters above sea level. This

[6] Basandorj and Davaa (2005).

Map 5: Study area



The outer red line denotes the boundary of Khan Khentii Strictly Protected Area and the blue and red shapes of the Limited Use Zone and Tourism Zone denote the Gorkhi-Terelj National Park.

altitudinal variation has led to the development of diverse habitat types,[14] including high mountain tundra, high mountain meadow pasture, boreal forest (taiga), mountain steppe, forest steppe, and steppe, interspersed with lakes, rivers, streams, mountains, hills, and rocky outcrops (Map 6).[15] More than 30 percent of Mongolia's forest resources are found in the Khentii Mountains[16] with dominant species, including the Siberian Larch (*Larix sibirica)* and Siberian Pine (*Pinus sibirica)*, which are also rich in mosses and lichens.[17] At lower elevations, where taiga forest meets the steppe, mixed conifer and broadleaf forests are intermingled with grasslands. In addition to the Tuul and Terelj, two other major river systems have their sources in the area: the Onon and Kherlen, which flow east to join the Amur before emptying into the Pacific Ocean.

Most of the Upper Tuul Basin has been officially designated as protected areas since the early 1990s. Two protected areas together account for some 80 percent of the Upper Tuul Basin. Khan Khentii Strictly Protected Area covers a total area of around 1.2 million hectares of the northern portion of the watershed and beyond, and the contiguous Gorkhi-Terelj National Park stretches over approximately 293,000 hectares to the south between the Terelj and Tuul Rivers.[18] According to the 1994 Law on Specially Protected Areas, most extractive activities and construction are forbidden in Khan Khentii, while controlled tourism and limited traditional land and resource uses are permitted in parts of Gorkhi-Terelj.

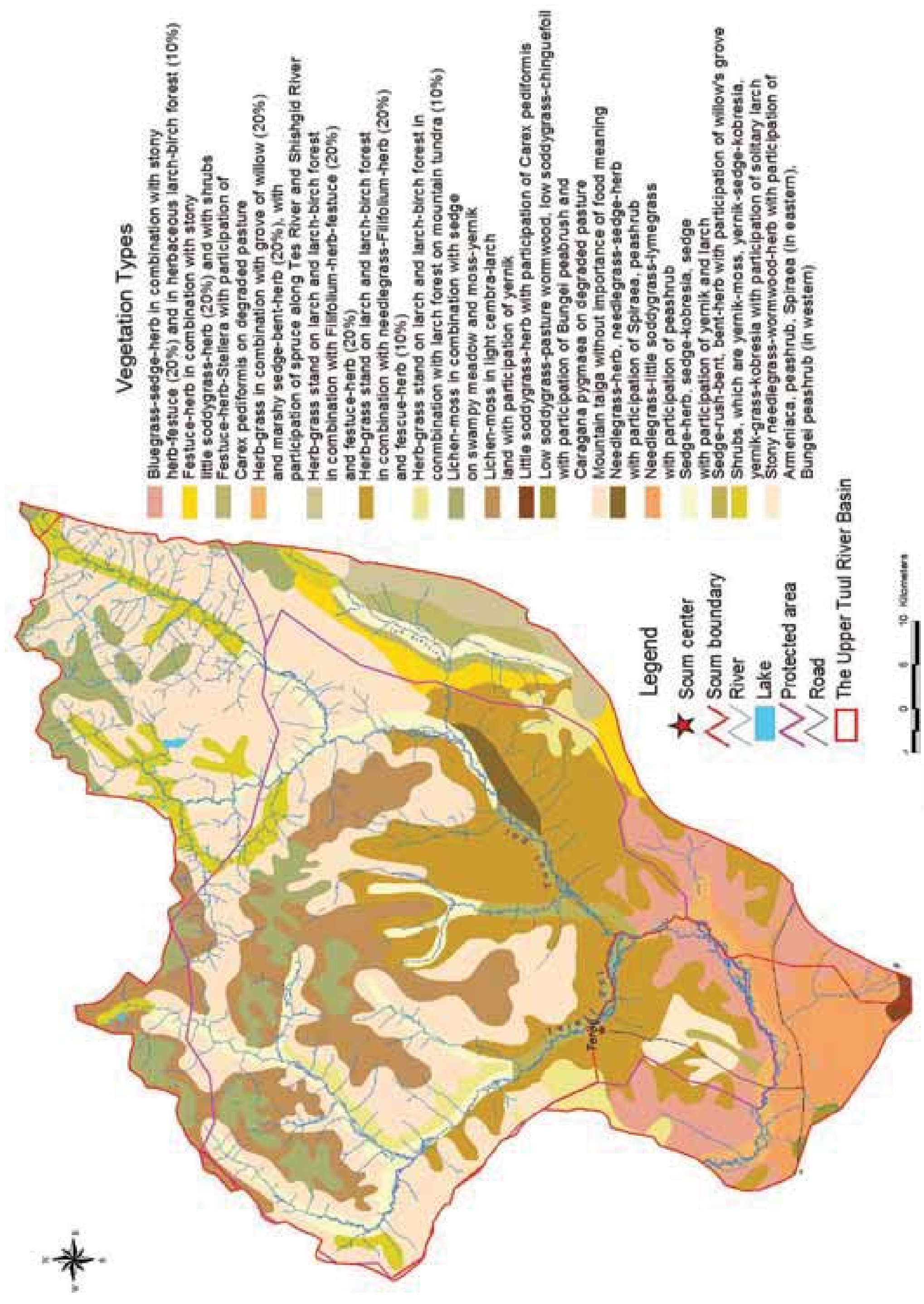
More than 1,150 species of plants, characteristic of both taiga and steppe, have been identified in the protected areas, and over 50 mammal species, 253 species of birds, and 34 species of fish are listed.[19] Globally threatened species [endangered (EN), vulnerable (VU), near threatened (NT)] of birds found at the site include the Saker Falcon *Falco cherrug* (EN), Lesser Kestrel *F. naumanni* (VU) and Yellow-breasted Bunting *Emberiza aureola* (VU). Cinereous Vulture *Aegypius monachus* (NT) also occurs. The site supports an assemblage of species restricted to the boreal forest (taiga) biome, including Black-billed Capercaillie *Tetrao parvirostris*, Ural Owl *Strix uralensis*, Northern Hawk Owl *Surnia ulula*, Eurasian Pygmy-owl *Glaucidium passerinum,* and Rufous-tailed Robin *Luscinia sibilans.* In excess of 50 species of mammal, 5 reptiles, 4 amphibians, and 30 fish have been recorded at the site, as well as more than 200 species of insect. Rare and threatened mammal species found at the site include Siberian Musk Deer *Moschus moschiferus* (VU), European Elk *Alces alces*, Red Deer *Cervus elaphus*, Brown Bear *Ursus arctos*, Wolverine *Gulo gulo* (NT), Eurasian Lynx *Lynx lynx*, Pallas's Cat *Felis manul* (NT), Eurasian Otter *Lutra lutra* (NT), and Taimen *Hucho taimen*.

The protected area landscape has been zoned for management and use purposes (as shown in Map 7), with the southern part of Gorkhi-Terelj National Park and surrounding buffer zone developed for tourism. These areas are now densely populated with restaurants, souvenir shops, horses and camels for rent, and tourist *ger* camps. Northern portions have been designated as limited use zones, protection zones, and core areas. Most of Khan Khentii Strictly Protected Area, in contrast, is zoned for protection and limited use and is as yet relatively undisturbed. There are few camps in these areas, which are used sparsely for hiking, trekking and horse riding. The Khentii Mountains form an effective natural barrier on the east side of Gorkhi-Terelj and also hinder access from the National Park into the south-west part of Khan Khentii Strictly Protected Area above the Terelj River.

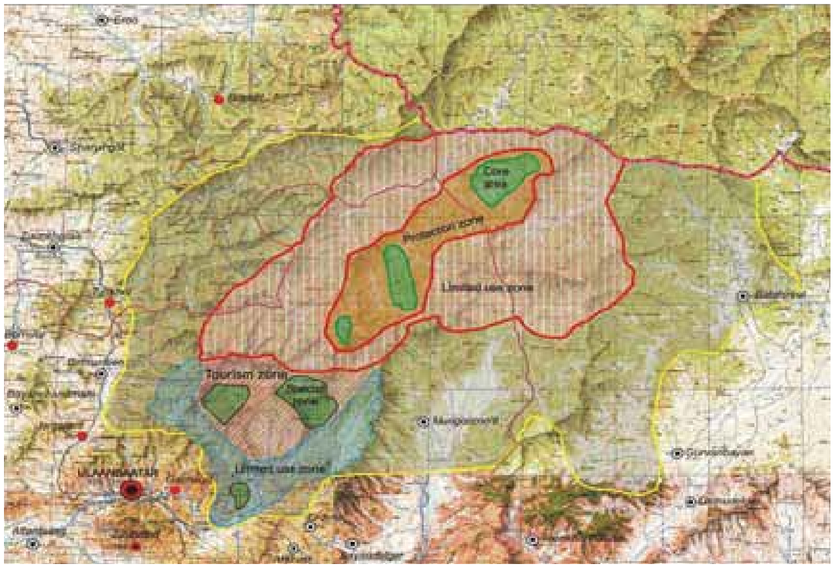
Human influence in the Upper Tuul Basin is therefore largely circumscribed by the natural

7 Birdlife International. Directory of Important Bird Areas in Mongolia. IBA CODE: MN05 – Khan Khentii Strictly Protected Area.
8 Basandorj and Davaa (2005).
9 Birdlife International. Directory of Important Bird Areas in Mongolia. IBA CODE: MN05 – Khan Khentii Strictly Protected Area.
10 World Wildlife Fund Ecoregions Report.
11 Varying figures are cited for the areas of Khan Khentii Strictly Protected Area and Gorkhi-Terelj National Park. These data were provided by Staff of Gorkhi-Terelj National Park and Khan Khentii Strictly Protected Area: Mr Dugersuren (Deputy Director Administration), Mr Khandmaa (Enforcement Officer), and Ms Betmuuk (Director HR).
12 Birdlife International. Directory of Important Bird Areas in Mongolia. IBA CODE: MN056 – Gorkhi-Terelj National Park.

Map 6: Vegetation of the Upper Tuul Basin



Map 7: Management and use zones in Gorkhi-Terelj National Park and Khan Khentii Strictly Protected Area



The outer red line denotes the boundary of Khan Khentii SPA and the blue line Gorkhi-Terelj National Park

landscape and topography (Map 8). It is possible to delineate 4 broad zones of human influence and management in the upper watershed, which are illustrated in Map 9, and will be referred to extensively in Chapter 5:

Khan-Khentii Strictly Protected Area: the northern boundary of the Upper Basin to the Terelj River

- **Zone I:** the north and north-western parts of the Upper Basin, comprising the central portion of Khan Khentii Strictly Protected Area, remain largely inaccessible due to steep slopes and hills and the absence of tracks or roads. There is little evidence of human influence.
- **Zone II:** most of the south and south-eastern portion of Khan Khentii Strictly Protected Area and a strip to the far west part of Erdene Soum down to the Terelj River; although in principle accessible from Gorkhi-Terelj National Park, it has shown relatively few signs of disturbance. There is evidence of increasing human influence, with grazing and resource exploitation starting to expand northwards along the Terelj and Tuul Rivers.

Gorkhi-Terelj National Park: the Terelj River to the Tuul River

- **Zone III:** most of Gorkhi-Terelj National Park is accessible, and parts are showing signs of intense use and degradation. There are high concentrations of herder settlements in eastern areas, and tourist camps in the central and western areas, as well as the small commercial centers of Terelj and Bosgo.

South-west Erdene Soum and Nalaikh: Gorkhi-Terelj National Park buffers

- **Zone IV:** the strip of land skirting the eastern, southern, and western boundaries of Gorkhi-Terelj National Park is comprised of a mosaic of settlements and permanent pasture, with several mines in the far south-east. This zone

Map 8: Topography and elevation of the Upper Tuul Basin

is showing signs of severe degradation, and the landscape is being rapidly transformed. Permanent houses and denser areas of settlement are spreading toward the southern buffers of the National Park, from the direction of Gachuurt, Ulaanbaatar, and Nalaikh. Permanent grazing is carried out throughout this zone, and pasturelands are heavily stocked and degraded in the south-west toward Gachuurt.

Map 9: Major zones of human influence and management in the Upper Tuul Basin

The downstream area

After the Tuul River leaves Gorkhi-Terelj National Park, it flows north-west and then westwards some 50 kilometers to Ulaanbaatar. The city's water supply depends wholly on groundwater drawn from the alluvial aquifer, which extends along the bed of the Tuul. There are 3 main categories of water user in this downstream area: domestic user, industries and businesses, and agricultural enterprises.

Domestic users

The population of Ulaanbaatar is estimated at 1.031 million, having grown steadily from only 30,000 people in the mid-1940s, to 650,000 in 1998 to just under 900,000 in 2003. The city's residents can be differentiated between those who live in apartments and those who reside in ger settlements. Less than 1 percent of the population lives in individual houses. As will be described later, apartment dwellers and ger residents access and use water in very different ways.

Geographically, ger settlements make up for 70 percent of Ulaanbaatar's residential area.[20] They also constitute one of the most rapidly growing sectors of the urban population: according to National Statistical Office data, the registered population in ger settlements grew by 10 percent from 2000 to 2002 while the number of apartment dwellers remained more or less stable. Current population data indicate that 60 percent of Ulaanbaatar's inhabitants live in ger settlements. Nearly 40 percent of the city's residents are registered as living in apartment blocks.

The de facto boundaries of Ulaanbaatar are extending steadily outwards as the urban population grows and formerly unsettled areas transform into suburbs and satellites of the city. In particular, residential and commercial zones are spreading

[13] Herro and others (2003).

Figure 2: New fences being constructed in the outskirts of Ulaanbaatar in anticipation of land privatization

rapidly along the Tuul River toward Gachuurt[21] and along the road toward Nalaikh Town. The ongoing process of land allocation and subdivision is hastening this process, and effecting permanent changes to the landscape with fences going up, ger settlements being created, and more permanent dwellings being built (Figure 2).

Industries and businesses

Ulaanbaatar is an important hub for commerce and industry. Nearly 70 percent of national production comes from the city,[22] which accounts for 48 percent of industrial output, 52 percent of construction, 41 percent of trade, 75 percent of hotels and restaurants, and 56 percent of transportation and communication services.[23] Official statistics show a total of 20,327 registered industries and businesses in Ulaanbaatar, including major manufacturing enterprises, which produce textiles and related goods, leather and footwear, soap, paper, iron castings, cement, glassware, beer and spirits, and processed foods. Also located in the city are 3 thermal power stations that supply electricity and hot water to its residents.

Commerce is expanding, with some parts of the city gradually being given over to industry and manufacturing. Over the past 4 years, the number of businesses in Ulaanbaatar has increased by 26 percent, and this rate of growth looks set to continue or even escalate.[24] As well as being major water users, industries contribute to the growing problem of urban water pollution—the Tuul River Basin is now characterized as the most pressured and polluted river basin in the country.[25]

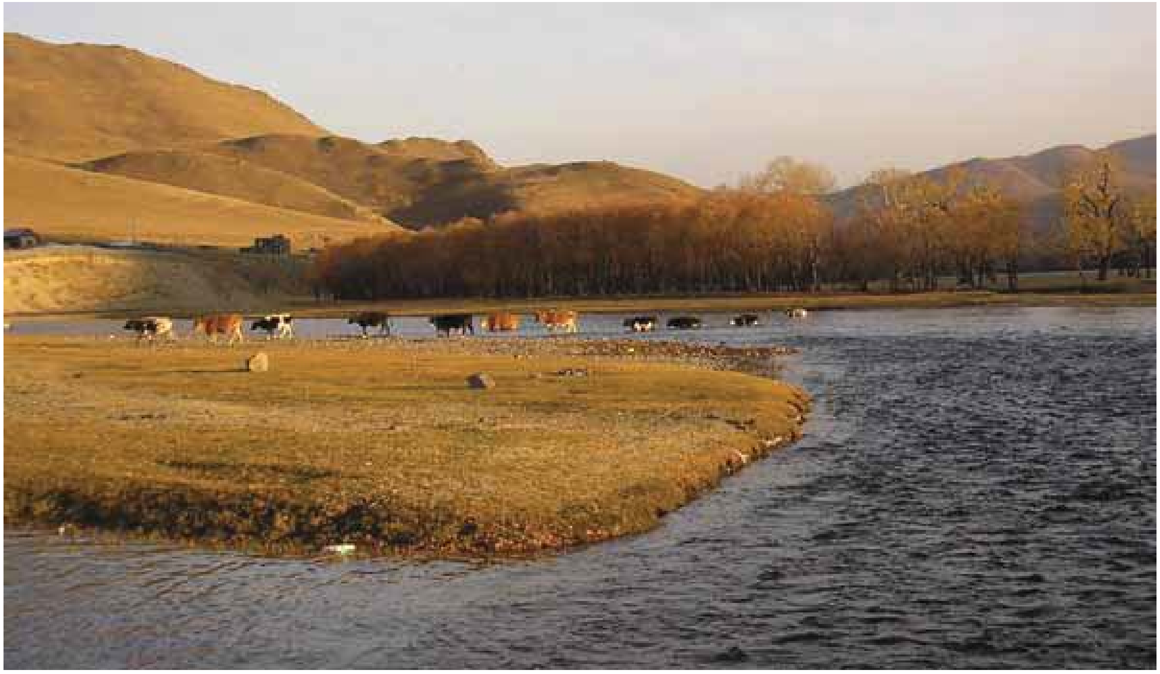
Farmers and herders

The peri-urban belt around Ulaanbaatar is being progressively transformed by the growth of agriculture, including both livestock and crops. These farms provide important supplies of milk, meat, and vegetables to the city. According to official statistics there are 133 farms in Ulaanbaatar covering 372 hectares (more than double the number that existed in 2004), and almost 7,800 herders keeping more than 330,000 livestock (Figure 3).

Irrigated agriculture, in particular, is spreading, with implications for both water use and

[14] Zandaryaa and others (2003).
[15] Zandaryaa and others (2003).
[16] Herro and others (2003).
[17] Sharav (2007).
[18] Basandorj and Davaa (2005).

Figure 3: Dairy cattle being watered in the Gachuurt Tuul River



water quality. The area under irrigated crops now accounts for around 78 percent of all urban and peri-urban farmland and has risen almost fourfold over the last 5 years. The Government is putting emphasis on expanding these farms, with ambitious plans to construct new small-scale irrigation systems over coming years. Most of these will be sited along the Tuul River.

3. Upstream Values: Land and Resource Uses in the Upper Tuul

Socio-economy and land use

Administratively, the Upper Tuul Basin is located mainly in Erdene Soum (85 percent of the total area), also includes several Khoroos of Nalaikh District to the south-west (14 percent), and touches on neighboring Batsumber and Mungunmorit Soums. As shown in Table 1, just under 700 households or 2,600 people live in the Upper Tuul and depend in some way on its natural resources.[26] This is approximately 8 percent of the total combined population of Erdene Soum (3,067 people) and Nalaikh District (28,152 people).

Herders comprise the vast majority of the Upper Tuul's human population at around 80 percent.

[19] Excluding temporary tourist populations, tourist industry workers and mining labor. As no published data exist on the population of the Upper Tuul, these figures are estimates based on the study-conducted survey, compared with estimates given by local government officials.

Table 1: Distribution of the human population in the Upper Tuul

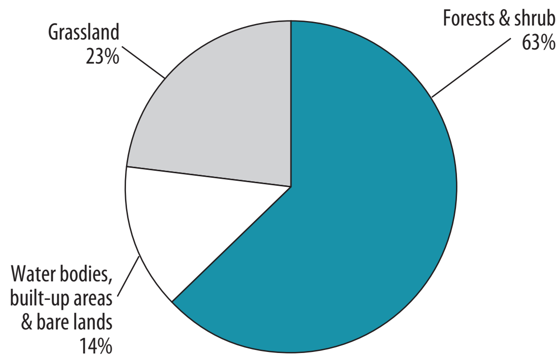
	No. of households
Gorkhi	120
Bulnain	20
Galtain	24
Beside the Tuul River	26
Other parts of Erdene Soum	273
Other parts of Nalaikh District	219
Total	682
Of which:	
Herders	545
Other residents of Terelj, Bosgo and tourist camps	137

From study data. Excludes populations of temporary populations of tourists, tourist industry workers and mining labor.

The remaining population groups comprise business people and residents of the main centers of area settlement, Terelj and Bosgo, both located within the protected area complex. The town of Erdene lies to the south-east of the Upper Tuul Basin, Nalaikh is close to the southern boundary, and Gachuurt abuts the Basin to the south-west. Although these settlements are not part of the study area, their populations and local economies both depend and impact on the Upper Tuul.

As shown in Figure 4 and Map 10, forest and shrubland dominate the landscape, and there are also large areas of grasslands. Most of the Upper Tuul (3,970 square kilometers or 79 percent) is comprised of Gorkhi-Terelj National Park and Khan Khentii Strictly Protected Area. Although private land title cannot be given and there are restrictions on the exploitation of natural resources in Gorkhi-Terelj and Khan Khentii (and on tourism in the Strictly Protected Area), a wide variety of economic activities are carried out in the Upper Basin, including in the National Park and Strictly Protected Area. Major land and resource uses include tourism, herding, collection of wood, and non-timber forest products. These activities are described in subsequent sections of this chapter.

Figure 4: Land cover and land use in the Upper Tuul



From study data. Delineation of the major land cover types in the watershed established by joint application of remote sensing, GIS maximum likelihood tool, ground truth, and triangulation with data of government departments.

Tourism

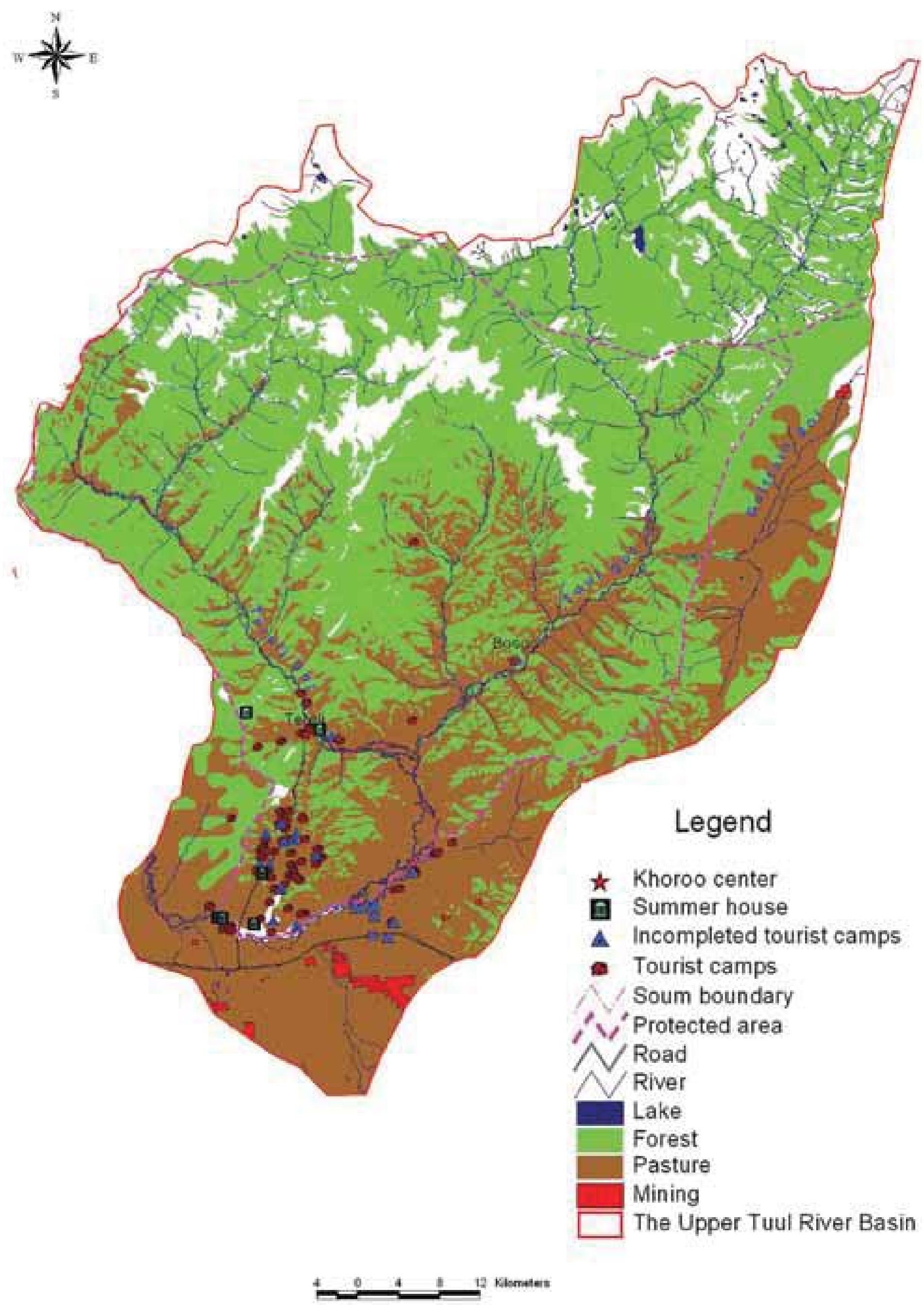
How land and resources are used

The part of Gorkhi-Terelj National Park that lies between the Tuul and Terelj Rivers is one of Mongolia's most popular tourist destinations, for foreign and domestic visitors alike. It is an area of outstanding natural beauty that also contains important historical and cultural sites. The National Park is famous for its unique granite rock formations and pristine alpine scenery and offers activities such as golfing, hiking, river rafting, horse riding, and rock climbing. Other attractions include Khagiin Khar Lake, a glacial lake some 80 kilometers from the tourist camps, and Yestii Hot Water Springs further upstream. There is also a Buddhist monastery in Gorkhi-Terelj National Park, which is open to visitors. There are many rock formations for climbers, including two particularly famous ones, Turtle Rock (Melkhii Khad) and Praying Lama Rock.

Use of the National Park has increased hugely over recent years. Between 1996 and 2007 domestic visitor numbers more than quadrupled from 25,000 to 106,300, and international tourist entries rose from 6,000 to 27,000. Many of the domestic visitors are day-trippers or weekenders from Ulaanbaatar, while international tourists can be categorized into 3 main categories: East Asian visitors (mainly from Korea and China), Western package tourists, and Western backpackers. While the first 2 groups remain for the most part in the tourist zone of Gorkhi-Terelj and its buffers, backpackers often travel further afield and move into northern areas of the National Park and even into Khan Khentii Strictly Protected Area, staying with local families.

The number and density of tourist establishments in and around the National Park has grown accordingly (Map 11). Until 2003 there were only 30 tourist ger camps. Now, more than 150 land permits to run tourism activities in the National Park have been issued. A total of 180 tourists establishments operate in Gorkhi-Terelj National Park and its buffers, offering an estimated 6,000 beds. The range of tourist accommodation is di-

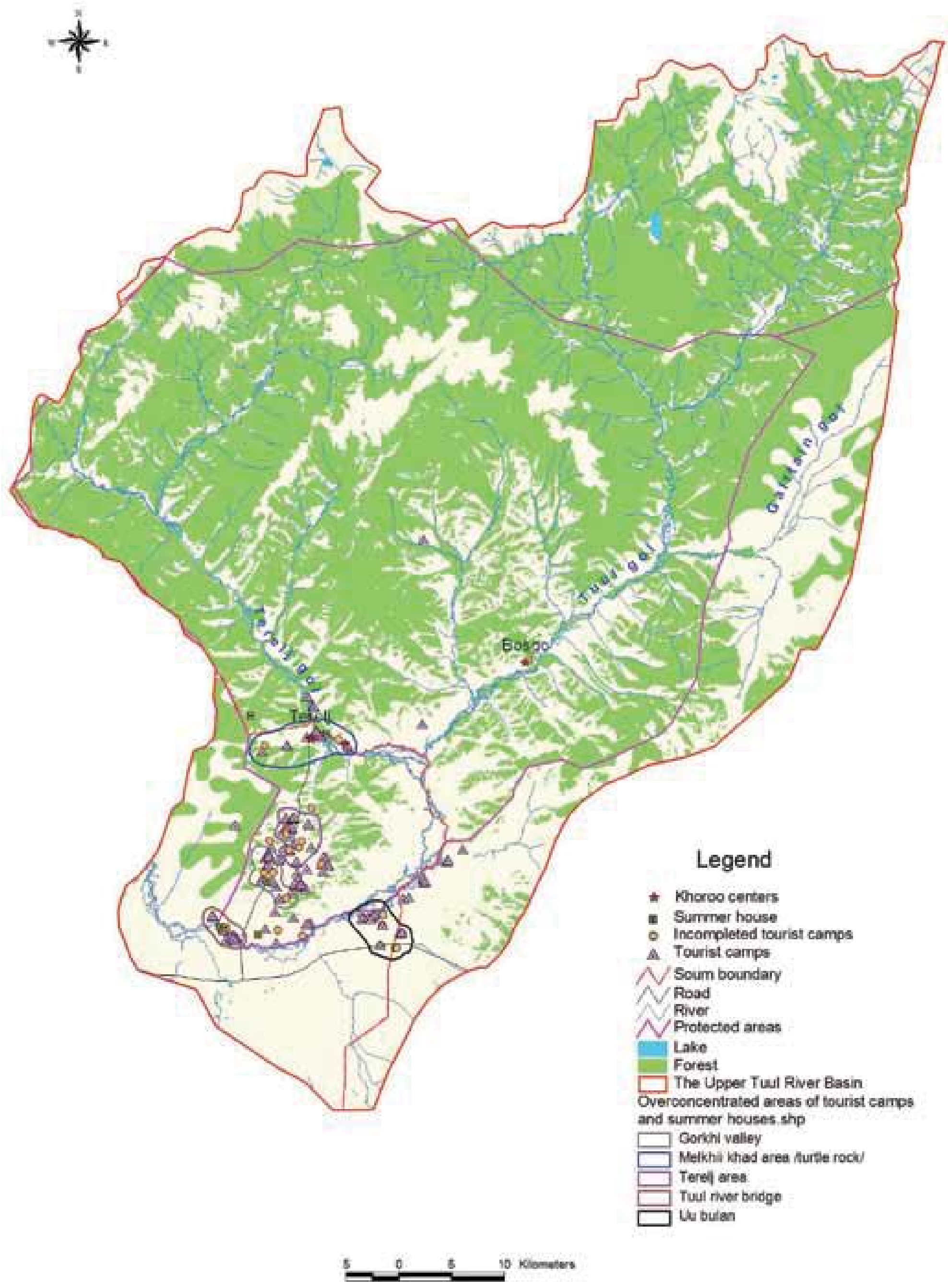
Map 10: Land cover and land use in the Upper Tuul



verse, including up-market hotels, more basic ger camps (including several run by local residents and communities), guesthouses and wooden houses, as well as resorts, sanatoria, and children's camps for both government and company employees.

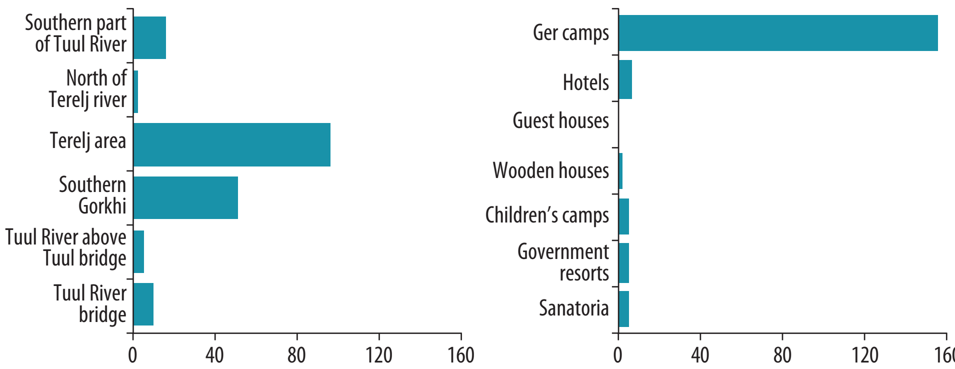
As illustrated in Figure 5, Figure 6, and Map 12, most tourist establishments are concentrated in the Terelj and Southern Gorkhi areas (around 80 percent), and ger camps account for the majority of establishments and beds offered (around

Map 11: Tourist camps in the Upper Tuul



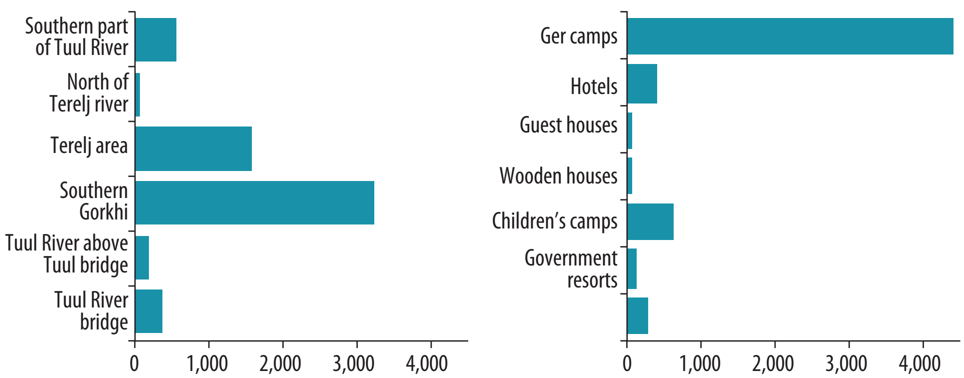
75 percent). Tourist numbers are highest in the summer season of June to October (around 97 percent of annual bednights are purchased at this time), with peak weekend capacity estimated at 80 to 90 percent. Most tourist operations close down during the winter season. Only hotels and a limited number of ger camps are equipped to function year-round, on average operating half of their bed capacity at an occupancy rate of less than 30 percent.

Figure 5: Number of tourist establishments by type and location in the Upper Tuul



From study data

Figure 6: Number of tourist beds by type and location in the Upper Tuul



From study data

Map 12: Location of tourist camps in the Upper Tuul

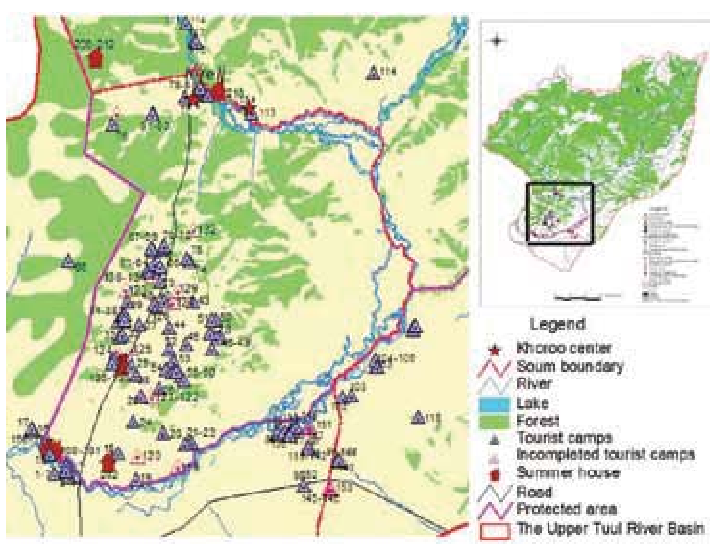


Table 2: Gross revenues from tourist enterprises in the Upper Tuul

	No establishments	Bednights	Gross revenues (Tug mill)
Ger camps	156	683,575	17,570.38
Hotels	6	67,111	5,972.91
Guest houses	1	9,302	130.23
Wooden houses	2	11,783	312.25
Children's camps	5	94,055	611.36
Government resorts	5	20,263	—
Sanatoria	5	43,399	—
All tourist establishments	180	929,488	24,597.13

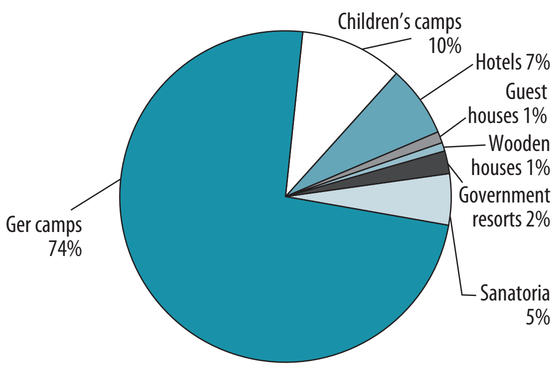
From study data

The value of land and resource use

The tourist establishments operating in the Upper Tuul are estimated to generate gross annual revenues of Tug 24.6 billion a year (Table 2), most of which is contributed by ger camps (Figures 7 and 8).

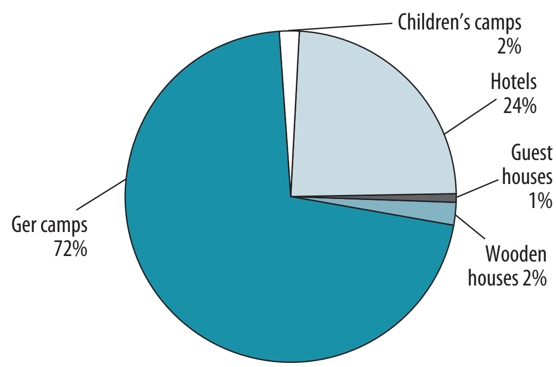
Most tourism income accrues to companies or entrepreneurs from outside the area as owners and managers of the larger camps and hotels. There are just 5 community-run ger camps and 80 small ger camps owned by the residents of Terelj town, earning around Tug 433 million a year or 1.8 percent of total income. Local participation and benefits from the tourism industry remain extremely limited. Some seasonal income can be earned from selling food, renting horses, and acting as guides; the few longer-term employment opportunities that exist tend to be restricted to unskilled casual labor (such as cleaning and security staff). Tourist establishments' semi-skilled, skilled, and manage-

Figure 7: Share of bednights by type of tourist establishment



From study data

Figure 8: Share of income by type of tourist establishment



From study data

Table 3: Government revenues from tourism in the Upper Tuul

	Tug million		
	2006	2007	2008 to Oct
Entrance fees	98.4	112.9	94.2
National Park land fees to PA administration	3.7	30.4	21.4
National Park land fees to Nalaikh District	12.3	101.3	71.3
Buffer zone land fees paid by tourist camps to Erdene Soum	7.2	16.0	18.9
Buffer zone land fees paid by tourist camps to Nalaikh District	1.6	5.8	0.7
Income tax to Nalaikh District from tourist activities	nd	nd	2.0
Total	123.2	266.4	208.5

From study data

rial staff are sourced mainly from Ulaanbaatar and, for some of the high-end resorts, from outside Mongolia.

Tourism in the Upper Tuul also generates revenue for the Government through park entry fees, land fees, and income taxes. As illustrated in Table 3, Some Tug 266 million was earned in 2007 for the Protected Area administration, and Erdene and Nalaikh authorities.

Land and resources use impacts

The southern part of Gorkhi-Terelj National Park is densely settled with tourist establishments, and is showing clear signs of degradation, including unsightly and crowded developments, land degradation, erosion around tracks and roads, and improper disposal of solid waste and sewage. Carrying capacity is thought to have been exceeded in the zone between the Tuul River Bridge and the Terelj River where there are more than 80 camps in a relatively small area some 25 kilometers in length and 5–10 kilometers in width. Areas around the Tuul Bridge, Turtle Rock, East Gorkhi, Terelj, and Shiree's meadow are particularly intensively used.

The northern part of Gorkhi-Terelj National Park and Khan Khentii Strictly Protected Area show few signs of human influence as a result of tourist activities. Over the last year several companies have however entered the area and started to build permanent camps and run in electricity lines. This indicates that tourist developments may be spreading outwards, further into the Upper Tuul, and it is likely that additional camps will soon follow into these relatively untouched areas.

Herding

How land and resources are used

Around one-third of the land area of the Upper Tuul is used for herding by an estimated 545 herding families (or 2,057 people) from the surrounding areas of Erdene Soum and Nalaikh District. Herders traditionally breed and raise 5 types of livestock (sheep, goats, cattle, horses, and camels) according to particular ratios and herd structure, consistent with their lifestyle, migration, labor, and demand for products. Livestock census figures put the number of animals at just over 50,000, about 75 percent of which are goats and sheep, 20

Figure 9: Tuul River and tourist camp

Figure 10: Ger camp, Gorkhi-Terelj National Park

Figure 11: Terelj town

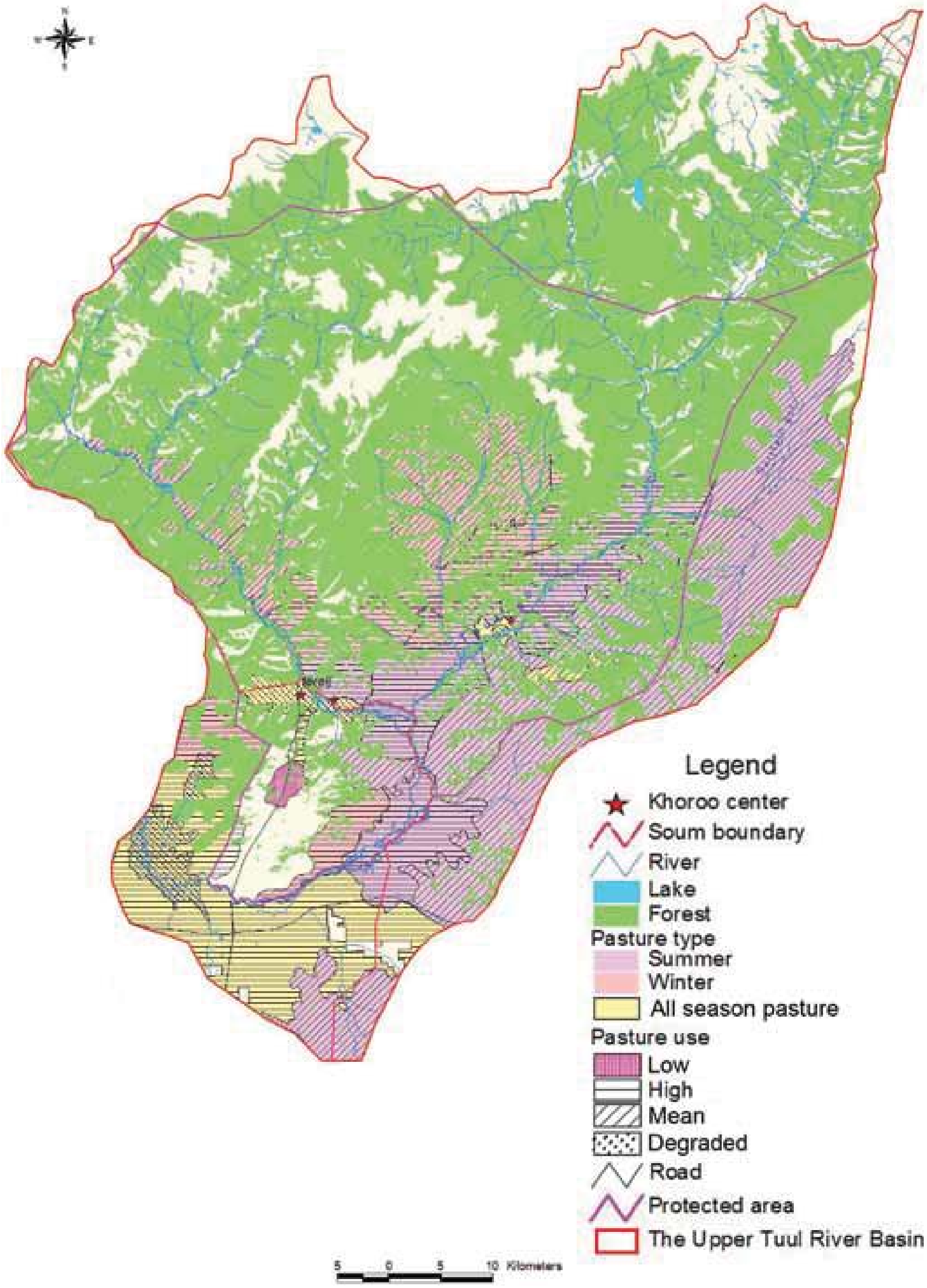
Figure 12: Horse riding by Turtle Rock

percent cattle, and the remainder horses and camels. Camels do not now form a major part of herds in the Upper Tuul, primarily because herders' movement patterns have decreased (lessening the need for camels for transport), and also because pasture conditions are no longer suitable.

Traditionally, herders move between different pasture areas during summer, autumn, winter, and spring months. Although around 40 percent of the herders in the Upper Tuul have become more or less settled in one place, more than half still follow some form of seasonal transhumance. Rotations are however decreasing, with most herders moving between only winter (November-April) and summer (May-October) pastures and many using seasonal pasture areas that are only a few kilometers apart from each other. Three reasons explain this change: a reduced area of pasture available to graze animals, increasing integration into the market economy and concentration of settlements around commercial areas, and a shift toward a more sedentary lifestyle.

The lands suitable for pasture are distributed unevenly across the Upper Tuul. As shown in Map 10 and Map 13, the main year-round pasture lands are located within and outside eastern, southern, and western parts of Gorkhi-Terelj National Park, with summer pastures also stretching northwards along the Tuul River (and to a lesser extent the Terelj River) into

Map 13: Pasture use in the Upper Tuul



Khan Khentii Strictly Protected Area. A strip of land in the south-central part of Gorkhi-Terelj National Park provides important winter grazing.

The herder families who use the Upper Tuul can be divided into two main groups, based on the location of their settlements and pasture lands, the type of animal husbandry they practice, and the kinds of products they generate and sell: the *Nalaikh* and *Erdene* groups. As shown in Table 4, whereas each of these two groups include similar numbers of families, Erdene herders utilize a wider pasture area and manage a herd that is almost twice as large as that of the Nalaikh herders.

Nalaikh herders tend to live close to tourist camps and paved roads in areas around the Tuul River Bridge, Bolor, Melkhii, Khad, Ogoomor, and Terelj. Their main pastures are located in Gorkhi-Terelj, Ikh baga dendiin am, Shiljrengin am, Saikhanii Saravch, and Ovor Gorkhi. Many herders are retirees, each owning a relatively small number of livestock and focusing mainly on dairy production. A relatively high proportion of Nalaikh herders tend to live in the same areas year-round, meaning that the pastures they use cannot sustain large numbers of animals. Only families with larger herds move between winter and summer pastures, including areas outside the Upper Tuul in the south of Erdene Soum.

Erdene herders reside over a wide area of the north and north-east of Terelj River Shugui, covering areas of Mongon Mority and Bayan Delger Soums of Tov Province. Their settlements are for the most part in remote areas, far from other population centers and paved roads. Almost 80 percent of families move their livestock over the course of the year, shifting between summer and winter pastures. Their main pastures are located in Baruun Zuun Bayan, Kharztai, Seruun bulag, Shokhoi tsagaan bulag, Bumbat, Khaluiriin tokhoi, Sandrakh dov, and Galtai, Zamt. Since pasturelands are relatively abundant in these areas, livestock numbers tend to be quite high.

Table 4: Characteristics of herders in the Upper Tuul

	Nalaikh group	Erdene group	All herders
	Pasture		
Area used for grazing (ha)	78,100	91,800	169,900
Human population			
No of herders	909	1,148	2,057
No of herder families	274	271	545
	Livestock population		
Sheep	6,220	15,034	21,254
Goats	6,715	10,417	17,132
Cows	3,686	5,849	9,535
Horses	1,450	2,531	3,981
Camels	7	11	18
All stock	18,078	33,842	51,920
Sheep equivalent units (SEU)	44,565	77,275	121,840

From study data: Note: SEU is the standard measure used to express stock numbers, compare the feed requirements of different classes of stock, and assess the carrying capacity and potential productivity of a given area of grazing land. Goat = 0.9 SEU, cow = 6 SEU, camel = 5 SEU, horse = 7 SEU.

The value of land and resource use

Herders utilize and sell a wide range of livestock products. Wool and hair are used to make felt, ropes and garments; hides and skins are processed to produce bridles, halters, and hobbles; and dung is used for fuel. Meat and milk are central to herders' diets and are also an important source of income. Livestock products are mainly sold locally, directly to urban centers and tourist camps or through middlemen, with most of the cashmere eventually being exported to China.

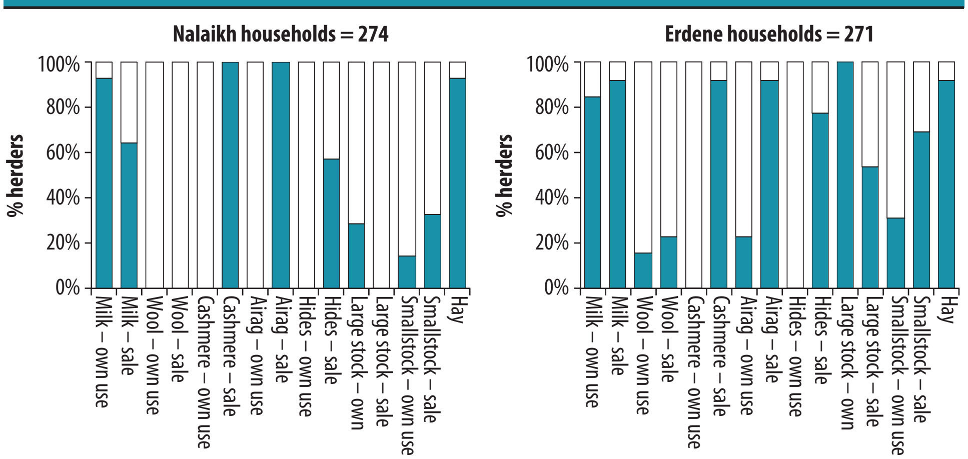
As shown in Figure 13 herders from Erdene tend to produce a wider variety of livestock products than those from Nalaikh and also rely more on livestock products for home consumption. Between 60 to 80 percent of Erdene herders are estimated to meet all their food needs from their own herds.

In total, livestock are estimated to be worth some Tug 3.4 billion a year in the Upper Tuul, around three-quarters of which is generated by the Erdene herder group (Table 5). Erdene herders earn considerably higher returns from livestock than Nalaikh herders per household and per unit of land and livestock; and—due to a larger surplus over own needs—they are able to sell a higher proportion of their production. On average, Erdene households produce a greater diversity of livestock products than Nalaikh households, each at a higher value and volume (Figure 14). Whereas meat and live animals contribute to the bulk of livestock value for Nalaikh herders, milk provides the mainstay of livestock income among Erdene herders (Figure 15).

Land and resources use impacts

Overgrazing is becoming a serious problem in parts of Upper Tuul. It is estimated that available pasture is sufficient for between 55,000 and 141,000 sheep equivalent units (SEUs), and carrying capacity has been exceeded in many areas. As shown in Map 12, permanent pasture areas in the north-west of Gorkhi-Terelj National Park, Gachuurt, and the south-west of the Upper Tuul are showing signs of severe degradation. Indicators of pasture degradation include the disappearance of fodder and other plant species, reduced plant growth, shorter and scarcer vegetation, and increased bare soil areas. The use of land for herding remains high around much of the buffers and in the eastern part of Gorkhi-Terelj National Park, raising concerns that these areas are also deteriorating fast.

Figure 13: Percentage of household participating in livestock product use and sale in the Upper Tuul



From study data

Table 5: Value of livestock production in the Upper Tuul

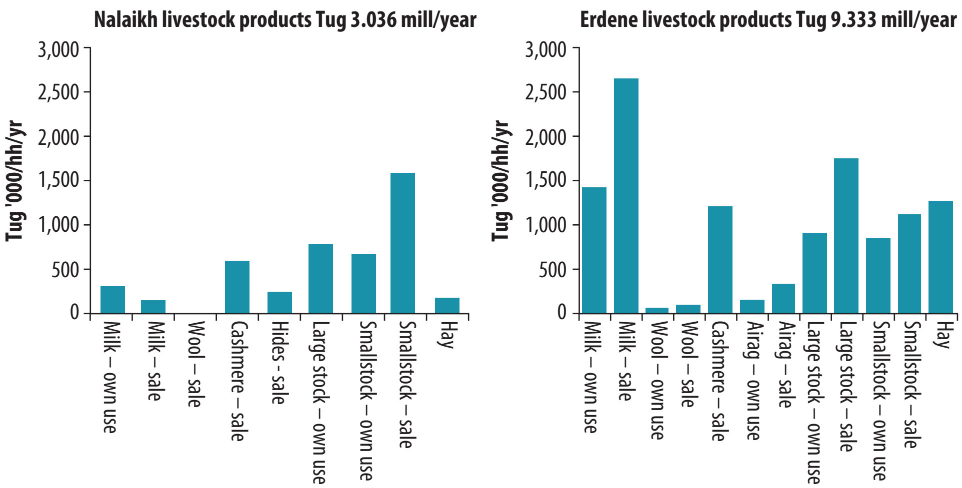
	Nalaikh group	Erdene group	All herders
	Total value of livestock production (Tug mill/year)		
Milk	100.21	1,026.99	1,127.19
Wool	0.98	9.71	10.69
Cashmere	109.54	294.97	404.51
Airag	—	29.29	29.29
Hides	77.21	—	77.21
Hay	53.95	313.24	367.19
Large stock (meat and sales)	223.39	472.61	696.01
Small stock (meat and sales)	266.66	382.32	648.98
All production	831.94	2,529.13	3,361.07
% own use	57%	41%	45%
% sale	43%	59%	55%
	Returns across all households (Tug mill/hh/year)		
Total for own use	1.72	3.84	2.77
Total for sale	1.31	5.49	3.39
Total all production	3.03	9.33	6.16
	Returns to production (Tug/unit/year)		
Returns to land (Tug/ha)	10,652	27,550	19,783
Returns to stock (Tug/SEU)	18,668	32,729	27,586

From study data

Ongoing land use changes are hastening and exacerbating the problem of over-stocking. As more and more land is being fenced in for tourist development, grazing pressure is intensifying. This has had two effects: to force herders to reduce their livestock numbers because of lack of pasture and to increase pressure on the areas of land that remain open for use. At the same time, a reduction in water availability (thought to be linked to climate change as well as increased water use by tourist camps) has also placed limitations on herding. This poses a particular problem for Nalaikh herders, whose settlements tend to be concentrated in tourist areas.

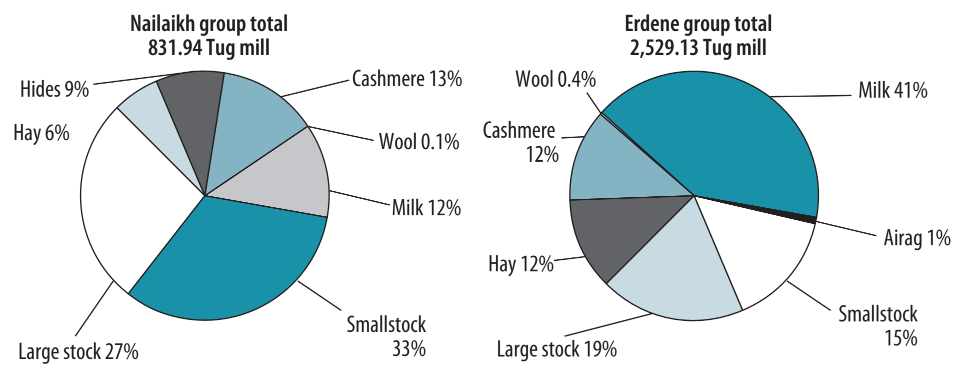
Land use pressure has given rise to conflicts. In several cases, serious land disputes have arisen between herders and land developers. For example, 120 hectares of land were recently fenced off for a golf course in Ogoomor Am. Area herders opposed the action, and the fenced land was reduced to 30 hectares. For Erdene herders, pasture is becoming insufficient to sustain the increased number of livestock in the area, especially during

Figure 14: Average annual value of household livestock production in the Upper Tuul



From study data. Note: figures for individual products indicate average annual value for households participating in these households; value for all livestock products calculated as average across all herder households and is therefore not the sum of average values of individual products.

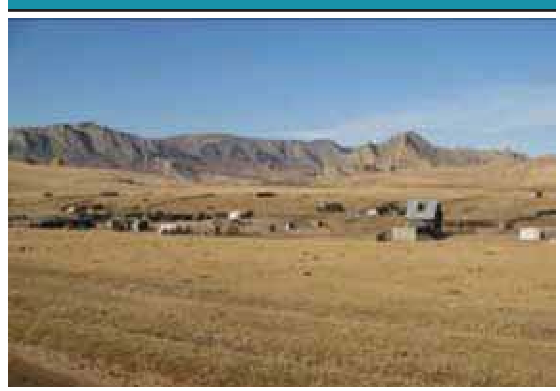
Figure 15: Share of livestock products in total herding income



From study data

Figure 16: Erdene herders' homestead

Figure 17: Nalaikh herders' settlement



winter months when settlements are more concentrated and herders from outside Erdene Soum move their livestock into the area. Herding settlements tend to be located relatively close to each other, meaning that multiple families use the same pasture area. While in some cases these overlaps do not cause problems, in other cases herding families have made efforts to exclude others from the pasture areas they use.

Timber and firewood

How land and resources are used

Approximately 113,672 hectares of the Upper Tuul Basin is forested.[27] More than 95 percent of forest is located inside Gorkhi-Terelj National Park and Khan Khentii Strictly Protected Area. As illustrated in Figure 20 the majority is closed natural forest (79,512 hectares), dominated by Siberian Larch (*Larix sibirica)* and Siberian Pine (*Pinus sibirica)*. Together the two species account for 93.5 percent of natural forest area. The remainder is comprised of small patches of Scotch pine, Birch, Spruce, Poplar, Willow, and Aspen. There are also an estimated 18,802 hectares of open, logged, and fire-damaged forest, and a very small area of plantation (less than 200 hectares).

According to Forest and Water Research Center figures, the total growing stock of all coniferous and deciduous forest in the Upper Tuul is estimated at just over 10 million cubic meters, around half of that in a mature forest (Table 6). General indicators show a growing density of 0.52, the mean annual increment is 1.02 cubic meters per hectare, and the mean ages of coniferous trees are between 100–140 years and deciduous trees 42–74 years.

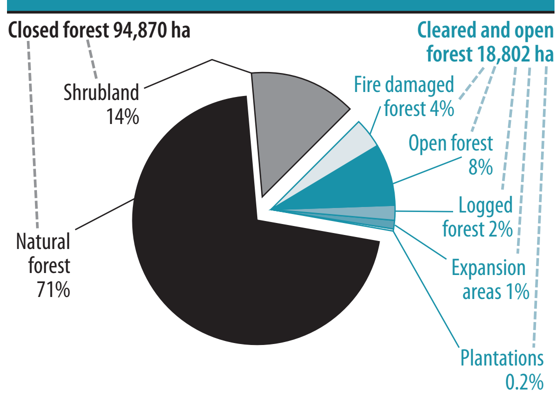
Intensive timber harvesting in the Upper Tuul commenced in the 1940s, with timber being rafted to Ulaanbaatar along the Tuul River. Timber

[20] There is some variation between estimates. These figures are taken from a forest inventory carried out in 2007 by the Forest and Water Research Centre of the Ministry of Nature and Environment.

Figure 18: Permanent grazing area, Tereljiin shugui

Figure 19: Erdene winter grazing area

Figure 20: Composition of forest cover in the Upper Tuul



From 2007 Forest Inventory, Forest and Water Research Center of the Ministry of Nature and Environment.

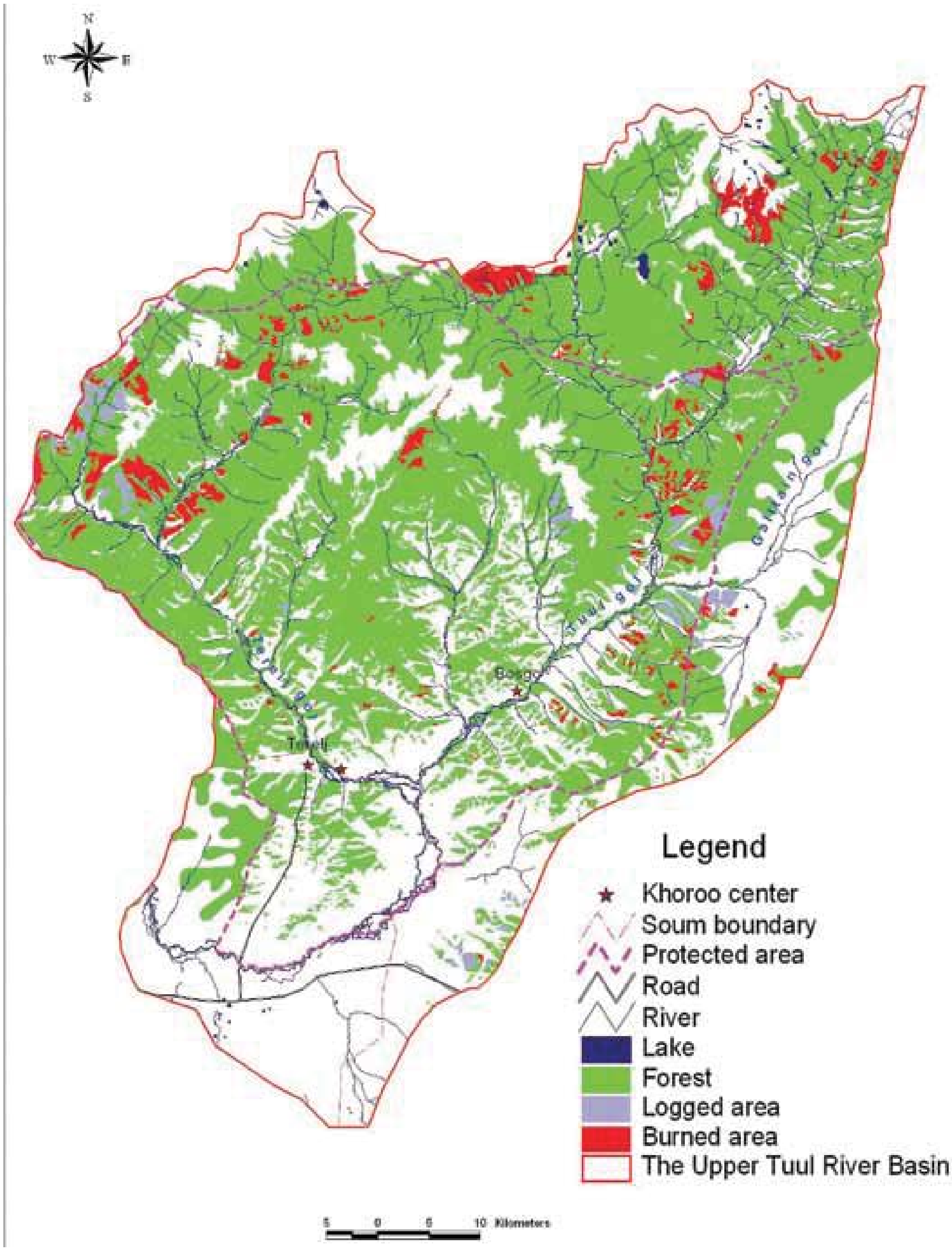
Table 6: Growing stock of natural forest in the Upper Tuul according to species and zone

	All natural forest		Mature natural forest	
Species	**Area (ha)**	**Growing stock (m^3)**	**Area (ha)**	**Growing stock (m^3)**
Siberian Larch	60,763	7,895,420	30,422	4,557,200
Siberian Pine	16,016	2,097,580	2,378	389,410
Spruce	105	11,280	—	—
Birch	1,304	53,470	55	2,760
Poplar	575	31,360	282	21,000
Aspen	72	6,280	10	900
Willow	677	9,630	—	—
Total	79,512	10,105,020	33,147	4,971,270
Of which:				
Protected Forest of special zones of Gorkhi-Terelj National Park (16.1 % of natural forest area)				
Siberian Larch	6,988	958,870	4,647	686,190
Siberian Pine	5,791	804,790	1,219	202,960
Protected Forest of limited zones of Khan Khentii Strictly Protected Area (6.1 % of natural forest area)				
Siberian Larch	1,332	147,740	1,268	140,990
Siberian Pine	3,542	406,280	537	77,930
Protected Forest of travel, tourism and limited zone of Gorkhi-Terelj National Park (73.0% of natural forest area)				
Siberian Larch	48,671	6,409,380	23,779	3,617,540
Siberian Pine	6,638	885,610	622	108,520
Spruce	105	11,280	—	—
Birch	1,304	53,470	55	2,760
Poplar	575	31,360	282	21,000
Aspen	72	6,280	10	900
Willow	677	9,630	—	—
Utilization Forest zone (4.8 % of natural forest area)				
Siberian Larch	3,772	379,430	728	112,480
Siberian Pine	45	900	—	—

From 2007 Forest Inventory, Forest and Water Research Center of the Ministry of Nature and Environment. In practice, not all of this growing stock is utilizable, due to restrictions on wood harvesting in the protected areas.

exploitation was stopped in 1952. Firewood harvesting (for both domestic and commercial purposes) continued up to 1990 in order to supply the demand in Ulaanbaatar, accounting for an estimated 50,000 to 70,000 cubic meters per year. Today, legal utilization of forest resources in the Upper Tuul is lower since the majority of trees are within the protected areas. Forests are managed primarily for biodiversity and watershed conservation purposes, not for extractive use (Map 14).

Map 14: Timber use in the Upper Tuul



Most of the households living in the Upper Tuul source all of their domestic energy and construction needs from local forests, consuming an estimated 8 cubic meters of firewood per year and around 30 cubic meters of timber per decade for construction needs. Some of this use is licensed. Of the 5,000 cubic meters of logging and firewood licenses that were issued in 2007, most were allocated for domestic consumption and institutions such as cooperatives, schools, and hospitals. Forest industries were however engaged in salvage operations, involving at least 5 commercial operators.

Actual levels of wood exploitation are far higher than the licensed volume. In all of Mongolia between 36 to 80 percent of wood harvest is thought to be illegal,[28] and illegal timber and firewood extraction remains a problem in the Upper Tuul. Local households are involved in timber and firewood harvesting without a license, and commercial forestry operations from Nalaikh District and Ulaanbaatar also operate outside the law. Local people estimate that between 8–10 small trucks with loads of between 4–5 cubic meters of timber are illegally brought out of the Upper Tuul each week by more than 25 commercial operators, supplying urban demand and mining needs. As shown in Table 7, the current harvest from the Upper Tuul is estimated to be 3,300 cubic meters of timber and 8,500 cubic meters of firewood, just under half of which is licensed.

The value of land and resource use

Wood products extracted from the Upper Tuul are estimated to be worth around Tug 308 million a year (Table 8). Local household use accounts for the majority of this, in terms of both volume and value.

Land and resources use impacts

Although over time timber and firewood exploitation have had an impact on the forests of the Upper Tuul, their effects tend to be highly localized. Unsurprisingly, firewood harvesting levels are particularly high around Terelj and the buffers of Gorkhi-Terelj National Park, particularly for Siberian Larch, Willow, and Poplar. Fires have also been a recurrent problem over the last decade, affecting large areas of forest in Artsat uul, Ar matakh, Ulaan khadnii uul, Dakhad uul, Ar Minj, Khalzangiin davaa, Ikh Chuluut, Nenekhiin gol, Khogoriin gol, Khar yamaat, Shinest, and Shorlogtoi (Figures 21–24).

[21] Crisp and others (2004).

Table 7: Harvest of timber and firewood harvests in the Upper Tuul

	Harvest (m^3/year)	
	Timber	**Firewood**
Legal cutting	643	4,384
Illegal cutting	606	4,114
Additional use for household structures	2,046	—
Total	3,295	8,498

From study data. Harvest refers to timber round logs and useable firewood; standing volume of timber felled is greater than this. Household use included in overall firewood estimates, but timber use (all assumed unlicensed) is in addition to these. There is (until May 2010) a prohibition on timber and firewood harvesting, thinning, salvage, and sanitation cuttings in the Tuul watershed by the order of the Minister for Nature and Environment in 2008, No 186/234 – data on licensed use therefore refer to previous year.

Table 8: Value of timber and firewood harvests in the Upper Tuul

	Harvest (m^3/year)		Market value (Tug million/year)		
	Timber	Firewood	Timber	Firewood	Total
Legal cutting	643	4,384	38.58	87.68	126.26
Illegal cutting	606	4,114	22.73	82.28	105.01
Additional use for household structures	2,046	—	76.73	—	76.73
Total	3,295	8,498	138.03	169.96	307.99
Local households	2,046	5,456	76.73	109.12	185.85
Commercial operators	1,249	3,042	61.31	60.84	122.15
Government royalties			9.65	19.48	29.13

From study data. Government royalties earned only from legal cutting. Value figures for different groups are not added in total.

Figure 21: Siberian Larch (*Larix sibirica*) in Gorkhi-Terelj National Park—a timber species

Figure 22: Willow (*Salix mongolica*) along the banks of the Tuul River—a firewood species

Figure 23: Harvesting of dead trees in burnt-out forest in Bugatiin am

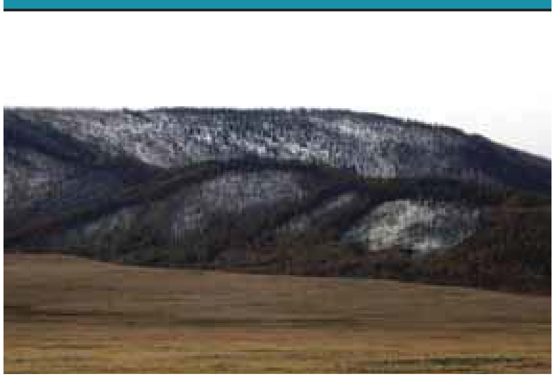


Figure 24: Small truck used to transport timber and firewood to Ulaanbaatar and Nalaikh

Non-timber forest products

How land and resources are used

A wide range of non-timber forest products are found in the Upper Tuul, including fruits and berries, pine nuts, wild vegetables, fungi, and medicinal plants (Table 9). Non-timber forest products are distributed fairly widely to the south of the Terelj River in the western part of Khan Khentii Strictly Protected Area as well as in central and northern parts and (for wild berries and fruits) along the Tuul River in the south-eastern portion of the Strictly Protected Area (Map 14). Resources are collected both by local households and by people from Nalaikh and Baganuur Districts. Harvesting takes place throughout the summer months and is concentrated in more accessible areas around the Tuul and Terelj Rivers (Map 15).

Although there are limitations on use, much of the exploitation takes place without licenses. Collection of non-timber forest products for home use only is permitted in restricted zones of the protected areas, and all harvesting of pine nuts in the Upper Tuul is currently prohibited. Just under half of households harvest fruits, berries, wild vegetables, and pine nuts, while a relatively small proportion (5 percent) of the population collects medicinal plants (Figure 25).

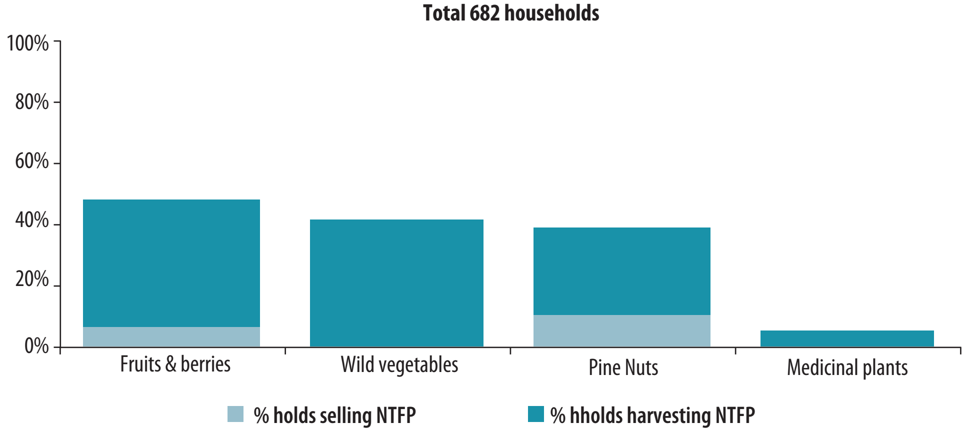
With the exception of pine nuts, the bulk of non-timber forest products are collected for home use—where they provide an important

Table 9: Commonly harvested non-timber forest products and main harvest periods

Fruits & berries	Siberian Hawthorn	*Crataegus sanguinea*	mid Aug–end Sep
	Wild Strawberry	*Fragaria orientalis*	
	Crabapple	*Malus baccata*	
	Asiatic Bird-Cherry	*Padus asiatica*	
	Alpine Blackcurrant	*Ribes altissimum*	
	Blackcurrant	*Ribes nigrum*	
	Northern Bilberry	*Vaccinium uliginosum*	
	Lingonberry or Cowberry	*Vaccinium vitis-idaea*	
Nuts	Pine nut	*Pinus sibirica*	Sep–Oct
Fungi	—	*Agaricus spp.*	Jun–Jul
	—	*Lactarius sp.*	
	—	*Leccinum sp.*	
	—	*Russula sp.*	
	—	*Suillus sp.*	
		Tricholoma mongolicum	
Wild vegetables	Wild Onion	*Allium altaicum*	May–Jun
	Alpine Leek	*Allium citorialis*	
Medicinal plants	—	*Adonis sibiricus*	May–Oct
	Wormwood	*Artemisia macrocephala*	
	Elephant Ears	*Bergenia crassifolia*	
	Shrubby Cinquefoil	*Dasiphora fruticosa*	
	—	*Gentiana macrophylla*	
	Wild Daisy	*Leontopodium spp.*	
	Plantain	*Plantago spp.*	
	—	*Rhodiola quadrifida*	
	Siberian Currant	*Ribes diacanthum*	
	Prickly Wild Rose	*Rosa acicularis*	
	Great Burnet	*Sanguisorba officinalis*	
	Stinging Nettle	*Urtica dioica*	
	Lingonberry	*Vaccinium vitis-idaea*	
	Valerian	*Valeriana officinalis*	

From study data.

Figure 25: Local household participation in NTFP harvesting in the Upper Tuul



From study data.

source of fruits, vegetables, and medicines, which are unavailable or unaffordable elsewhere to many members of the local population. Although there is a high-market demand for fruits, nuts, wild vegetables, fungi, and medicinal plants, especially in Ulaanbaatar, the relatively short harvest period of individual products combined with inaccessibility of many of the most productive areas for harvesting in the central and northern parts of Khan Khentii Strictly Protected Area mean that labor and transport costs are high. Although 77.5 percent of local households (or 528 households) collect various non-timber forest products, two-thirds harvest them only for use at home. Just 15 percent of households sell a portion of the non-timber forest products they collect, and 7.5 percent harvest only to sell (153 households in total). With the exception of pine nuts, sales tend to take place at a relatively small scale and on an informal basis, with portions of the harvest occasionally being sold on to local shops and traders.

Pine nuts from Siberian Pine (*Pinus sibirica*) are the most important commercial non-timber forest product in the Upper Tuul, and the only one that is sold at any scale or for which there is a well-organized and regular marketing system. There are more than 16,000 hectares of Siberian Pine in the Upper Tuul, which provide regular yields of cones and nuts as well as peak germination periods (or "big-bang" harvests), which occur every 4–6 years. Big-bang harvests potentially produce 1,662 tons of cones, yielding 332.4 tons of nuts. The majority of the pine nut harvest leaves the area unprocessed; there is only one small processing factory in Mungunmorti Soum of Tov Province.

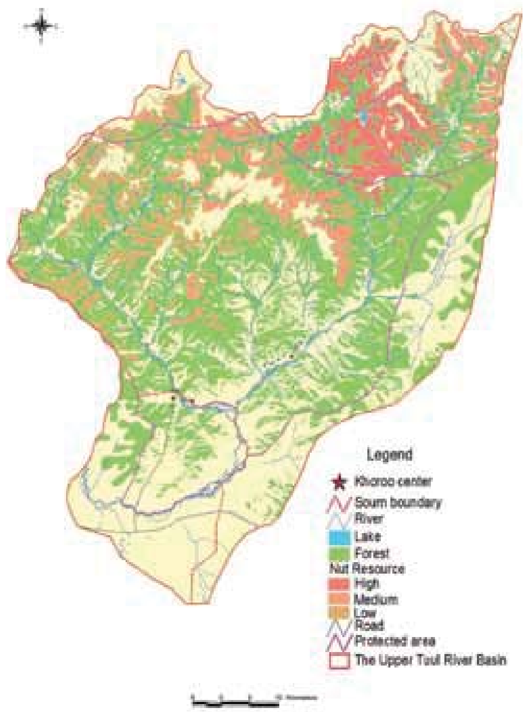
The value of land and resource use

In total, local exploitation of non-timber forest products are estimated to be worth some Tug 37.24 million a year, with fruits, berries, and pine nuts contributing the majority of this value (Table 10). Most of the harvest is consumed at home: only 15 percent of this value is accounted for by sales of non-timber forest products. An estimated 40–50 persons are engaged in harvesting pine nuts, working under the direction of middlemen who come in from Ulaanbaatar. Commercial utilization of pine nuts, including those bought from local households for onward sale, are estimated to have an average annual value of Tug 43.16 million (Table 11).

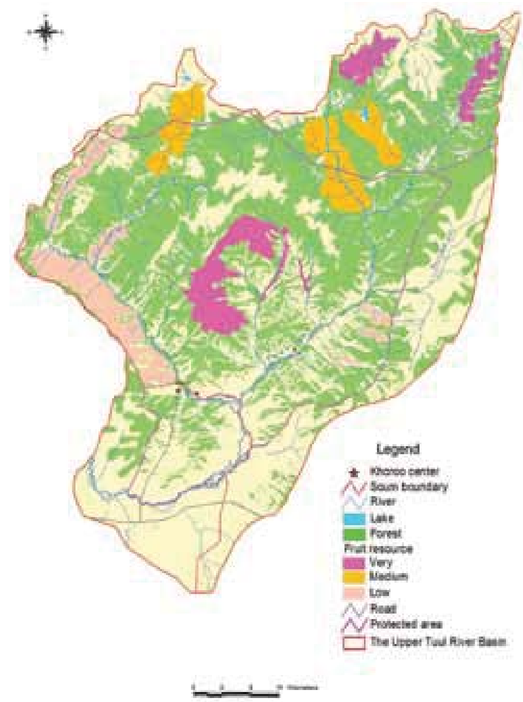
Land and resources use impacts

Little information is available on the sustainability of non-timber forest product utilization, although

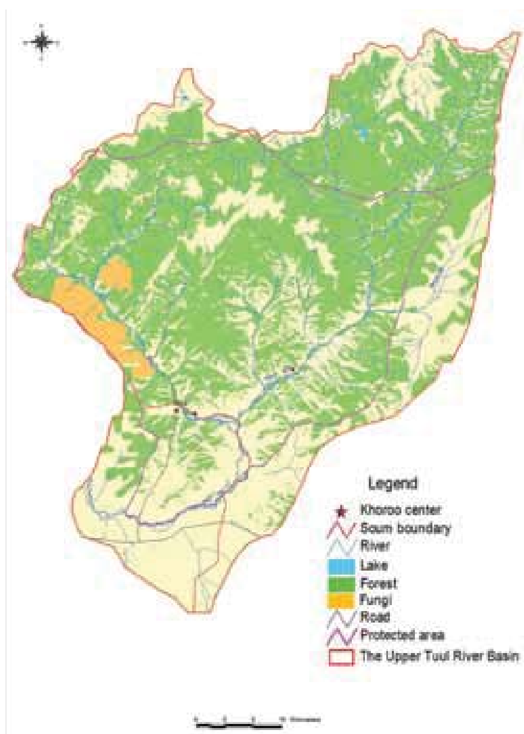
Map 15: NTFP use in the Upper Tuul



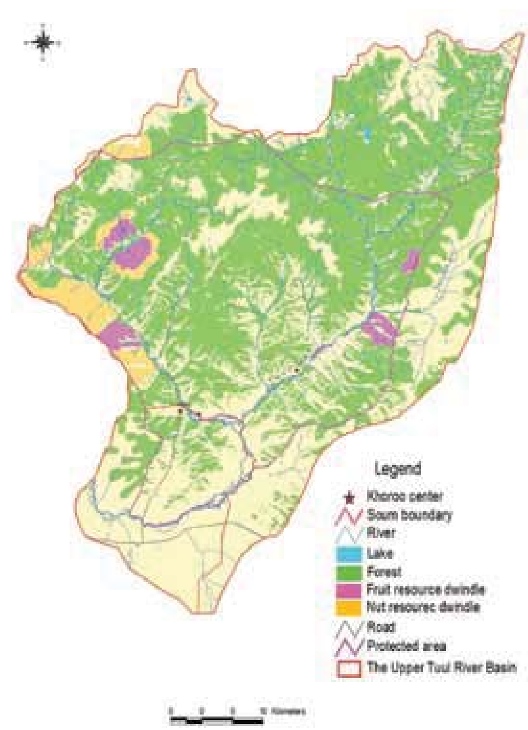
Location of pine nuts



Location of wild fruits



Location of fungi



NTFP harvesting impacts

Table 10: Value of NTFP harvests to local households in the Upper Tuul

	Average harvest (kg/hh/year)	Average price (Tug/kg)	Average value for users (Tug/hh/year)		Total value (Tug mill/yr)		
			Home	Sale	Home	Sale	Total
Fruits & berries	25	2,750	60,470	45,783	17.05	2.33	19.39
Wild vegetables	7.5	1,500	11,250	—	3.17		3.17
Pine nuts	47.5	1,500	55,355	47,447	11.07	3.18	14.25
Medicinal plants	2.5	5,000	12,500	—	0.43		0.43
Total					31.72	5.51	37.24

From study data.

Table 11: Value of pine nut harvests to middlemen in the Upper Tuul

	Value (Tug million/yr)
Non-peak harvest years	6.36
Additional value in "big bang" years	36.80
Total	43.16

From study data. Figures not additive to household values. "Big-bang" assumed to occur once every 6 years, and 25% of available yield currently harvested, so additional markup converted to annualized value.

it is known that some areas of the Upper Tuul are used intensively and that resources appear to be dwindling on the west bank of the Tuul-Bosgo and around the Terelj River in the west of the study area (Map 14). Surveys in 1998 found that local households perceived that all types of non-timber forest products had decreased in availability over time. In some places where they were found previously, they are no longer available. A particular problem, said to be caused mainly by people coming in from outside, is indiscriminate harvesting, where whole areas of vegetation or whole plants are destroyed.

Figure 26: Edible mushroom *Agaricus silvaticus*

Figure 27: Siberian pine nuts

Figure 28: Lingonberry or Cowberry *Vaccinium vitis-idaea*

Figure 29: NTFPs from the Upper Tuul marketed as medicinal plants

Summary of the current value of upper basin land and resource uses

Table 12: Summary of the current value of Upper Basin land and resource uses

Land/resource use	Total value (Tug mill/ year)	Local users			Value to outsiders (Tug mill/year)	Value to government (Tug mill/year)
		No. hh	Average value (Tug/hh/year)	Total value (Tug mill/year)		
Tourism	24,597.13	83	5,216,892.86	433.00	24,164.12	268.44
Herding	3,361.07	545	6,167,107.79	3,361.07	—	221.25
Timber	138.03	682	112,500.00	76.73	61.31	9.65
Firewood	169.96	682	160,000.00	109.12	60.84	19.48
Non-timber forest products	77.22	528	70,523.20	37.24	43.16	—
Total	28,343.40	682		4,017.16	24,329.43	518.82

From study data. Local tourism values refer to ger camps only, and exclude income from employment, sales of food, hire of horses, etc. 2008 figures for income tax from tourism used, as none before. Values for different groups do not sum to total, as this would result in double-counting.

4. Downstream Values: Water Use in Ulaanbaatar

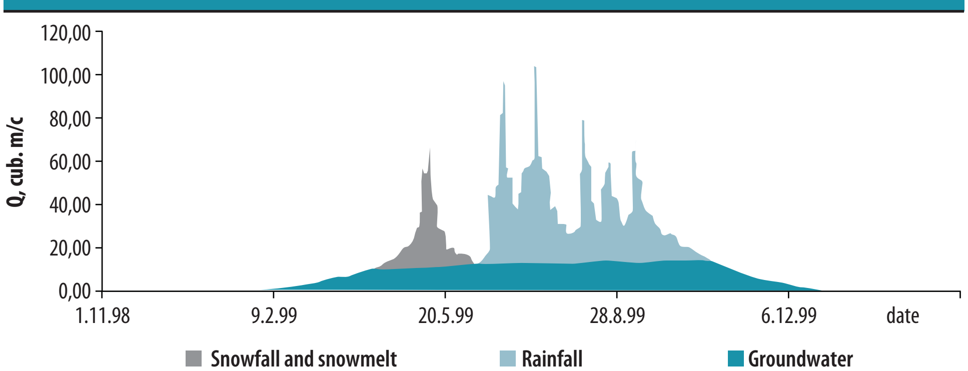
The eco-hydrology of the Tuul watershed

A brief description of the natural features of the Upper Tuul Basin has been provided in Chapter 2. The Tuul watershed has a continental climate, with a long cold winter and a short summer. Average annual precipitation is estimated at 403 millimeters, almost three-quarters of which occurs in summer between June and August. The area is covered by snow in winter, from October until as late as May, with snow depth reaching 15 centimeters. The upper basin is divided into 3 permafrost zones, which also affect the temporal runoff response of the watershed. Just over two-thirds of the runoff to the Tuul River is composed of rainfall, 6 percent is from snowfall and snowmelt, and one-quarter is sustained from groundwater (Figure 30).[29]

Average annual river flow of the Terelj at the confluence with the Tuul is estimated to be 9.12 cubic meters per second (m^3/sec) and annual river flow of the Tuul is 13.6 m^3/sec at the Bosgo Bridge and 26.6 m^3/sec at Ulaanbaatar. The river's flow varies considerably over the course of the year, depending on climatic and other conditions in the upper watershed (Figures 30, 31, and 32). Discharge usually increases toward the end of April and continues up to mid-May, when the maximum spring flood occurs due to snowmelt from the high mountains. Flow then decreases through the second half of May, settling to a stable drought period in late May and June. In July and August, and occasionally also in September, the river again

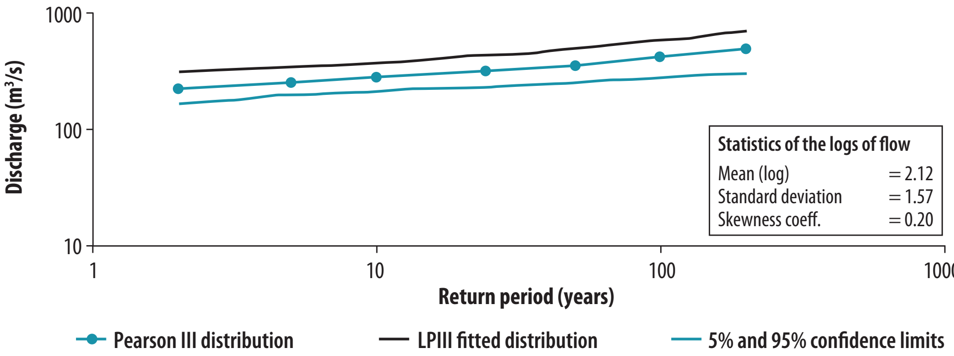
[22] Basandorj and Davaa (2005).

Figure 30: Runoff components in Tuul River flow at Ulaanbaatar



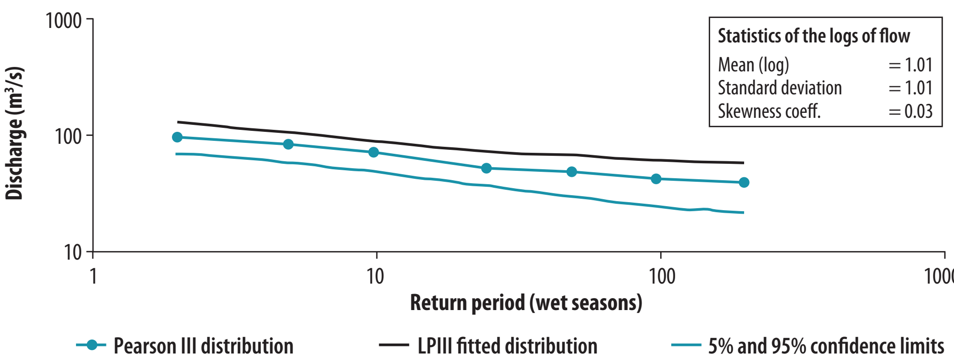
From Basandorj and Davaa (2005).

Figure 31: Flood frequency analysis for the Tuul River at Zaisan



From study data. Flood frequency analysis using average mean daily streamflow values (2000–2006); low flow frequency analysis using mean daily minimum streamflow values from June-September (2000–2006).

Figure 32: Low flow frequency analysis for the Tuul River at Zaisan



From study data. Flood frequency analysis using average mean daily streamflow values (2000–2006); low flow frequency analysis using mean daily minimum streamflow values from June-September (2000–2006).

floods due to rainfall in the upper watershed. At this time the maximum discharge is usually between 1.5 to 3 times higher than the peak flow of the spring flood. In winter, between October and March, the river freezes. The observed maximum discharge reaches 1,580 m³/sec in the Tuul River at Ulaanbaatar and 564 m³/sec at Terelj, while during low flow periods the river's 30-day minimum flow drops to 1.86 m³/sec and 0.44 m³/sec, respectively.[30]

Both unconfined and artesian aquifers underlie the area from the upper watershed to Ulaanbaatar, with water occurring to a depth of 2 to 75 meters.[31] The Tuul River interacts with groundwater in upper parts of the basin by being a "losing stream": it recharges the surrounding unconfined aquifer (the upper water source for Ulaanbaatar (as described in the next section). The bulk of groundwater recharge occurs from the Tuul River and runoff from the surrounding hills—recharge through precipitation is negligible when weighed up against the yearly groundwater extraction. Measurements of the groundwater

[23] Basandorj and Davaa (2005).
[24] Zandaryaa and others (2003).

table in production wells have shown that the groundwater table declines in winter and spring months (when precipitation is at the lowest) and returns to its average during spring thaws and the first rains. In spring, when ground defrosts, the recharge rate increases, causing the surface water table in the Tuul River to decline and in some to dry up seasonally.[32]

This unconfined aquifer provides the source of Ulaanbaatar's water. The groundwater table fluctuates depending on natural conditions (such as seasonal changes in atmospheric precipitation, evaporation, elevation of the surface water table, and atmospheric pressure), as well as levels and rates of water abstraction, but is also heavily influenced by the ecological and hydrological conditions in the upper watershed. Land use, land cover, and soil condition in the Upper Tuul govern the contact time and water pathway through which the various soil-water interactions occur. Vegetative cover in the upper watershed is particularly critical as it impacts on interception, runoff, and discharge patterns. The quality and extent of forest, grassland, and other vegetation in the Upper Tuul affect mean flow, flow duration, intensity and timing of peak and low flows downstream, soil moisture, groundwater recharge, and sediment loads.

Water supplies in Ulaanbaatar

Ulaanbaatar's water supplies are extracted from deep wells, located in 4 sites: the "upper source" just below the confluence of the Terelj and Tuul Rivers in the upper basin, and 3 sources in the city itself ("central", "industrial", and "meat factory"). Ulaanbaatar Water Supply and Sewerage Company (USAG) manages most of the city's water supplies, supplying in bulk to the Housing and Public Services Company (OSNAAG) that is responsible for distributing water to apartment buildings and institutions in the core area of the city. The Ministry of Food, Agriculture and Light Industry (MFALI) is responsible for irrigation water; wells are also operated by the Ulaanbaatar's 3 power plants and used by surrounding factories.[33]

Different data sources provide varying estimates of both the total number of wells and those that are actually in use.[34] This study uses figures presented in the 2007 Ulaanbaatar City Masterplan for USAG-operated wells and figures from Basandorj and Davaa (2005) for wells operated by power plants since these seem to provide the most up-to-date figures as well as give the most comprehensive information on their capacity. As shown in Table 13, the 120 large wells currently in operation pump a maximum of just over 195,000 thousand cubic meters per day. In addition to these major water sources, an estimated 297 private wells have been dug, which serve something over 600 businesses and industries and supply around 3,000 cubic meters of water per day.

Some 56.26 million cubic meters of water were recorded as being supplied to users in Ulaanbaatar by USAG/OSNAAG in 2007 (Figure 33). The amount of water supplied decreases between February and May, when the Tuul River is in low flow and groundwater levels drop. This is however also the time of the year when demand peaks, and shortages frequently occur in the city. In addition, leakage is a major problem. It is estimated that unaccounted water accounts for around 30 percent of total water abstractions in Ulaanbaatar City.[35]

Water is pumped from the wells via distribution pipelines to industries and some government offices, to central distribution points for onward supply to apartment blocks, and to a pipeline and water tanker operation delivering to water kiosks in ger settlements. Apartment dwellers are by far the largest consumers of water, accounting for over half of the total supplied by USAG/OSNAAG (Figure 34). This is because of the large number of users, as well as their high per capita water consumption rates. Ger settlements, although contributing 60 percent of Ulaanbaatar's population, account for

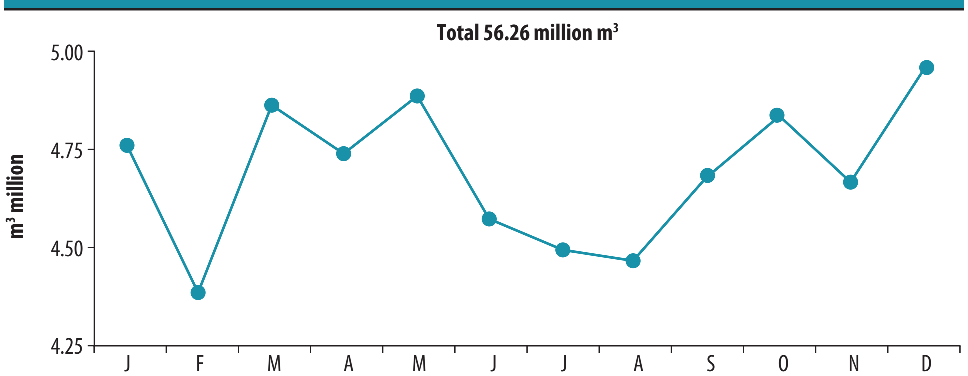
[25] Zandaryaa and others (2003).
[26] Basandorj and Davaa (2005).
[27] Staff of Ulaanbaatar Water Supply and Sewerage System Company estimate that 100 of 175 wells are in use, Davaa and Basandorj (2005) cite figures of 163 wells in use, and the Ulaanbaatar City Masterplan 2007 refers to 180 wells of which 90 are in use.
[28] JICA and Government of Mongolia (2007).

Table 13: Water capacity in Ulaanbaatar City, 2007

Water source	Number of wells: Total	Number of wells: Operating	Capacity (m³/day): Design	Capacity (m³/day): Working
Upper	56	19	72,000	47,307
Central	97	55	114,000	64,150
Industrial	16	11	40,000	22,200
Meat factory	11	5	15,000	11,160
USAG water sources	180	90	241,000	144,817
Power plant no. 2 (Central)	—	5	—	4,800
Power plant no. 3 (Central)	—	13	—	29,300
Power plant no. 4 (Industrial)	—	12	—	16,200
Other water sources	—	30	—	50,300
Private wells	—	297	—	3,000
Total	—	417	294,300	198,117

From JICA and Government of Mongolia (2007); Basandorj and Davaa (2005).

Figure 33: Water supplied by USAG, 2007



From USAG data.

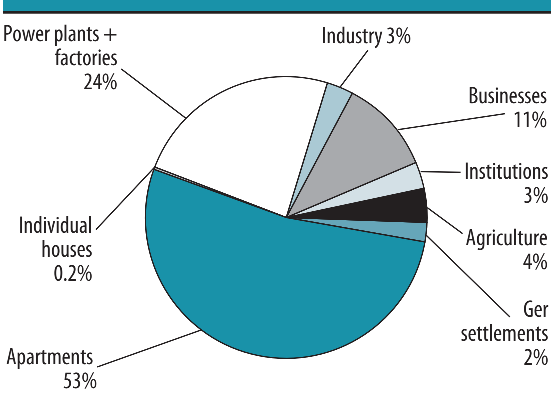
just over 2 percent of total demand. Estimates for total water demand (Table 14) show that domestic demand for water accounts for some 117,000 cubic meters per day, and industrial and commercial demand (including power plants) for some 95,000 cubic meters per day. The estimates provided by this study are consistent with those provided by recent data, which indicate that industrial water use is between 85,000 and 100,000 cubic meters per day and that total demand is between 200,000 and 250,000 cubic meters per day.[36]

[29] Presentation made by Tuul Songino Water Resource Joint Stock Company 2007.

Table 14: Water demand in Ulaanbaatar by user group, 2007[37]

Type of user		USAG/OSNAAG water supply		Estimated total demand	
		No. users	Volume (m^3 mill/year)	No. users	Volume (m^3 mill/year)
Ger settlements	using water kiosks supplied by tanker	300,000 people	0.73	620,950 people	1.70
	using water kiosks supplied by pipeline	31,782 people	0.41		
Apartment dwellers		269,569 people	27.32	403,260 people	40.87
Individual houses	domestic	953 connections	4.47	6,990 people	0.22
	non-domestic			18,333 businesses	4.25
Industries		304 connections	2.30	304 industries	2.3
Power plants				3 plants + factories	18.36
Business and commercial users		1,379 connections	4.04	1,379 businesses	4.04
Other institutions		311 connections	2.67	311 institutions	2.67
Agricultural	Crops			367 farmers	1.50
	Livestock			7,797 herders	1.37
Total			41.94		77.28
Water kiosks supplied by tanker		296 kiosks	0.73	296 kiosks	0.73
Water kiosks supplied by pipeline		163 kiosks	0.41	163 kiosks	0.41
Water tankers		61 tankers	—	61 tankers	—

Figure 34: Water demand in Ulaanbaatar by user group, 2007



Urban water values

Tariffs for water use in Ulaanbaatar vary according to the type of user and the means by which water

[30] USAG data on water supply do not concur with the population figures presented in official statistics, or with estimates of per capita water demand provided by other studies. Records of water supplied via kiosks indicate a user population that is only around one-half of ger settlement dwellers. Figures for individual household connections cover only around two-thirds of apartment dwellers, as well as showing extremely high daily consumption rates per user as compared to other estimates. Estimates for total demand take census estimates of the population living in ger settlements, apartments, and individual houses and apply average per capita consumption figures from other studies of 7.5 liters per capita per day for ger dwellers and 87 liters per

Table 15: Water tariffs in Ulaanbaatar

User group	Water tariff (Tug/m^3) 1999	2002	2005	2007
Piped water to industries and businesses	200	200	315	329
Piped water to budget organizations	200	200	315	329
Piped water to households	95	181	160	167
Piped water to metered apartments	40	112	160	167
Tanker water to industries within 10 km	885	2,435	2,435	2,435
Tanker water to industries above 10 km	1,328	2,609	2,609	2,609
Tanker water to summer houses	885	1,500	2,000	2,727
Water sold from kiosks	442	442	500	909
Other tanker water	885	885	1,000	1,818
Irrigation water		200	500	3,000

From USAG and MFALI data.

is supplied. The USAG collects revenues from city water supplies while the MFALI charges for irrigation water. As shown in Table 15, water tariffs have been subject to several revisions over recent years. The relatively high tariff for water supplied to ger settlements from kiosks is notable, especially given that these contain some of poorest sectors of the urban population.

Despite these increases, the price of water remains highly subsidized. It is estimated that current tariffs cover only about 30 percent of the unit cost of supply. The actual value of water to users is far higher than the price they pay. However, as data are lacking that would enable more accurate calculations (for example, the returns to water in different productive uses or detailed and disaggregated water user surveys), this study bases its valuation of water on the current tariffs paid. In order to compensate at least partially for the fact that water tariffs are so much lower than real water values, an inflator is applied to these figures (this is described below). The inflator represents consumers' actual willingness to pay for water, which exceeds the tariff, and is closer to its real value—although, it should be noted, is still a considerable underestimate. It is also worth noting that as shortages persist, the marginal value of additional water is likely to increase substantially. For all these reasons, the water values presented in the study should be taken as an absolute minimum preliminary estimate.

Domestic

From the data provided by the USAG, MFALI, and other sources, it is possible to build up a

capita per day for domestic users living in individual houses. The average consumption rate for apartment dwellers of 278 liters per capita per day implied by USAG data is taken. The balance of water supplied through USAG to individual houses is assumed to be used for non-domestic purposes (small-scale business or commercial purposes) by establishments that are not recorded under the industrial, business, and commercial user category of water connections, using numbers of enterprises taken from the census. This gives an average daily consumption for business establishments of 635 liters per day. Data for agricultural (crop and livestock) water demand are taken from Ministry of Agriculture figures, and estimates for power plants and surrounding factories are from Basandorj and Davaa (2005).

picture of the ways in which water is accessed for domestic use in Ulaanbaatar:

- The majority of the 620,950 people, or 141,125 households, living in ger settlements obtain their water from kiosks. A proportion of ger dwellers still access their daily water needs from shallow wells, open springs, streams, and rivers. Of the 459 kiosks, 163 are connected by pipeline to the main water network. A fleet of 61 tankers, each carrying 5 tons of water, supplies the remainder. For most people in ger settlements, water consumption is less than 10 liters per capita per day,[38] with an average of 7.5 liters:[39] figures which are far lower than for any other category of water users.
- Most of the 403,260 apartment dwellers, or 91,650 households, receive their water via a central supply to the entire block. Although water meters were introduced several years ago, they have only been installed in a small proportion of apartments—an estimated 15,000 meters covering around 20,000 households.[40] Average water consumption for apartment dwellers is 290 liters per capita per day for those without a meter and 230 for those with a meter,[41] or an average overall of 278 liters per capita per day.[42]
- Almost all of the 6,900 people living in 1,968 individual houses have their water supplied via pipelines or private wells. Average daily water consumption is estimated at 87 liters per capita.[43]

It is far harder to value accurately the use of water for domestic purposes. Although data are available for the amount of money people pay for water use, the prices set by authorities present an underestimate of the actual value of water. Water tariffs in Ulaanbaatar remain low[44] and continue to be heavily subsidized.[45] Consumer willingness to pay provides a more generally accepted estimate of water values. There are no private or informal water markets in Ulaanbaatar, but surveys have however been carried out on water affordability and consumer willingness to pay in ger settlements of the city, as part of a 2007 study by the World Bank and the Public-Private Infrastructure Advisory Facility.[46] This study found that ger dwellers' willingness to pay for water was significantly higher than prevailing tariffs, on average 1.5 times as much as the actual charges levied. This study applies the same inflation factor (1.5 times the current water tariff for ger dwellers) in order to impute a minimum value of water in domestic use, giving a total value of water of Tug 58.35 billion a year (Table 16).

[31] World Bank and PPIAF (2007).
[32] JICA and Government of Mongolia (2007), and Zandaryaa and others (2003).
[33] Basandorj and Davaa (2005).
[34] JICA and Government of Mongolia (2007), and Zandaryaa and others (2003).
[35] From USAG figures.
[36] JICA and Government of Mongolia (2007).
[37] Basandorj and Davaa (2005).
[38] World Bank and PPIAF (2007).
[39] World Bank and PPIAF (2007).

Table 16: Value of domestic water use

	No. people	Volume (m^3 mill/year)	Tariff (Tug/m^3)	Imputed willingness to pay (Tug/m^3)	Value (Tug mill/year)
Ger settlements	620,950	1.70	909.09		2,317.98
Apartment dwellers	403,260	40.87	167.27	1,364	55,730.64
Individual houses	6,990	0.22			302.68
Total	1,031,200	42.79			58,351.30

From study data and USAG figures.

Industrial and commercial

Official statistics show a total of 20,327 registered businesses, industries, and other enterprises and institutions in Ulaanbaatar. These include major manufacturing enterprises that produce textiles and related goods, leather and footwear, soap, paper, iron castings, cement, glassware, beer and spirits, bottled water, and processed foods. Three thermal power stations are also located in the city, each with its own water supply. All of these enterprises depend in some way on water. While some industrial processes require water as a direct input into the products being manufactured, others require water for cooling and cleaning purposes.[47]

The power plants and a few other large factories consume the major proportion of water used by all industries and businesses in Ulaanbaatar.[48] Water use is increasing rapidly as the number of factories and other production facilities increases. In 2003, total industrial and commercial consumption was put at 50,000 to 60,000 cubic meters per day or 18.25 to 21.90 million cubic meters per year.[49] Current demand for water is estimated at just over 30 million cubic meters.

As for domestic users, the value of this water has been calculated by taking the prevailing USAG-charged industrial and commercial tariff and applying a willingness to pay inflator of 1.5. As illustrated in Table 17, this gives an annual value of commercial and industrial water use of Tug 15.6 billion. Again, this is an underestimate of the actual value of water since available data do not permit more accurate indicators to be calculated, such as the marginal value of water in different production uses or the value-added to production per unit of water input.

Agricultural

There are currently an estimated 121 irrigated farms in Ulaanbaatar involving 367 families and covering 290 hectares. These farms are irrigated from the Tuul River and from shallow wells using an estimated 1.5 million cubic meters of water per year. They mainly produce potato, cabbage, turnip, spinach, cucumber, tomato, and other vegetables for sale in the city. Around 8,000 herder families also live in the peri-urban areas that surround Ulaanbaatar, managing more than 330,000 camels, horses, sheep, and goats or 724,000 SEUs.

As for other types of water use, the value of water used for agriculture has been calculated

[40] Sharav (2007).
[41] Zandaryaa and others (2003).
[42] Zandaryaa and others (2003).

Table 17: Value of industrial and commercial water use

<table>
<tr><th></th><th>No. users</th><th>Volume (m^3 mill/year)</th><th>Tariff (Tug/m^3)</th><th>Imputed willingness to pay (Tug/m^3)</th><th>Value (Tug mill/year)</th></tr>
<tr><td>Industries</td><td>304</td><td>2.30</td><td rowspan="3">329.32</td><td rowspan="4">494</td><td>1,136.15</td></tr>
<tr><td>Business & commercial</td><td>19,712</td><td>8.29</td><td>4,094.12</td></tr>
<tr><td>Other institutions</td><td>311</td><td>2.67</td><td>1,318.93</td></tr>
<tr><td>Power plants</td><td>3</td><td>18.36</td><td>—</td><td>9,069.23</td></tr>
<tr><td>Total</td><td>20,330</td><td>31.62</td><td></td><td></td><td>15,618.43</td></tr>
</table>

From study data and USAG figures. No charge is levied for power plants' use of water, and so the prevailing industrial tariff has been applied.

Table 18: Value of agricultural water use

	Production	Volume (m^3 mill/year)	Tariff (Tug/m^3)	Imputed willingness to pay (Tug/m^3)	Value (Tug mill/year)
Irrigated farms	413 ha	1.50	3,000	4,500	6,755.40
Livestock production	331,224 stock or 724,341 SEUs	1.37	—		6,180.36
Total		2.87			12,935.76

From study data and MFALI figures. Production area for irrigated farms takes account of double cropping. No charge is levied for livestock use of water, and so the prevailing irrigation tariff has been applied.

by taking the prevailing MFALI-charged irrigation water fee and applying a willingness-to-pay inflator of 1.5 (and as mentioned, this represents very much a minimum estimate of the value of water in these uses). As shown in Table 18, this gives an annual value of Tug 12.94 billion for the 2.87 million cubic meters of water used for agriculture.

Summary of the current value of downstream water use

As shown in Table 19, the total value of water use in Ulaanbaatar is some Tug 86.9 billion per year. Actual revenues earned by USAG are in the region of Tug 9.3 billion a year (63 percent of their total revenues) and an estimated Tug 4.5 billion for MFALI.

Table 19: Water use values in Ulaanbaatar

	Volume (m^3 mill/year)	Value to users (Tug mill/year)	Revenues collected by government (Tug mill/year)
Ger settlements	1.70	2,317.98	9,276.70
Apartment dwellers	40.87	55,730.64	
Individual houses	0.22	302.68	
Industries	2.30	1,136.15	
Business & commercial	18.36	9,069.23	
Other institutions	8.29	4,094.12	
Power plants	2.67	1,318.93	
Irrigated farms	1.50	6,755.40	4,503.60
Livestock production	1.37	6,180.36	
Total	77.28	86,905.49	13,780.30

5. Ecosystem Water Services: Hydrological Consequences of Land Use Change in the Upper Tuul

Changes in the ecology and hydrology of the Upper Tuul

Ecological and hydrological changes have been taking place in the Upper Tuul Basin over the last decades with impact on downstream water flows and groundwater levels. Groundwater tables in the unconfined aquifer underlying Ulaanbaatar show a marked decline: a fall of some 3.1 meters over the last 50 years in the central water source, and a lowering of up to 8.5 meters in the aquifers of the Tuul River tributaries.[50] Depression cones (the areas of influence of the wells) are indicating groundwater shortage, and in some areas have reached critical levels. Presently there is less cause for concern about water abstractions during summer months—it is estimated that an amount of water equal to half of the summer recharge can be abstracted annually without causing a negative impact on the groundwater regime, and this limit does not yet appear to have been reached.[51] However, in the winter months (when the groundwater table is at its lowest level), abstraction exceeds the recharge rate, and the water table in the production wells drops—drawdown of the groundwater table of between 7 and 13 meters has been observed within a radius of 0.5–1.3 meters surrounding the wells.[52]

One reason for the lowering of groundwater levels is the rapid rate of withdrawal. Water is being abstracted faster than the rate of recharge.[53] The current water demand of Ulaanbaatar is estimated by this study to be some 212 thousand cubic meters per day (as outlined in Table 14, Chapter 4), which is consistent with the figures presented in other documents. According to date provided by the National Statistical Office, USAG, and the Ulaanbaatar City Masterplan prepared by the Japan International Cooperation Agency, Ministry of Construction and Urban Development, Ministry of Roads, Transport and Tourism, and Ulaanbaatar City Government, future water demand for the city is predicted to reach 286,000 cubic meters in 2010, 438,000 cubic meters in 2020, and 708,000 cubic meters in 2050. The projections for future water demand made in this study follow these estimates.

The design capacity of all existing wells (USAG and others) is about 300,000 cubic meters per day, and their current operating capacity is something over 200,000 cubic meters. The total groundwater development capacity from the unconfined aquifer is estimated to be in the vicinity of 348,000 cubic meters per day,[54] of which 215,000 to 220,000 cubic meters are of adequate

[43] Zandaryaa and others (2003), and Basandorj and Davaa (2005).
[44] Zandaryaa and others (2003).
[45] Zandaryaa and others (2003).
[46] Basandorj and Davaa (2005).
[47] Basandorj and Davaa (2005).

quality for human consumption.[55] As a comparison of these figures shows and as several authors have noted, it seems clear that under current conditions and likely future trends Ulaanbaatar will be facing severe water shortfalls within the next 10 years.[56]

Supply-side factors are also critical in determining the water balance in Ulaanbaatar. The city's groundwater resources are being severely compromised due to changes in the ecology and hydrology of the Upper Tuul, which have been caused by human land and resource use pressures. Most notable is the loss of vegetative cover and soil degradation resulting from deforestation, overgrazing, and the conversion of natural areas to housing and tourism developments.[57] The results of hydrological analysis show a serious deterioration, including increased runoff, maximum flows and flow variability, and decreased regulation of seasonal flows (lower dry-season flows and more serious flood peaks, as well as changes in their timing and duration).[58] The proportion of direct runoff (or overland flow) in the annual flow of the Tuul River has increased over the last 6 decades. The runoff coefficient for the Upper Tuul (the ratio of annual runoff to average precipitation in the upper watershed) increased from 0.49 in the period 1945–74 to 0.57 in 1975–2000. While average annual precipitation has remained steady or fallen slightly (from 255 to 250 millimeters per year), discharge has increased (from 126 to 149 millimeters per year) and there has been a drastic decrease in evapotranspiration (a change of 22 percent, from 129 to 101 millimeters per year). There has, in turn, been a significant reduction in water storage and groundwater recharge in the unconfined aquifer that supplies Ulaanbaatar.[59]

Climate change is a third factor that is undoubtedly influencing the ecology and hydrology of the Upper Tuul—although as yet there are few quantitative data and little detailed analysis to draw on. Evidence of increasing temperatures in the Upper Tuul shows that over the last 60 years annual mean air temperature increased by 1.56ºC (particularly in winter months, to a lesser extent in the spring and autumn, and showing unclear trends in the summer season).[60] This has led to a decrease in both the duration and the depth of snow cover, altered the timing and length of snowmelt periods, and impacted on downstream flooding regimes. Meanwhile, water temperature in the Tuul River is recorded to have increased by 1.9ºC over the same period, and there has been a decrease in the number of days with ice cover as well as changes in the thickness of ice cover and timing of ice formation and break-up.[61] Although their exact impact in the Upper Tuul remains unknown, there is little doubt that climate variability and change pose a substantial risk—and give rise to considerable uncertainty—for the future water security of Ulaanbaatar.

Future management scenarios for the Upper Tuul

Chapter 2 delineates 4 zones of human influence in the Upper Tuul Basin, marked out by both physical and human features. Summarized in Table 20, zones I to IV (from the north to the south of the watershed area) are characterized by rising population and settlement, growing human influence, and increasing ecosystem disturbance, with land and resource uses becoming more intensive and exerting a progressively greater influence on the natural landscape.

A review of historical records shows that these zones of human influence have been expanding steadily outwards into the Upper Tuul Basin. This is driven by a wide range of factors, including a growing human population, increasing urbanization, intensifying land and resource demands, progressive market integration, and shifting lifestyles and aspirations. Figure 35 indicates current pressure points and expanding zones of

48 Zandaryaa and others (2003).
49 Zandaryaa and others (2003).
50 Basandorj and Davaa (2005), and Davaa and Erdenetuya (2005).
51 Davaa and others (2006: 55–68).
52 Basandorj and Davaa (2005), and Davaa and Erdenetuya (2005).
53 Natsagdorj and Batima (2003) , and Basandorj and Davaa (2005).
54 Basandorj and Davaa (2005).

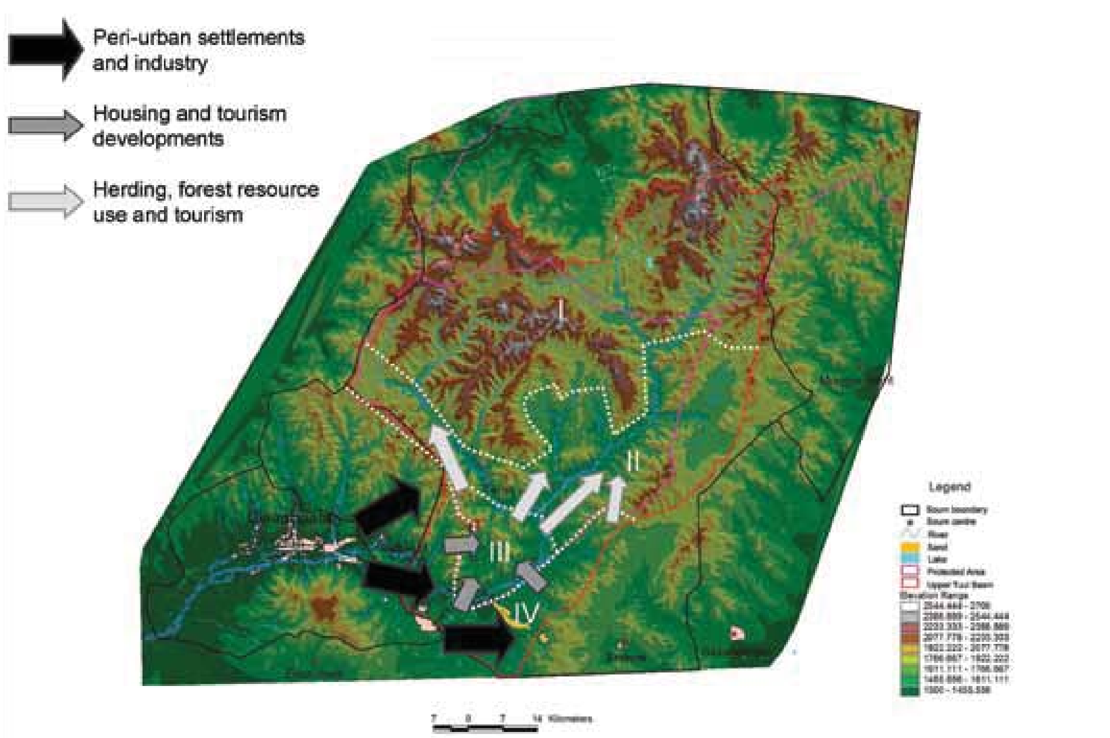
Table 20: Characterization of current status of zones of human influence in the Upper Tuul Basin

Zone of influence	Zone I	Zone II	Zone III	Zone IV
Area of watershed	**North**	**Central and east**	**South-central**	**South**
Description	Central Khan Khentii Strictly Protected Area	South and south-eastern Khan Khentii Strictly Protected Area	Gorkhi-Terelj National Park	Eastern, southern and western buffers of Gorkhi-Terelj National Park
Accessibility	Largely inaccessible except for far south and west around Terelj River	Some accessibility from west, south and east	Accessible from west, south and east	Easily accessible
Human population	Little or none	Small population of summer season herder camps and occasional tourists	Large seasonal influx of tourists, camp workers and herders; permanent resident population in Terelj and Bosgo	Permanent resident population of business people and herders, large seasonal influx of tourists and camp workers
Main land cover	Forest, rocky areas	Forest, grassland in riverine areas	Grassland, built-up areas and small patches of forest	Pasture and small patches of forest
Main land and resource uses	Occasional pine nut collection, small amount of summer grazing along river, burnt and logged forest	High levels of NTFP collection (wild fruits, fungi, pine nuts) summer grazing along river, burnt and logged forest	Tourism, seasonal and permanent herding, centers of settlement	Permanent grazing, tourism
Impacts of human use	Minor	Minor but growing: patches of forest beginning to show signs of intensive use for NTFP, increasing grazing	Significant changes in vegetation: conversion to settlement and tourism, some land and pasture degradation	Major changes in vegetation: conversion to settlement and tourism, severe pasture degradation

human influence into the Upper Tuul. It shows the spread of peri-urban settlements and industry from Ulaanbaatar, Gachuurt, and Nalaikh into the protected area buffer zone (zone IV), the expansion of housing and tourism developments into the area abutting and immediately inside Gorkhi-Terelj National Park (zones IV and III), and the growing incursion of herding, forest resource use, and tourism into Khan Khentii Strictly Protected Area (zone II).

There is little doubt that these land and resource use pressures will continue and intensify in the future. To a large extent, they are interlinked: as each wave of land use change expands into the upper watershed, it opens up the area (and displaces prior land uses) for further changes. Over time, if current trends remain unchecked, zone IV is likely to evolve progressively into a more densely settled area. This is already happening as peri-urban zones push outwards from Ulaanbaatar and Gachuurt, land privatization and sub-division take place, infrastructure and roads are extended, and more and more city-dwellers build weekend homes. In turn, tourism is being pushed further into zones IV and III and toward the north of Gorkhi-Terelj National Park and south of Khan Khentii Strictly Protected Area.

Figure 35: Expanding zones of human influence in the Upper Tuul Basin



Herders, losing their permanent grazing lands to settlement and tourism development, are increasingly moving along the Tuul and Terelj Rivers into zone II. As pasture areas and herding expand, the forest resources surrounding the riverine area are becoming more intensively used. It is only zone I, the central area of Khan Khentii Strictly Protected Area, which is likely to remain relatively untouched—due to the mountain range that presents a physical barrier to further human incursion and land use change.

The pace at which the boundaries of human influence expand into the Upper Tuul and the resulting levels of ecosystem change will depend largely on how the watershed is managed in the future. The study models three possible future management scenarios for the Upper Tuul over the next 25 years: gradual ecosystem deterioration (a continuation of current trends), rapid resource depletion and land degradation, and conservation and sustainable use. Table 21 summarizes each of these scenarios for the future management of the Upper Tuul, and the land and resource use changes that are projected to accompany them.

The study models changes in land cover and ecology according to these future management scenarios for the Upper Tuul. It should be noted that fairly conservative estimates of change are used, based on observed current and recorded historical patterns. This is to avoid over-estimating the level of land and resource degradation that might occur in the Upper Tuul in the future. In line with these projected changes in population, land, and resource use and allowing for possible climate variability, the proportion of bare, built-up, and grassland land cover will increase over time while forest cover will decrease. As illustrated in Figure 36 the rate of these changes is most rapid under the scenario of no protection, and slows considerably under the conservation and sustainable use scenario.

Table 21: Summary of possible future management scenarios for the Upper Tuul

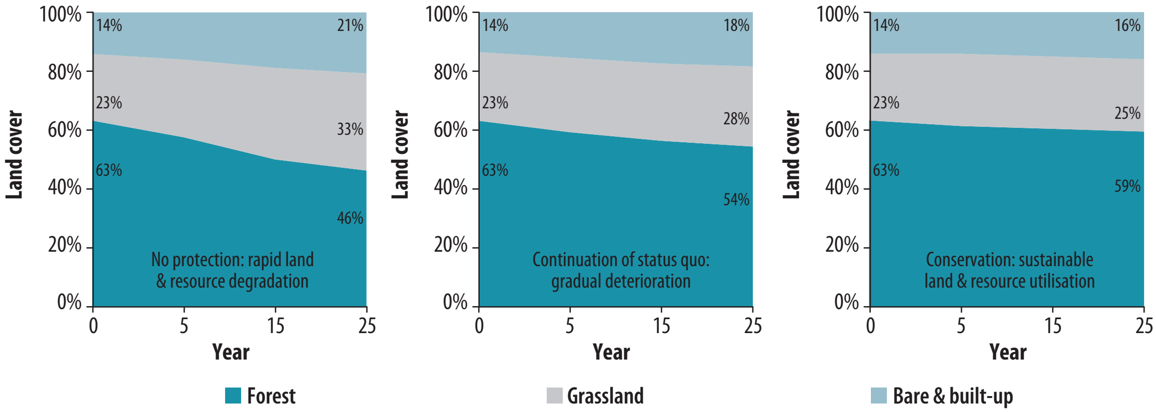
Scenario	No protection: rapid land & resource degradation	Continuation of status quo: gradual deterioration	Conservation: sustainable land & resource utilization
Summary	Current population growth rates in Ulaanbaatar, Gachuurt and Nalaikh are maintained, and land privatization and sub-division continues. Tourism, both domestic and international, continues to grow, and tourist establishments increase to supply this demand. There is a continuing demand, and market, for timber and non-timber forest products. Livestock and herder family numbers continue to grow at current rates, and immigration from other parts of the country continues.		
Ecosystem management	Insufficient budgets and other resources mean that protected area management remains weak, and it is difficult to enforce environmental regulations and laws. There are few checks on unlicensed land and resource uses in the Upper Tuul. The integrity of the protected area boundaries and management zones is challenged by the spread of settlement, tourism and herding.	Protected area management is constrained by low budgets and other resources, but efforts are made to enforce environmental regulations and management/use zoning. Unlicensed land and resource uses continue to some extent. Continuing changes in population and land use exert some pressure on the boundaries of the protected areas.	Effective protected area management means that biodiversity and ecosystems are conserved according to the PA management plan and zoning. Environmental regulations are well-enforced, and future developments comply with sustainability requirements. Land and resource uses are kept at sustainable levels, and are carried out so as to minimize environmental impacts.
Zone IV	By year 25, zone IV has become a largely peri-urban area, comprising the outskirts of Ulaanbaatar, Gachuurt and Nalaikh.	By year 25, zone IV has become densely settled and intensively used for permanent grazing.	By year 25, zone IV has an increased density of settlement and herding, both of which are however managed sustainably.
Zone III	By year 25, zone III is dominated by dense tourism developments and summer houses.	By year 25, tourism in zone III has more than doubled, largely displacing herding.	By year 25, zone III has shown a slight increase in tourism, but land use impacts are managed effectively.
Zone II	By year 25, zone II has become a mosaic of tourist camps and permanent herder settlements, and NTFP and timber exploitation is widespread.	By year 25, parts of zone II are used intensively for grazing and tourism, and NTFP and timber use has increased in line with population increase.	By year 25, zone II contains a few summer pastures in which carrying capacity is not exceeded, scattered tourist camps which are run to minimize environmental impact, and NTFP and timber use is maintained at sustainable levels.
Zone I	By year 25, zone I remains largely untouched.		

The hydrological effects of land use change

Eco-hydrological modeling provides estimates of the response of the basin to changes in land cover in the Upper Tuul and the effects of different scenarios on surface water and groundwater. Calculations focus on the water cycle processes in the watershed, in particular on the generation of surface and sub-surface runoff. Variation in land cover in the basin is accounted for by using different interception and transpiration rates.

The analysis indicates that ecosystem degradation in the Upper Tuul causes an increase in mean flow, a shifting upwards of the flow duration curve, higher annual minimum series, and a decrease in the storage needed to maintain a given yield. This translates into lower soil moisture recharge, earlier and higher intensity spring floods, lower recharge capacity in the valley aquifer, higher return periods of extreme flows (both high and low), and a lower relative groundwater contribution (base flow) to the total runoff volume. Loss of land cover would impair the storage soil moisture.

Figure 36: Changes in land cover under future Upper Tuul management scenarios



	No protection: rapid land & resource degradation			Continuation of status quo: gradual deterioration			Conservation: sustainable land & resource utilization		
Year	Forest (ha)	Grassland (ha)	Bare & built-up (ha)	Forest (ha)	Grassland (ha)	Bare & built-up (ha)	Forest (ha)	Grassland (ha)	Bare & built-up (ha)
0	3,969	1,449	882	3,969	1,449	882	3,969	1,449	882
1–5	3,654	1,638	1,008	3,717	1,606	976	3,874	1,512	913
6–15	3,150	1,953	1,197	3,528	1,701	1,071	3,811	1,543	945
16–25	2,886	2,079	1,323	3,402	1,764	1,134	3,717	1,575	1,008

From study data.

A clear consequence would be an increase in sediment loads in the Tuul River, involving reduced storage capacity, higher maintenance, and a shorter lifespan for eventual reservoirs. Under the most extreme scenario, soil moisture may become low enough in some years to affect transpiration of the vegetation, meaning that patches of forested land in the upper watershed could show signs of water stress.

The model suggests that average runoff increases as land cover is lost, while mean annual maximum and low flows—and subsequent peaks over threshold (POT) and flows under threshold (FUT)—clearly increase as forest and grassland areas are degraded. The predicted changes in runoff parameters over a 25-year period are illustrated in Table 22 and Figure 37 and Figure 38 shows the projected discharge under each management scenario in 25 years time.

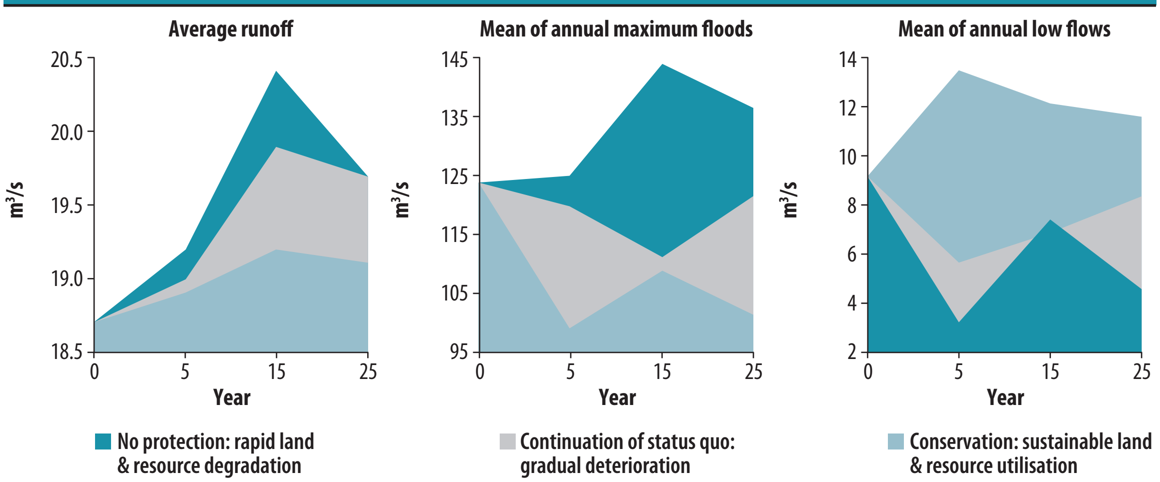
The impacts of the hydrological and ecological changes resulting from different management scenarios in the Upper Tuul on groundwater availability in the deep well areas for Ulaanbaatar are calculated by modeling the physical and temporal aquifer-river interaction processes at the upper water source. The contribution of precipitation to groundwater recharge is negligible when weighed up against annual abstractions; therefore analysis focuses on recharge occurring from the Tuul River and runoff from the surrounding hills. Even though progressive degradation of the upper watershed will induce a higher mean annual

Table 22: Predicted runoff parameters in the Upper Tuul over the next 25 years

Year	Average runoff (m^3/s)	Mean of annual maximum floods (m^3/s)	Mean of annual low flows (Jun-Sep) (m^3/s)	POT 200 m^3/s (25 yr)	FUT 5.0m m^3/s (Jun-Sep) (25 yr)
0	18.7	123.6	9.2	—	—
		No protection: rapid land & resource degradation			
1–5	19.2	124.7	3.2	—	1
6–15	20.4	144.0	7.4	2	2
16–25	19.7	136.2	4.5	2	3
		Continuation of status quo: gradual deterioration			
1–5	19.0	119.8	5.7	—	—
6–15	19.9	111.3	6.8	—	1
16–25	19.7	121.4	8.4	1	2
		Conservation: sustainable land & resource utilization			
1–5	18.9	99.3	13.4	—	—
6–15	19.2	108.7	12.1	—	—
16–25	19.1	101.2	11.6	—	2

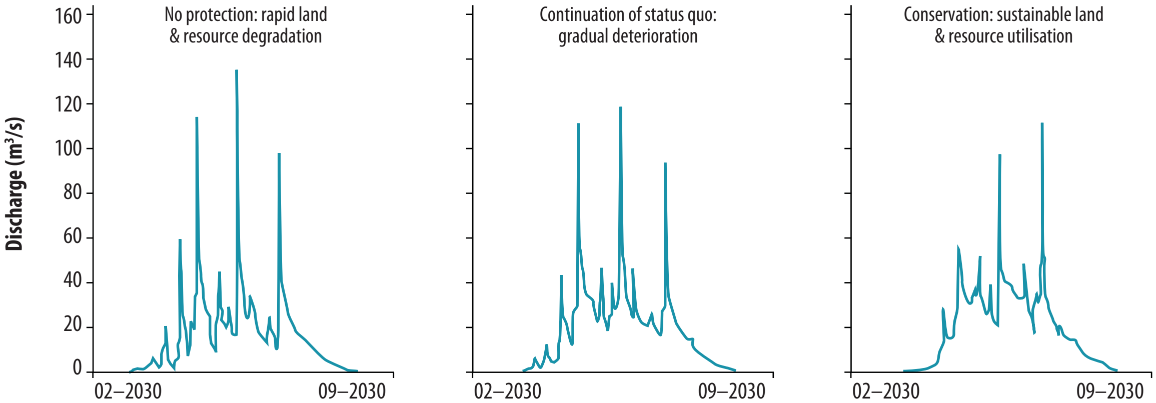
From study data.

Figure 37: Predicted runoff parameters in the Upper Tuul over the next 25 years



From study data. The changes in runoff parameters year on year are unlikely in reality to follow a straight line; the model however only generates 5 yearly figures.

Figure 38: Runoff scenario prediction for the Upper Tuul in 25 years time



From study data.

streamflow, the highly indented runoff pattern and lower base flows prevents this from becoming a positive influence on groundwater levels. A decrease in base flow affects the infiltration of water, limits the maximal amount of groundwater extraction, and increases existing water shortages.

The study modeled a crude water balance calculation of the diminished extractable volume of water from currently utilized groundwater reserves at the upper source. For central and lower sources, historical records of groundwater table lowering were extrapolated to the future.[62] As shown in Table 23, under the scenarios of no protection and continuation of the status quo, the groundwater tables at all water sources would be lowered due to diminished discharge. Assuming that each well is pumped to a similar base level in both scenarios, this gives a reduction in extractable volume for each well. After 25 years, the amount of groundwater available for extraction under a scenario of no protection would have diminished by 48 percent or 141,130 cubic meters per day as compared to the current design capacity of wells; and under a continuation of the status quo it would have diminished by 29 percent or 84,678 cubic meters per day. The conservation scenario implies no appreciable distortion in the Tuul River's base flow, so that groundwater levels at the upper water source would not be affected significantly and therefore water abstraction could be maintained at similar rates and quantities as at present.

Extrapolating these projections to all of Ulaanbaatar's production wells, according to their design capacity, indicates that by 2030 annual water availability from existing large and small wells would have declined to 55.91 million cubic meters per year under the scenario of no protection, and 76.51 million cubic meters per year under a continuation of the status quo Figure 39. Under a scenario of conservation and sustainable use, water availability would remain at 107.42 million cubic meters per year.

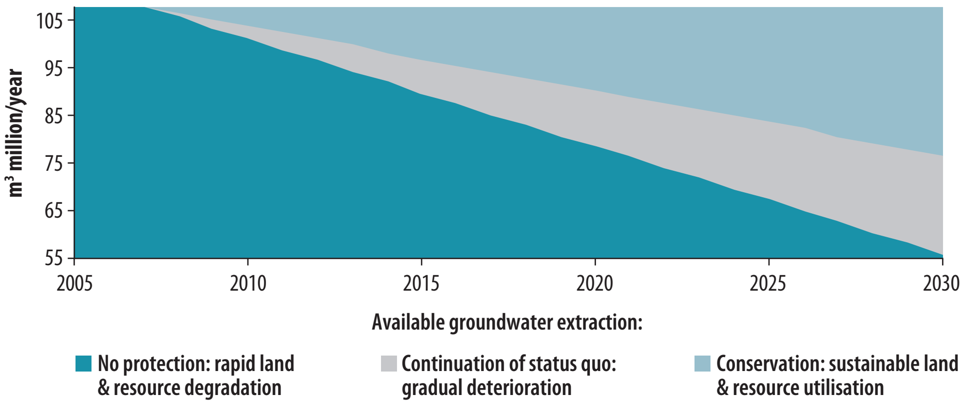
[55] Zandaryaa and others (2003), and Basandorj and Davaa (2005) cite that groundwater levels in the alluvial deposits supplying Ulaanbaatar have fallen by between 2 and 8.5 meters over the last 50 years. This study takes the mid-point of these two estimates, and extrapolates the average annual decrease in the water table over the next 25 years. It attributes only one-half of the fall in groundwater tables to changes in upper watershed ecology; the remainder is assumed to be accounted for by other factors and by drawdown occurring from water abstraction for use in Ulaanbaatar.

Table 23: Impacts of hydrological and ecological change on groundwater availability after 25 years

	No protection: rapid land & resource degradation	Continuation of status quo: gradual deterioration	Conservation: sustainable land & resource utilization
Average runoff (m^3/second)	19.7	19.7	19.1
Upper source			
Total number of wells (design capacity)		56	
Lowering of groundwater table (meters)	0.40	0.24	No appreciable change
Decrease in groundwater withdrawals per well (m^3/day)	251	151	No appreciable change
Decrease in groundwater withdrawals all wells (m^3/day)	14,080	8,448	No appreciable change
Total available groundwater extraction at upper source as per design capacity of wells (m^3/day)	57,920	63,552	72,000
Central source			
Total number of wells (design capacity)		97	
Lowering of groundwater table (meters)	1.31	0.79	No appreciable change
Decrease in groundwater withdrawals per well (m^3/day)	825	495	No appreciable change
Decrease in groundwater withdrawals all wells (m^3/day)	80,025	48,015	No appreciable change
Total available groundwater extraction at upper source as per design capacity of wells (m^3/day)	33,975	65,985	114,000
Industrial, meat factory and power plants			
Total number of wells (design capacity)		57	
Lowering of groundwater table (meters)	1.31	0.79	No appreciable change
Decrease in groundwater withdrawals per well (m^3/day)	825	495	No appreciable change
Decrease in groundwater withdrawals all wells (m^3/day)	47,025	28,215	No appreciable change
Total available groundwater extraction at upper source as per design capacity of wells (m^3/day)	58,275	77,085	105,300
Total decrease in groundwater withdrawals (m^3/day)	141,130	84,678	—

Lowering of groundwater table in Upper Source taken from study data, for central and lower water sources uses estimates based on those presented in Zandaryaa and others (2003) and, Basandorj and Davaa (2005). Table refers to large wells only, and excludes small private wells.

Figure 39: Water demand and availability in Ulaanbaatar under different future management scenarios



From study data. The decrease in water availability is unlikely in reality to follow a straight line; the downward trend between 2005 and 2030 has been regularized for the purpose of the model

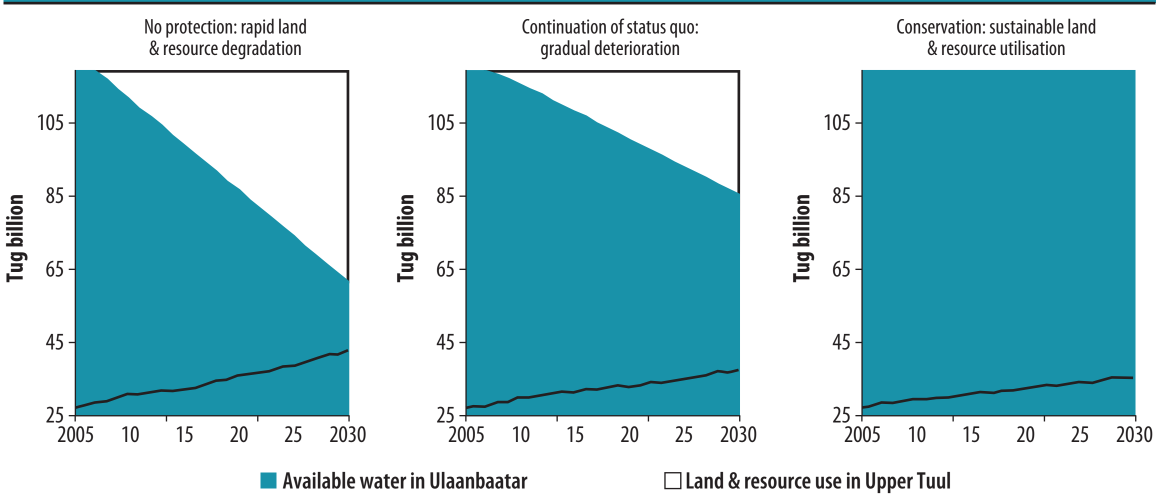
6. Economic Returns to Ecosystem Conservation: The Value of Investing in the Upper Watershed

The present value of ecosystem conservation and sustainable use

Based on the data presented in the previous chapter, the study looks at the economic implications of changes in upstream ecology and downstream water availability. It begins by showing how different management scenarios influence the value of land and resource uses in the Upper Tuul and the value of water availability in Ulaanbaatar. The changes in these values over time are illustrated in Figure 40:

- Under all of the scenarios, the value of land and resource uses in the Upper Tuul will gradually increase over time as the human population grows and as human influence expands into the watershed. Under the conservation scenario, land and resource uses are maintained at sustainable levels, and the lowest growth in value is recorded. Under a continuation of the status quo and the scenario of no protection, land and resource uses will rise at a more rapid pace, and continue to grow as the

Figure 40: Upstream and downstream values under different future management scenarios



From study data.

watershed population increases. However, as use rates exceed ecologically sustainable levels, the per capita value of land and resource uses will decline (even though the total value will continue to rise, as more and more people utilize the land and resources in the upper watershed).

- The value of water in Ulaanbaatar shows a different trend. As the Upper Tuul ecosystem becomes more degraded and impacts on the supply of water downstream, available water in Ulaanbaatar diminishes over time. This decrease is most marked under a scenario of no protection. In contrast, under the scenario of conservation, current water availability can be sustained.

In order to compare these streams of benefits over the 25 years covered in the scenario modeling, the study team discounted future values in order to express the value of each scenario as a single figure—their present value[63] or value in today's terms. As shown in Table 24, the present value of land and resource uses in the Upper Tuul is highest under a scenario of no protection (estimated at Tug 283.96 billion), and lowest under a scenario of conservation (Tug 275.11 billion). The increased value of water availability under a scenario of conservation (estimated at Tug 1,095 billion as compared to Tug 1,014 billion under a continuation of the status quo and Tug 959 billion under a scenario of no protection) outweighs the lower value for land and resource uses in the Upper Tuul.

This analysis therefore shows that conservation and sustainable use is the most economically desirable future management scenario for the Upper Tuul as a whole—it gives the highest overall value for the 25-year study period (Figure 41). Conservation and sustainable use generates an estimated present value of Tug 1,370 billion, which is 6 percent or Tug 77 billion more than would be gained under a continuation of the

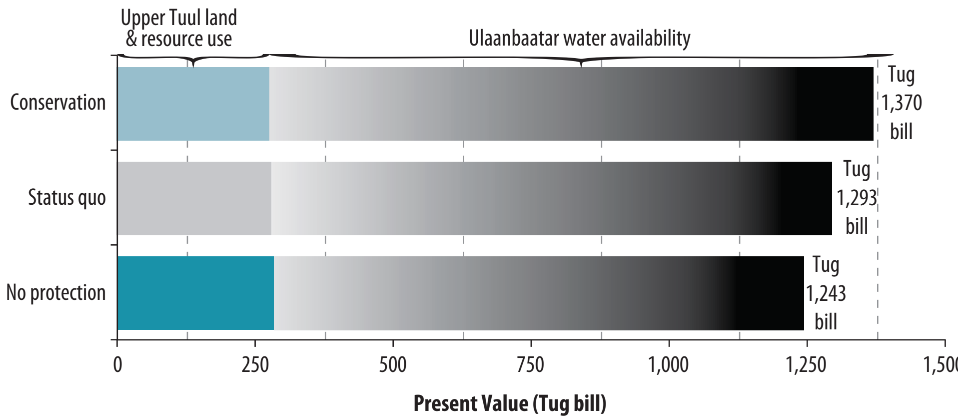
[56] Present value provides a single measure of the current value of the sum of a stream of future costs or benefits. It brings each future cost or benefit to today's value using a discount rate (10% in the case of this study) and adds them together. Discounting (essentially the opposite of a compound interest rate) is based on the principle that the further into the future a cost or benefit accrues, the less it is worth at the current time.

Table 24: Upstream and downstream values under different future management scenarios

	PV (Tug billion)		
	No protection: rapid land & resource degradation	Continuation of status quo: gradual deterioration	Conservation: sustainable land & resource utilization
Tourism	246.16	242.26	238.47
Pasture	32.64	32.37	32.34
Non-timber forest products	1.04	0.91	0.89
Timber	1.34	1.34	1.24
Firewood	2.78	2.78	2.17
Upper Tuul land & resource uses	283.96	279.68	275.11
Ulaanbaatar water availability	959.01	1,013.53	1,095.31
Total upstream & downstream value	1,242.97	1,293.21	1,370.42

From study data. PV calculated over 25-year scenario period using 10% discount rate.

Figure 41: Present value of land, resource, and water benefits under different future management scenarios



From study data. PV calculated over 25-year scenario period using 10% discount rate.

status quo (present value of Tug 1,293 billion) and 10 percent or Tug 128 billion more than under a scenario of no protection (Tug 1,243 billion).

Weighing up the costs and benefits of ecosystem conservation and sustainable use

Although the most economically desirable option overall and from a public viewpoint, future management scenario of ecosystem conservation and sustainable use will give rise to a range of costs. It is important to factor these costs into the analysis.

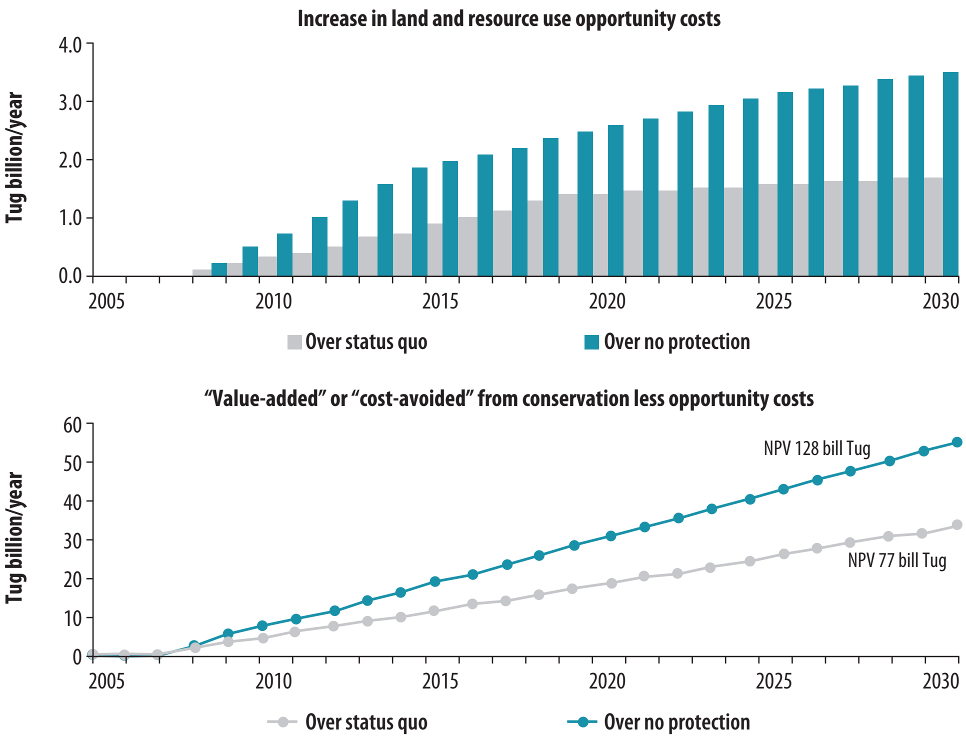
Factoring in the opportunity costs of conservation

Opportunity costs are reflected in the calculations of Table 24 and Figure 41. Opportunity costs are the reductions in land and resource uses that must take place in order to conserve the watershed ecosystem—basically any loss in values that is implied by keeping activities at ecologically sustainable levels. Current and future land and resource users in the Upper Tuul ecosystem incur these costs.

Table 24 indicates the opportunity costs of conservation—basically the difference in the value of Upper Tuul land and resource uses between different scenarios. It shows that there is an opportunity cost with a present value of around Tug 5 billion associated with conserving the Upper Tuul ecosystem instead of continuing the status quo, and around Tug 8 billion as compared to a scenario of no protection.

As shown in Figure 42 the annual value of these opportunity costs rises progressively over time. This is because land and resource use levels in the Upper Tuul are assumed to increase as human population grows and anthropogenic influences in the watershed expand. However, these opportunity costs are more than compensated by the additional water values generated by ecosystem conservation. Figure 42 also shows that, even taking opportunity costs into account, the scenario of conservation and sustainable use consistently generates a net "value added" or "cost avoided" over the 25-year study period, as compared to a continuation of the status quo and a scenario of no protection. By the year 2030, the annual value added or cost avoided from conservation is estimated between Tug 33 billion (compared to a continuation of the status quo) and Tug 54 billion (compared to a scenario of no protection). Overall, conservation has an estimated net present value of Tug 77 billion (compared to a continuation of the status quo) and Tug 128 billion

Figure 42: Conservation "value-added" or "cost-avoided" including land/resource use opportunity costs



From study data. PV calculated over 25-year scenario period using 10% discount rate.

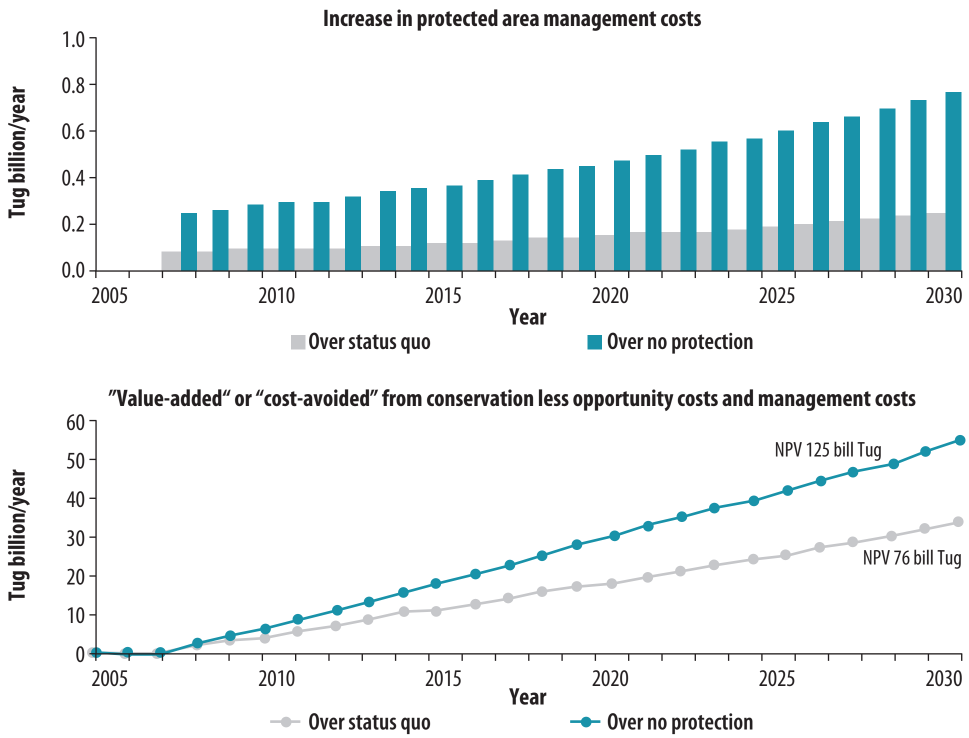
(compared to a scenario of no protection), taking opportunity costs into account.

Factoring in conservation management costs

A second important cost element, which is not included in the previous sections of this chapter, is the direct physical expenditures that are required to conserve the Upper Tuul ecosystem. These management costs include items such as capital, equipment, infrastructure, staffing and operating costs, as well as expenditures on such activities as awareness raising, education, outreach, policing, and promoting sustainable land and resource uses. The Government of Mongolia incurs these costs. Although the boundaries of the Upper Tuul watershed do not correspond exactly with those of Gorkhi-Terelj National Park and Khan Khentii Strictly Protected Area, there is a large overlap. This study therefore uses the budget projections for these two protected areas as an estimate of the direct management costs of ecosystem conservation.

Gorkhi-Terelj National Park and Khan Khentii Strictly Protected Area management authorities receive an average annual conservation budget of around Tug 170 million. Although this budget is insufficient to manage the protected areas effectively and does not cover any capital costs, it represents conservation management costs under a continuation of the status quo. For effective conservation, protected area authorities estimate that an annual budget of at least Tug 250 million is required. This represents conservation management costs under a situation of conservation and sustainable use. Under the scenario of no protection, there is a zero budget for ecosystem conservation. The study assumes that protected area management costs will rise in real terms over the

Figure 43: Conservation "value-added" or "cost-avoided" including protected area management costs



From study data. PV calculated over 25-year scenario period using 10% discount rate.

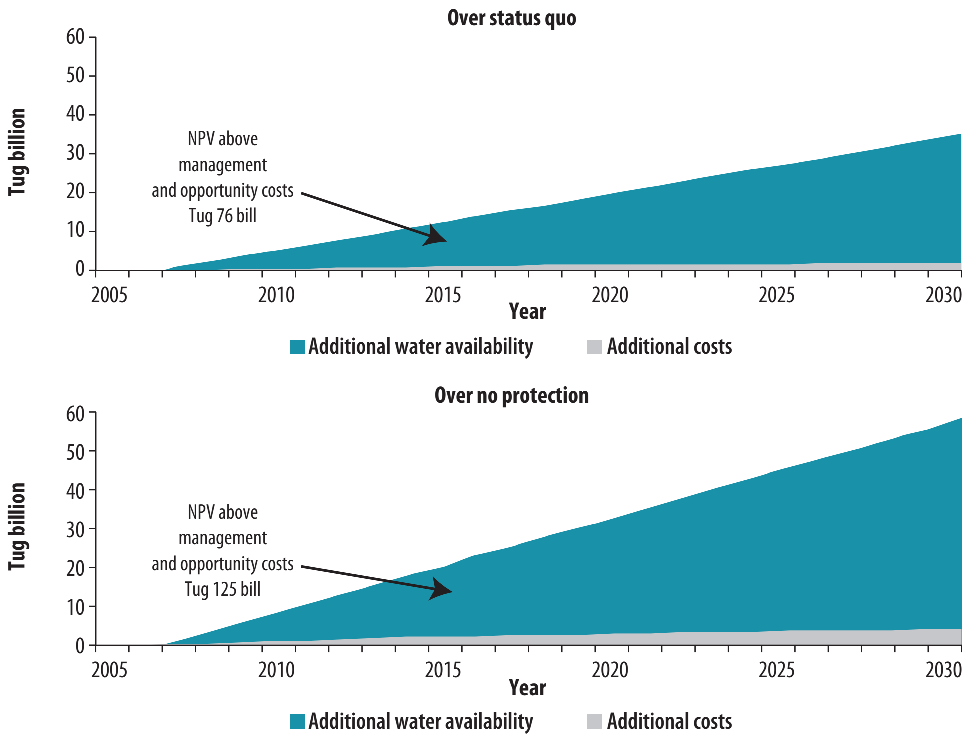
study period at a rate of 5 percent per year (over and above inflation). This responds to the growing human pressures on the ecosystem, which will necessitate rising expenditures on management planning and conservation interventions.

Figure 43 shows the rising additional management costs implied under a scenario of conservation and sustainable use as compared to a continuation of the status quo and scenario of no protection. Again, these additional costs are outweighed by the economic gains from conservation. The present value of additional management costs under a scenario of conservation and sustainable use is only 0.5 percent of the present value of increased water availability. Figure 43 therefore also shows that even when both management and opportunity costs are considered, conservation and sustainable use of the Upper Tuul ecosystem still generates significant value added or costs avoided over both a continuation of the status quo (an estimated net present value of Tug 76 billion) and a scenario of no protection (a net present value of Tug 125 billion).

The net present value of ecosystem conservation

The ecosystem conservation and sustainable use remains the most economically preferable option for the Upper Tuul even when the opportunity costs and management costs of conservation are taken into account. As shown in Figure 44 and Table 25, ecosystem conservation—because it sustains water availability in Ulaanbaatar—generates additional benefits that are worth an estimated Tug 76 billion in today's terms as compared to a continuation of the status quo and Tug 125 billion over a scenario of no protection.

Figure 44: Net present value of ecosystem conservation and sustainable use



From study data

Table 25: Net present value of ecosystem conservation and sustainable use as compared to continuation of the status quo and scenario of no protection in the Upper Tuul

	Increase in PV (Tug billion) implied by conservation scenario as compared to:	
	Continuation of status quo: gradual deterioration	**No protection: rapid land & resource degradation**
Management costs	0.89	2.78
Opportunity costs	4.47	8.76
Total costs	5.36	11.54
Ulaanbaatar water availability	81.78	136.29
Net present value	76.421	124.75

From study data. PV calculated over 25-year scenario period using 10% discount rate.

The distribution of conservation costs and benefits between stakeholder groups

The preceding sections have shown that there is a tangible—and substantial—economic gain from conservation and sustainable use of the Upper Tuul ecosystem as compared to either a continuation of the status quo or a scenario of no protection. The groups who benefit from ecosystem conservation are however not the same as those who must bear its costs. As shown in Table 26, it is Ulaanbaatar water users who stand to benefit the most from a shift to ecosystem conservation and sustainable use and who will suffer the greatest costs if the watershed is further degraded. In contrast, the major cost-bearers under a scenario of ecosystem conservation and sustainable use are the Upper Tuul land and resource users who must bear the main opportunity costs of conservation and the protected area authorities who must meet the direct management costs.

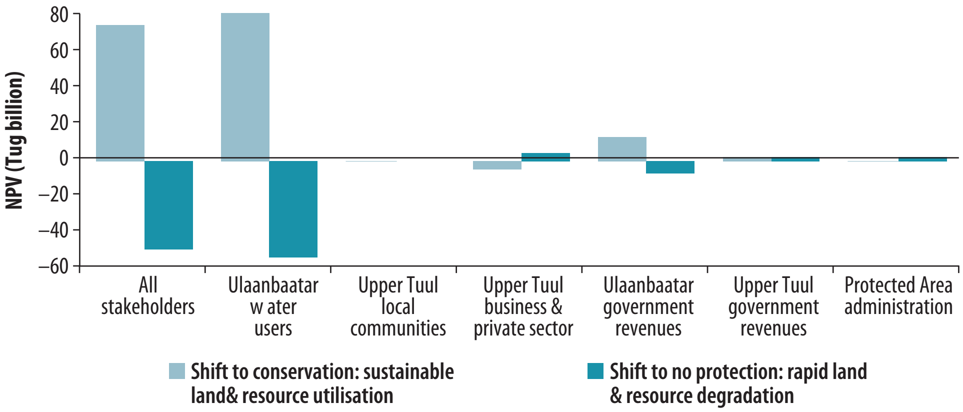
Further illustrated in Figure 45, local communities, businesses, and private sector groups in the Upper Tuul will all face some level of reduction in the values they receive under a scenario of conservation and sustainable use as land and resource use values (at least initially) decrease. It is not in their immediate financial interests to effect a shift to conservation and sustainable land and resource use—at least in the short term while unsustainable levels of land and resource uses can be maintained. This then becomes an important challenge: how to cover these costs and convince the Upper Tuul land and resource users, who lose out in financial terms from conservation and sustainable use of the water shed, to adjust their land and resource activities to ensure the continued provision of downstream economic water benefits. The next chapter of the report discusses these issues further.

Table 26: Distribution of stakeholder values under different future management scenarios

	Change in PV (Tug billion)	
	Change from status quo to conservation	Change from status quo to no protection
Ulaanbaatar water users	+81.78	–54.52
Upper Tuul land & resource users	–4.56	+4.29
Local communities	–0.07	–0.01
Business and private sector	–4.37	+4.29
Ulaanbaatar government revenues	+12.97	–8.64
Upper Tuul government revenues	+0.01	+0.13
Protected Area administration	–1.89	+0.89
All stakeholders	+75.33	–49.34

From study data. PV calculated over 25-year scenario period using 10% discount rate. Note: figures for different stakeholder groups cannot be summed to give total figure, as would give rise to double-counting.

Figure 45: Distribution of stakeholder values under different future management scenarios



From study data. PV calculated over 25-year scenario period using 10% discount rate. Note figures for different stakeholder groups cannot be summed to give total figure, as would give rise to double-counting.

7. Moving Forward: Investing in the Upper Tuul Ecosystem as an Economic Part of Water Infrastructure

Factoring the Upper Tuul ecosystem into water infrastructure planning

This study underlines the recent and widespread concern that urgent actions are needed to address Ulaanbaatar's water security in the future. It also presents the economic rationale for investing in the conservation of the Upper Tuul ecosystem as part of these actions. In addition to demand-side measures (targeting both consumers and distribution losses), four approaches are currently being proposed to improve and expand Ulaanbaatar's water supply infrastructure:

Tapping into additional groundwater reserves

As well as increasing the operating capacity of existing wells in line with their full design capacity,[64] there is some potential for developing new groundwater resources in the vicinity of Ulaanbaatar.[65] The development potential of the existing alluvial groundwater deposits of the Tuul River is estimated at 350,000 cubic meters per day, of which around 215,000 cubic meters are suitable for human consumption. According to studies performed in the late 1970s by Russian hydrogeologists, this can be augmented up to 441,000 cubic meters per day (an additional 93,000 cubic meters) by adding the potential groundwater reserve that can be extracted from the alluvial-proluvial deposits of the Tuul River tributaries.[66]

Developing surface water storage

Since the time of the USSR, various options have been proposed for developing surface water supplies to Ulaanbaatar through constructing a dam across the Tuul River drainage area and creating a reservoir that would store the flow of the river.[67] Three potential water storage reservoirs have been identified for future development, located upstream of the city. Little information is available about the proposed capacity or design of these reservoirs, although it is estimated that a single multi-purpose dam on the Tuul River could have a construction cost of US$60–70 million.[68]

Treating and re-using wastewater

Retreatment of the wastewater released from the central drainage facility of Ulaanbaatar has been proposed as a way of generating water for use by the thermal power plants

---

57 World Bank (1997).
58 Basandorj and Davaa (2005).
59 Zandaryaa and others (2003).
60 Basandorj and Davaa (2005).
61 Davaasuren and Basandorj (2008).

and manufacturing industries in the city. This alternative to the direct use of groundwater is intended to free up additional groundwater for domestic use. It is estimated that current facilities could enable the production of an additional 165,000 cubic meters of retreated water per day for use by industry (about half of which would be sold) and make available an additional 100,000 cubic meters of groundwater per day for domestic use.[69]

Supplementing groundwater recharge

An important characteristic of the extraction bores is that they have a non-stationary pattern of extraction: when the cone of depression has reached a critical level, the pump is turned out and the water table is given time to go back to its static level. Under these conditions, it is unwise to increase production since higher abstraction will likely result in faster-dropping groundwater levels. The maximum sustainable volume of abstraction for wells has been reached and no added volume can be extracted. However, if measures can be taken to supplement groundwater recharge around running and unused wells by artificial recharge techniques, the capacity of the current extraction fields might be improved significantly. This allows wells to recharge as well as withdraw water from the aquifer: to inject water directly into the aquifer during high flow periods, increase groundwater volumes, and create storage for low flow periods.[70]

In reality, the most likely future course of action will involve some combination of these approaches.[71] Land and resource management in the Upper Tuul will however impact on the ability of all of these types of infrastructure to deliver water to Ulaanbaatar. Although watershed conservation alone is neither going to guarantee water security nor abrogate the need to develop additional water supplies, this study has made it clear that the sustainable management of the Upper Tuul is an essential (and economic) part of any future water sector development, whether they are based on groundwater or surface water or both.

Stimulating private and public investment in ecosystem conservation

Alongside measures to construct and operate the physical infrastructure that is required to deliver adequate water in Ulaanbaatar, this report's analysis clearly presents a strong case for investing in conserving and maintaining the "natural" water infrastructure that shapes the Upper Tuul ecosystem. The study shows the economic rationale for a scenario of conservation and sustainable use (yielding higher values to society than either gradual deterioration of the upper watershed or rapid degradation of its land and resources) as well as the economic returns that can be gained from such investments (the value of water added for downstream use).

One component is public investment in the protected areas that lie at the source of the Tuul River. This has many aspects, ranging from effective planning and management (through awareness and outreach) to enforcement of restrictions and penalties against illegal land and resource activities. The structures and mechanisms to effect these actions are already in place via the 5-year management plan for Gorkhi Terelj National Park and Khan Khentii Strictly Protected Area, the management and use zoning that has been carried out for the area, and the host of laws and regulations that govern environmental management across Mongolia. A pressing problem however remains. Public budgets at present levels are insufficient to manage the protected areas effectively: there is no capital budget and only scarce funds available to fund recurrent costs.

A second—and equally critical—component of ecosystem investment is addressing the current lack of financial incentives for land and resource users in the Upper Tuul to carry out their activities in an ecologically sustainable manner. It is neither

[62] Tuul Songino Water Resource Joint Stock Company.
[63] Acacia Institute and IGRAC. 2008.
[64] Basandorj and Davaa (2005).

realistic nor equitable to expect them to subsidize the provision of water services for the benefit of downstream urban dwellers. In practice, it is likely that a package of mutually reinforcing fiscal, financial, and economic measures will be required to redress these imbalances, generate additional finance for protected area management, and provide sufficient conservation incentives to upstream land and resource users.

Payment for ecosystem services is a widely used mechanism for ecosystem conservation for downstream water supplies and would seem to have potential in Upper Tuul. At a basic level, the mechanism addresses the problem with regard to groups who use and manage economically valuable ecosystems (for example government protected area authorities and local land and resource users) but do not typically gain in financial terms from conservation. In many cases, they are also faced with opportunities to generate substantial profits from unsustainable land and resource uses. At the same time, although other off-site groups benefit from ecosystem services that are generated as a result of conservation (for example, adequate and regular water supplies), they typically receive these benefits at low or zero cost. In order to make sustainable land and resource use options more financially attractive, payment for ecosystem services involves efforts to develop systems in which land users are paid for the ecosystem services they generate. The core principles of payment for ecosystem services are that those who provide ecosystem services should be rewarded for doing so (in this case land and resource users in the Upper Tuul) and those who use the services should pay for the provision (in this case downstream water users in Ulaanbaatar).

There are now many examples of payment for ecosystem services being used as a mechanism for funding watershed management. These services range from applications that are based solely on revenue transfers between different government departments to those that involve agreements between private parties. In Ecuador, the municipal water companies of Quito and Pimampiro have created water funds by charging levies on drinking water. These funds are used to invest in upland watershed conservation and to make direct payment to forest owners. In Colombia, agro-industrial water user associations have entered into voluntary contracts with farmers in their upper watersheds. In China, Beijing municipality compensates farmers in Miyun County, the source of Beijing's water supplies, with cash payments for planting trees on their land. In Vietnam, a wide range of payment for ecosystem services with protected area authorities and local landholders are being developed in Ho Chi Minh City's Dong Nai watershed, involving the municipal council, a hydropower producer, water bottling company, and agro-industries.

It is beyond the scope of this study to investigate such mechanisms in detail. The analysis of economic values that has been carried out indicates clearly that, however great the value of the Upper Tuul ecosystem is demonstrated to be in theory, these figures will have little impact or meaning unless translated into concrete incentives and funding. The incentives and funding will both persuade and enable the groups who use and manage the Upper Tuul land and resources to ensure that the ecosystem is conserved and assures clean, regular, and equitable water supplies for Ulaanbaatar's residents into the future.

Annex: Summary of Methods and Assumptions

The eco-hydrological model

The HBV Model is a computerized catchment model that converts precipitation, potential evaporation, and snowmelt, if applicable, into streamflow/reservoir inflow by simulating of the natural hydrological processes.

It is part of a computerized system for hydrological forecasting, discharge simulation, design flood computations and climate change studies, the HBV/IHMS (Integrated Hydrological Modeling System). Special versions of the model (HBV-N and PULSE) can be used for simulation of water quality (e.g., nitrogen, pH, and alkalinity).

In different model versions HBV has been applied in more than 40 countries all over the world. It has been applied to countries with such different climatic conditions as Sweden, Zimbabwe, India, and Colombia. The model has been applied for scales ranging from lysimeter plots (Lindström and Rodhe 1986) to the entire Baltic Sea drainage basin (Bergström and Carlsson 1994; and Graham 1999). HBV can be used as a semi-distributed model by dividing the catchment into sub-basins.

General HBV model information	
Data requirement	Sub-basin division and coupling, altitude and land cover distribution, time-series of precipitation and temperature (time-series of observed water discharge at some site).
Applicability	The model is simple, and has been applied in some 40 countries, in all parts of the world. The model runs under a Windows graphical user interface (IHMS), and a new modern interface (available in 2003).
Operational experience and skills requirement of users	Two weeks of training for model setup and applications. Basic knowledge in hydrology.
License agreements	The model is free for research purpose. For commercial use a license may be bought from the Swedish Meteorological and Hydrological Institute.
Cost indication	Application to one catchment requires about 2-weeks work of an experienced modeler (if necessary database is already available).
Training	Courses are organized regularly at the Swedish Meteorological and Hydrological Institute.

Each sub-basin is then divided into zones according to altitude, lake area, and vegetation. The model is normally run on daily values of rainfall and air temperature, and daily or monthly estimates of potential evaporation. The model is used for flood forecasting in the Nordic countries and for many other purposes such as spillway design floods simulation (Bergström and others 1992), water resources evaluation (Brandt and others 1994: 643–51), and nutrient load estimates. (Arheimer 1998).

Input data are observations of precipitation, air temperature and estimates of potential evapotranspiration. The time step is usually one day, but it is possible to use shorter time steps. The evaporation values used are normally monthly averages although it is possible to use daily values. Air temperature data are used for calculations of snow accumulation and melt. It can also be used to adjust potential evaporation when the temperature deviates from normal values, or to calculate potential evaporation. If none of these last options are used, temperature can be omitted in snow-free areas.

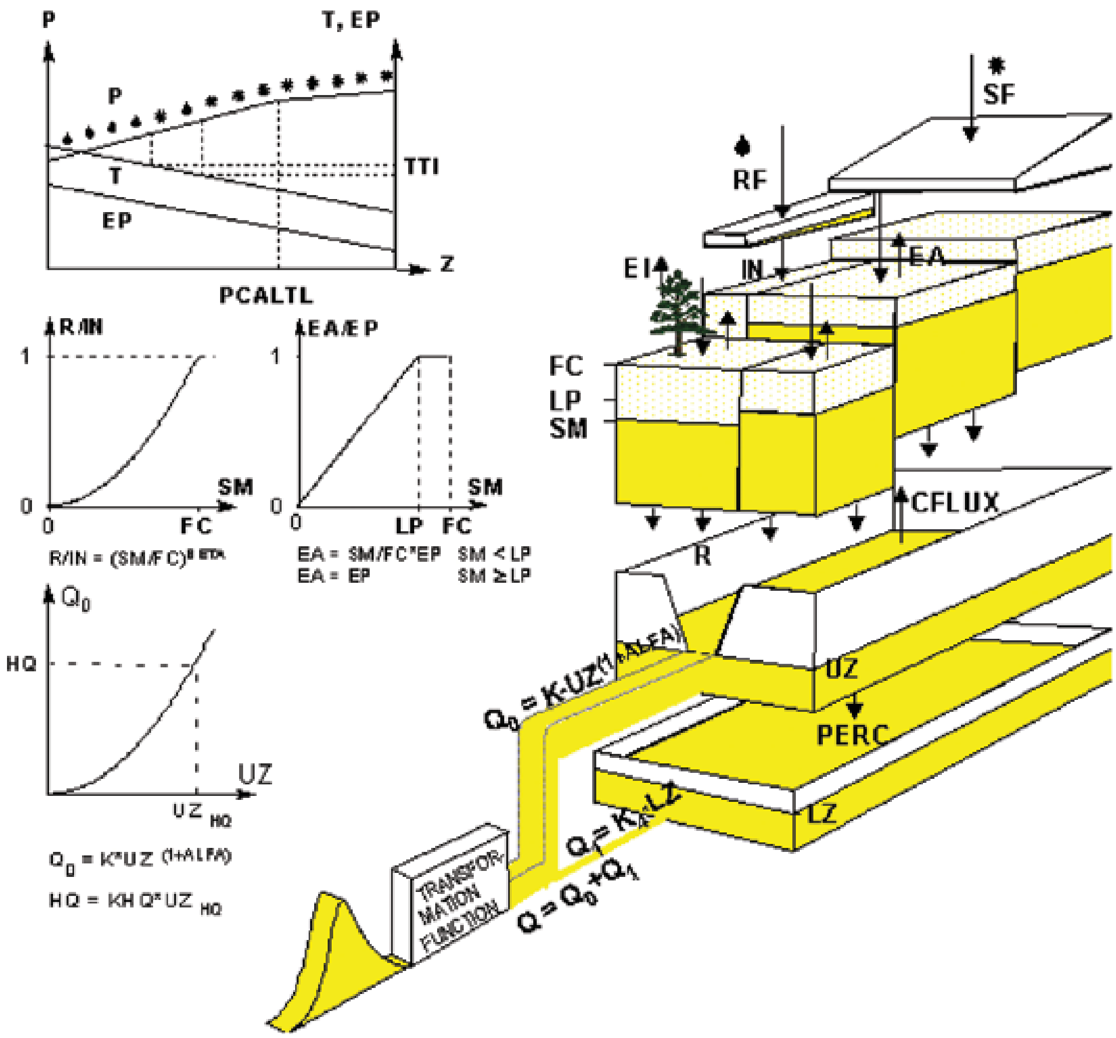
The model consists of subroutines for meteorological interpolation, snow accumulation and melt, evapotranspiration estimation, a soil moisture accounting procedure, routines for runoff generation, and finally a simple routing procedure between sub-basins and in lakes. It is possible to run the model separately for several sub-basins and then add the contributions from all sub-basins. Calibration as well as forecasts can be made for each sub-basin. For basins of considerable elevation range a subdivision into elevation zones can also be made. This subdivision is made for the snow and soil moisture routines only. Each elevation zone can further be divided into different vegetation zones (e.g., forested and non-forested areas).

The model structure of HBV-96 is presented schematically in Figure A.1 (Lindström and others 1997). This only shows the most important characteristics of the model, and some clarifications are given below. The classes of land use are normally open areas, forests, lakes and glaciers. It is possible to use different values of SFCF, SFDIST, CFMAX, ECORR, and the interception storage capacity IC for different vegetation zones, but the ratios between the values for forested and non-forested areas are kept constant.

Optimal interpolation of precipitation and temperature: The standard model uses a rather crude weighting routine and lapse rates for computation of areal precipitation and air temperatures. In HBV-96 a geostatistical method, based on optimal interpolation was introduced (Daley 1991). This method is frequently used in meteorological applications, and similar to kriging. The method may be based purely on data from meteorological stations and general knowledge of the precipitation/temperature pattern. One may also add the information included in a meteorological model to take into consideration (e.g., topography and prevailing winds); such a grid was developed for 40 years of daily values for Sweden (Johansson 2002).

Snow routine. The standard snowmelt routine of the HBV model is a degree-day approach, based on air temperature, with a water-holding capacity of snow, which delays runoff. Melt is further distributed according to the temperature lapse rate and is modeled differently in forests and open areas. A threshold temperature (TT) is used to distinguish rainfall from snowfall. If the parameter TTINT is used, the threshold is extended to an interval and within this interval precipitation is assumed to be a mix of rain and snow, decreasing linearly from 100 percent snow at the lower end to 0 percent at the upper end. The snowpack is assumed to retain melt water as long as the amount does not exceed a certain fraction of the snow. When temperature decreases below the threshold temperature, this water refreezes gradually. Glacier melt will occur only in glacier zones and follows the same type of formula as for snowmelt but with another degree-day factor. No glacier melt occurs as long as there is snow in the zone. A snow distribution can be made in each zone by subdividing it into a number of sub-areas with different snow accumulation. Normally three snow classes are used. This accounts for re-distribution of snow, snowdrift, and snow that is trapped in creeks and other irregularities in rugged terrain.

Figure A.1. Schematic structure of one sub-basin in the HBV-96 model[72], with routines for snow (top), soil (middle) and response (bottom)



P = Precipitation	BETA = Soil parameter
T = Temperature	R = Recharge
SF = Snow	CFLUX = Capillary transport
RF = Rain	UZ = Storage in upper response box
Z = Elevation	LZ = Storage in lower response box
PCALTL = Threshold for altitude correction	PERC = Percolation
TTI = Threshold temperature interval	K, K_4 = Recession parameters
IN = Infiltration	ALFA = Recession parameter
EP = Potential evapotranspiration	Q_0, Q_1 = Runoff components
EA = Actual evapotranspiration	HQ = High flow parameter
EI = Evaporation from interception	KHQ = Recession at HQ
SM = Soil moisture storage	HQ_{UZ} = UZ level at HQ
FC = Maximum soil moisture storage	
LP = Limit for potential evapotranspiration	

65 Lindström and others (1997).

Evapotranspiration. The standard HBV model is run with monthly data of long-term mean potential evapotranspiration, usually based on the Penman formula (Penman 1948). These data are adjusted for temperature anomalies (Lindström and Bergström 1992). As an alternative, daily values can be calculated as being proportional to air temperature but with monthly coefficients of proportionality. From the interception storage, an evaporation equal to the potential evaporation will occur as long as water is available, even if it is stored as snow. If the interception routine is used, it is also possible to reduce the soil evaporation to avoid values of total evaporation that are too large. The interception routine is however not always used. Instead the potential evapotranspiration from forested areas is often assumed to be 15 percent higher than that from open areas (Johansson 2002). The potential evapotranspiration is thus a function of the time of the year, the current air temperature, vegetation, elevation, and, as an option, precipitation. Evaporation from lakes will occur only when there is no ice. Ice conditions are modeled with a simple weighting sub-routine on air temperature, which results in a lag between air temperature and lake temperature. It is assumed that the lake is frozen when the weighted temperature drops below zero.

Soil routine. The soil moisture accounting of the HBV model is based on a modification of the bucket theory in that it assumes a statistical distribution of storage capacities in a basin. This is the main part controlling runoff formation. This routine is based on the three parameters—BETA, LP, and FC—as shown in the middle section of Figure A1. BETA controls the contribution to the response function or the increase in soil moisture storage from each millimeter of rainfall or snowmelt. The ratio $\Delta Q/\Delta P$ is often called runoff coefficient, and ΔQ is often called effective precipitation. LP is a soil moisture value above which evapotranspiration reaches its potential value, and FC is the maximum soil moisture storage in the model. The parameter LP is given as a fraction of FC.

Response function and routing. The runoff generation routine is the response function that transforms excess water from the soil moisture zone to runoff. It also includes the effect of direct precipitation and evaporation on a part, which represents lakes, rivers and other wet areas. The function consists of one upper non-linear and one lower linear reservoir. These are the origin of the quick (superficial channels) and slow (base-flow) runoff components of the hydrograph. Level pool routing is performed in lakes located at the outlet of a sub-basin. The division into sub-models, defined by the outlets of major lakes (not shown in the figure), is thus of great importance for determining the dynamics of the generated runoff. The routing between sub-basins can be described by the Muskingum method (Shaw 1988) or simple time lags. Each one of the sub-basins has individual response functions.

Lakes. Precipitation on lakes will be the same as for a non-forested zone at the same altitude and will be added to the lake water regardless of ice conditions in the same way for both rain and snow. Evaporation from lakes will equal the potential evaporation but can be modified by a parameter and will occur only when there is no ice. Transformation of runoff is taking place after water routing through the lake according to a rating curve. If no specific rating curve for the lake is given as input, the model will assume a general rating curve.

Model calibration. Although the automatic calibration routine is not a part of the model itself, it is an essential component in the practical work. The standard criterion (Lindström 1997) is a compromise between the traditional efficiency R^2 measure (Nash and Sutcliffe 1970) and the relative volume error, RD:

In practice the optimization of only R^2 often results in a remaining volume error. The criterion above gives results with almost as high R^2 values and practically no volume error. The best results are obtained with w close to 0.1. The automatic calibration method for the HBV model developed by Harlin used different criteria for different parameters (Harlin and Kung 1992). With the simplification to one single criterion, the search method could be made more efficient. The optimization is made for one parameter at a time while keeping the others constant. The one-dimensional search is based on a modification of the Brent parabolic interpolation (Press and others 1992).

HBV-96. A comprehensive re-evaluation of the model was carried out during the 1990s and resulted in the present model version called HBV-96 (Lindstrom and others 1997). The objectives were to improve the potential for making use of spatially distributed data in the model, to make the model more physically sound and to improve model performance. The model revision led to slight changes in the process descriptions for snow accumulation and melt, evapotranspiration, groundwater discharge, and automatic calibration. When combined, the modifications led to significant improvements in model performance. In seven test basins, the average value of the efficiency criterion R^2 increased from 86 to 89 percent, with improvements in both the calibration and verification periods. In general the results did not justify any increased resolution in time or space unless more detailed data are to be used as input or for validation. The option of higher resolution in space is also necessary for future integration of spatially distributed field data in the model. The improvements in model performance was more due to the changes in the processing of input data and the new calibration routine than due to the changes in the process descriptions of the model.

Assumptions used for economic valuation and scenario modeling

Upper Tuul land and resource uses

	Base year value*	No protection: rapid land & resource degradation	Continuation of status quo: gradual deterioration	Conservation: sustainable land & resource utilization
Tourism				
International tourists	27,000 people	Increases by 2.5% a year	Increases by 2.0% a year	Increases by 2.0% a year
Domestic visitors	106,000 people			
Number of bednights sold	929,488 bednights	Increases by 2% a year	Increases by 1.25% a year	Increases by 1% a year
Government land charges and other taxes		Increases by 1.75% a year	Increases by 1.00% a year	Stays the same
Pasture & herding				
Population of Erdene herder families	271 households	Grows by 4.7% a year (continues current trends)	Grows by 2.35% a year (half past rate of growth)	Grows by 1% a year
Population of Nalaikh herder families	274 households	Grows by 3.1% a year (continues current trends)	Grows by 1.55% a year (half past rate of growth)	
Erdene herder livestock population	77,725 SEU	Average herd size per family maintained until grazing becomes insufficient: reduces by 35% in 2015 and 55% in 2025	Average herd size per family maintained until grazing becomes insufficient: reduces by 25% in 2020	Average herd size per family maintained
Nalaikh herder livestock population	44,565 SEU			
Timber and firewood				
Legal roundlog harvest	643 m^3	Rises by 5% a year until sustainable harvest exceeded: harvest reduces by 5% a year from 2015	Rises by 1% a year until sustainable harvest exceeded: harvest reduces by 2.5% a year from 2020	No increase
Legal cut firewood harvest	4,384 m^3			
Illegal roundlog harvest	606 m^3	Rises by 10% a year until sustainable harvest exceeded: harvest reduces by 10% a year from 2015	Rises by 5% a year until sustainable harvest exceeded: harvest reduces by 5% a year from 2020	Rises by 5% a year
Illegal cut firewood harvest	4,114 m^3			

(continued on next page)

	Base year value*	No protection: rapid land & resource degradation	Continuation of status quo: gradual deterioration	Conservation: sustainable land & resource utilization
Timber roundlogs for household structures	2,046 m^3	Number of households increases in line with population growth rate (4.7%), per household consumption maintained at 30 m^3 every ten years until sustainable harvest exceeded: harvest reduces to 20 m^3 every ten years in 2015 and 10 m^3 every ten years in 2020	Number of households increases by half of population growth rate (2.35%), per household consumption maintained at 30 m^3 every ten years until sustainable harvest exceeded: harvest reduces to 20 m^3 every ten years in 2020 and 10 m^3 every ten years in 2025	Number of households increases by 1% year, per household consumption maintained at 30 m^3 every ten years
Household firewood harvest	4,955 m^3	Number of households increases in line with population growth rate (4.7%), per household consumption maintained at 8 m^3/year until sustainable harvest exceeded: harvest reduces to 5 m^3/year in 2015 and 3 m^3/year in 2020	Number of households increases by half of population growth rate (2.35%), per household consumption maintained at 8 m^3/year until sustainable harvest exceeded: harvest reduces to 5 m^3/year in 2020 and 3 m^3/year in 2025	Number of households increases by 1% year, per household consumption maintained at 8 m^3/year
Non-timber forest products				
Households harvesting wild fruits & berries	282 households	Rises by 3% a year until sustainable harvest exceeded: per household harvest reduces by 2.5% a year from 2015	Rises by 2% a year until sustainable harvest exceeded: per household harvest reduces by 2.5% a year from 2020	Rises by 0.5% a year
Households harvesting wild vegetables	282 households			
Households harvesting pine Nuts	200 households			
Households harvesting medicinal plants	34 households			
Big bang commercial pine nut harvest	147.2 tons	Occurs every 6 years, 50% of available harvest currently utilized, rising to 75% from 2016	Occurs every 6 years, 50% of available harvest utilized	

** 2007 is taken as the base year because it is the year immediately preceding the study, and therefore the reference point for most data and statistics collected. Scenario modeling is carried for the years 2005–2030. Prices are held constant between scenarios*

Ulaanbaatar water use

	Base year value*	Assumptions
Human population of Ulaanbaatar	1,031,200	Population growth rates taken from records for Ulaanbaatar in 2005, 2006 and 2007, future projections for 2010, 2020, 2025 and 2030 regularized to straight line growth rate between each projection year
Number of ger settlement residents	620,950	Current proportion of total population 60%, falling to 50% in 2016, 35% in 2020, 25% in 2025. Water consumption rises from current 7.5 liters per capita per day to in 22.5 liters in 2015 and 75 liters in 2020.
Number of apartment dwellers	403,260	Current proportion of total population 39%, rising to 45% in 2016, 55% in 2020, 60% in 2025. Per capita water consumption remains stable.
Number of individual household dwellers	6,990	Current proportion of total population 1%, rising to 5% in 2016, 10% in 2020, 15% in 2025. Per capita water consumption remains stable.
Number of businesses and industries	20,327	Growing by 5% a year, 6.5% from 2015, 9% from 2020
Number of power stations	3	Increasing to 4 in 2012, 7 in 2025
Number of livestock	724,341	Number of herders increases in line with ger dweller population increase, average herd size remains stable.
Area of irrigated farms	290 ha (cropped area 413 ha)	Area under irrigated farms increases by 10% a year from 2008, 5% from 2015, 2.5% from 2025

** 2007 is taken as the base year because it is the year immediately preceding the study, and therefore the reference point for most data and statistics collected. Scenario modeling is carried for the years 2005–2030. Prices are held constant between scenarios.*

References

Acacia Institute and IGRAC. 2008. Artificial Recharge of Groundwater in the World.

Arheimer, B. 1998. Riverine Nitrogen: Analysis and Modelling under Nordic Conditions. Institute of Theme Research, Water and Environmental Studies (S-581 83). Linköping University, Linköping, Sweden.

Basandorj, D., and G. Davaa. 2005. Mongolian National Case Study – Reference to Tuul River Basin. Case Study prepared for the 2nd World Water Report by UNESCO Office Beijing in collaboration with World Water Assessment Programme. UNESCO Paris and Mongolian National IHP Committee. Ulaanbaatar.

Bergström, B., and B. Carlsson. 1994. "River Runoff to the Baltic Sea: 1950–1990." *Ambio* 23: 280–7.

Bergström, S., Harlin, J. and G. Lindström. 1992. Spillway design floods in Sweden. I: New guidelines. Hydrological Sciences Journal 37(5): 505–519.

Brandt, M., T. Jutman, and H. Alexandersson. 1994. Sveriges Vattenbalans. Årsmedelvärden 1961–1990 av nederbörd, avdunstning och avrinnning. SMHI Hydrologi (NHP report No. 30). Norrköping. Norway, Kanaltryckeriet, Motala.

Crisp, N,, J. Dick, and M. Mullins. 2004. Mongolia Forestry Sector Review. World Bank. Washington, DC.

Daley, R. 1991. *Atmospheric Data Analysis.* Cambridge University Press.

Davaa, G., and M. Erdenetuya. 2005. Hydrological Changes in the Upper Tuul River Basin. Paper presented at 2nd Symposium on Water Cycle in Northern Eurasia. Hokkaido.

Davaa, G., D. Oyunbaatar, and M. Sugita. 2006. "Surface Water of Mongolia." In Konagaya, Y. (ed). *Handbook of Mongolian Environments*.

Davaasuren, J., and D. Basandorj, 2008. Status and Challenges of Water Infrastructure Development in Mongolia. Presentation made at UNESCAP First Regional Workshop on the Development of Eco Efficient Water Infrastructure for Socio-Economic Development in Asia and the Pacific Region. Seoul.

Graham, P. 1999. "Modelling Runoff to the Baltic Basin." *Ambio* 28: 328–34.

Harlin, J., and C.S. Kung. 1992. "Parameter Uncertainty and Simulation of Design Floods in Sweden." *Journal of Hydrology* 137: 209–30.

Herro, M., O. Naidan, M. Erdene, A. Lkhagva, S. Shagdarsuren, S. Samdantsoodol, M. Chimidhisig, U. Jadamba, O. Tumurbaatar, and T. Lookhondorj. 2003. Ulaanbaatar Rapid Needs Assessment. Report prepared by CHF International under USAID/CHF Growing Entrepreneurship Rapidly Initiative. USAID Cooperative Agreement No. AID 492-A-00-02-00017-00. Ulaanbaatar.

Isakson, R. 2002. Payments for Environmental Services in the Catskills: A Socio-Economic Analysis of the Agricultural Strategy in New York City's Watershed Management Plan. Report prepared for the Payment for Environmental Services in the Americas Project. FORD Foundation and Fundación PRISMA. San Salvador.

JICA and Government of Mongolia. 2007. The Study on City Master Plan and Urban Development Program of Ulaanbaatar City. Progress Report Volume 1: Summary. Report prepared by Almec Corporation in association with Pacific Consultants International and Aero Asahi Corporation for Japan International Cooperation Agency (JICA) and the Ministry of Construction and Urban Development, Ministry of Roads, Transport and Tourism, and Ulaanbaatar City Government. Ulaanbaatar.

Johansson, B. 2002. Estimation of Areal Precipitation for Hydrological Modelling in Sweden. Earth Science Centre (Report A76 2002). Göteborg University.

Jutman, T. 1992. Production of a New Runoff Map of Sweden. Nordic Hydrological Conference. Alta.

Lindström, G. 1997. "A Simple Automatic Calibration Routine for the HBV Model." *Nordic Hydrology* 28(3): 153–68.

Lindström, G., and A. Rodhe. 1986. "Modelling Water Exchange and Transit Times in Till Basins Using Xxygen-18." *Nordic Hydrol* 17: 325–334.

Lindström, G., and S. Bergström. 1992. "Improving the HBV and PULSE-Models by Use of Temperature Anomalies." *Vannet i Norden* 25(1): 16–23.

Lindström, G., B. Johansson, M. Persson, M. Gardelin, and S. Bergström. 1997. "Development and Test of the Distributed HBV-96 Hydrological Model." *Journal of Hydrology* 201: 272–88.

Nash, J.E., and J.V. Sutcliffe. 1970. "River Flow Forecasting through Conceptual Models. Part I – A Discussion of Principles." *Journal of Hydrology* 10(3): 282–90.

Natsagdorj, L., and Batima, P. 2003. Climate Changes in Mongolia. Ulaanbaatar.

Penman, H.L. 1948. Natural Evapotranspiration from Open Water, Bare Soil and Grass. *Proceedings of the Royal Society of London Series* A193: 120–145.

Press, W.H., S.A. Teukolsky, W.T. Vetterling, and B.P. Flannery. 1992. *Numerical Recipes in FORTRAN. The Art of Scientific Computing*. Second Edition, Cambridge University Press.

Reid, W. 2001. Capturing the Value of Ecosystem Services to Protect Biodiversity. In Chichilenisky, G., G.C. Daily, P. Ehrlich, G. Heal, and J.S. Miller (eds). *Managing Human-dominated Ecosystems*. Missouri Botanical Garden Press. St. Louis.

Sharav, M. 2007. Mongolia Country Report: Industrial Development Planning by Local Government. Paper presented at Asian Development Bank Cluster-Based Development Approach Policy Seminar. Tokyo.

Shaw, E.M. 1988. *Hydrology in Practice.* Second edition. London, U.K.: Chapman and Hall.

Sugiura, K., T. Kadota, T. Zhang, M. Ishikawa, T. Yamazaki, K. Purevdagva, Y. Amarsanaa, D. Oyunbaatar, G. Davaa, N. Sharkhuu, B. Dorjgotov, and T. Ohata. 2005. Snow Survey in the Tuul River Basin, Mongolia, 2002–2005. Paper presented at 2nd Symposium on Water Cycle in Northern Eurasia. Hokkaido.

World Bank and PPIAF (Public-Private Infrastructure Advisory Facility). 2007. Foundation for Sustainable Development: Rethinking the Delivery of Infrastructure Services in Mongolia. Washington D.C.

World Bank. 1997. Staff Appraisal Report: Mongolia Ulaanbaatar Services Improvement Project. Report No. 163 79-MOG. Washington D.C.

Zandaryaa, S., U. Borhculuun, and S. Munkhtuyat. 2003. "Reserves, Consumption and Contamination of Groundwater in Ulaanbaatar, Mongolia." In *The Ground Below Our Feet: Atlas of Urban Geology.* Volume 14, Chapter 39. United Nations Economic and Social Commission for Asia and the Pacific. Bangkok.