META-ANALYSIS ON THE EFFECTS OF GLOBAL ECONOMIC GROWTH ON BIRDS IN THE NATIONS OF THE THREE POLES

Master thesis

By

Cynthia Gabriela Reséndiz Infante

born 14 July1978
in Monclova, Mexico

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Supervisor/Betreuer:	Prof. Falk Huettmann, PhD
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List of abbreviations

ABC	Argentina, Brazil and Chile
ACC	Antarctic Circumpolar Current
HACIA	Arctic Climate Impact Assessment
BRIC	Brazil, Russia, India and China
CAFF	Conservation of Arctic Flora and Fauna
CAML	Census of Antarctic Marine Life
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CCAS	Convention on the Conservation of Antarctic Seals
CCNN	Climate Change Network Nepal
CITES	Convention on Intenational Trade in Endangered Species of Wild Fauna and Flora
CR	Critically endangered species
CSV	Comma-separated values
DDT	Dichloro-diphenyl-trichloroethane
EN	Endangered species
EPAT	Environmental Protection to the Antarctic Treaty
FAO	Food and Agriculture Organization
GATT	General Agreement on Tariffs and Trade
GDP	Gross domestic product
GHG	Green house gas
GIS	Geographical Information System
GLOF	Glacial lake outburst floods
HUP	Himalayan uplands plant
HKH	Hindu Kush-Himalaya
IBA	Important Bird Areas
ICIMOD	International Centre for Integrated Mountain Development
IMF	International Monetary Fund
IPA	Important Plant Areas
IPCC	Intergovernmental Panel on Climate Change
IWC	International Whaling Comission
LC	Least concern species
LDCs	Least developing countries
LUC	Land use change
NAFTA	North American Free Trade Agreement
NT	Near threatened species
OECD	Organization for Economic Co-operation and Development
PAHs	Polycyclic aromatic hydrocarbons
PCA	Priority conservation area
PCBs	Polychlorobiphenyls
PFC	Perfluorochemicals
PM10	Particulate matter of 10 microns in diameter or smaller
POP	Persistent organic pollutant
RSF	Resource Selection Functions

SCAR-MarBIN	Scientific Committee on Antarctic Research Marine Biodiversity Information Network
SF6	Sulfur hexafluoride
SIPRI	Stockholm International Peace Research Institute
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
VU	Vulnerable species
WTO	World Trade Organization
WWF	World Wildlife Fund

Units and symbols

As	Arsenic
° C	Degrees Celsius
Cd	Cadmium
CH_4	Methane
cm/year	Centimeters per year
CO_2	Carbon dioxide
Hg	Mercury
km	Kilometer
km^2	Square kilometer
kt	Kilotonne
m	Meters
m/year	Meters per year
$MtCO_2e$	Metric tons carbon dioxide equivalent
Pb	Lead
tons/year	Tons per year
US$	US dollar
Zn	Zinc

1. Abstract

Economic and population growth as well as global macroeconomic policies are contributing to increasing global greenhouse gas (GHG) emissions. Climate change effects are more pronounced in cold regions such as the 'Three Poles' (the Arctic, the Antarctic and the Hindu Kush-Himalaya regions) than anywhere else. The Three Poles are rich in natural resources but the extraction of resources is degrading ecosystems and processes, and affecting species. In the Three Poles, many species depend on ice and snow habitats, but these species are competing with human activities for space and resources on a finite globe. Local and global pressures cause bird species populations to decline. In this study I investigated how bird populations are affected by economic growth and subsequent effects on the environment in the Three Poles regions. Data mining based on machine learning algorithms was used to perform the analyses. TreeNet (based on regression trees), included in the software Salford Predictive Modeler Builder® v.6.6 was used to develop the models. An additional Random Forests analysis (classification trees) was used to analyze the datasets. Two response variables were chosen based on bird distribution maps provided by BirdLife and the IUCN RedList categories, including those that have risk of extinction or are in the Least Concern category but with declining populations. Data from the WDI Data Catalog of The World Bank (World Development Indicators) were used as predictors. The results include a total of 24 models, classified by pole and type of country according to their direct (primary countries) or indirect (secondary countries) link to the Three Poles regions. A combind model was also run (primary and secondary countries). Models were evaluated according to the response curves and gains charts. Models confirm that global demand for, and consumtion of, resources is affecting the Three Poles. Food production, rural population, CO_2 emissions, Gross Domestic Product (GDP) and agricultural land were the top ranked predictors to explain the number of birds classified as threatened or with populations decreasing. This finding supports that the global demand for resources such as oil, gas and fish that were exploited from the Three Poles, added to global warming from anthropogenic causes are significantly affecting bird species populations. However, further research has to be carried out in order to obtain sound information on what the best management and governance is for a sustainable outlook for the Three Poles and beyond.

2. Introduction

Scientific evidence shows that anthropogenic disturbance puts pressure on the global system altering natural cycles and contributing to enhanced effects (IPCC 2007, Raupach and Fraser 2011). While climates have changed for millions of years, man-made climate change is the result of unsustainable fossil fuel consumption and release of green house gases (GHG) into the atmosphere. The main sources of GHG come from burning fossil fuels to produce energy (CO_2: 56.6%), but also from deforestation (CO_2: 17.3%) (IPCC 2007). Most global GHG emissions have been increasing as a result of economic growth and human activities. According to the Intergovernmental Panel on Climate Change (IPCC 2007) global temperatures have risen by about 0.74°C on average (1906-2005) and are expected to increase by 1.8-4°C til the end of the 21th century. Climate change consequences include warmer atmospheric and ocean temperatures, ocean acidification, ice and glaciers melting, permafrost retreat, and therefore an increase in the intensity and frequency of natural disasters (floods, droughts) (IPCC 2007). Global warming is affecting physical, ecological and human systems alike (Chapin et al. 2006, Hinzman et al. 2005, IPCC 2007, Stern 2007).

Human impacts and sources of climate change are global and ignoring borders (Gomez-Pompa and Kaus 1992, Vitousek et al. 1997, Young and Steffen 2009, Sodhi and Elrich 2010, Huettmann 2011). The Earth system is complex and interconnected; even if changes are happening on one part of the globe they can affect far and remote areas elsewhere (Sodhi and Elrich 2010, Huettmann 2011). Some species and regions may suffer from negative impacts and some others may obtain what gets perceived as benefits from climate change (Fankhauser 2001, Stempniewicz et al. 2007). Nonetheless, there are unique systems that may be irreversible harmed by climate change. Climate change is significantly affecting the cryosphere (ice, snow, glaciers, ice sheets, ice shelves, permafrost, and river and lake ice) (Walsh et al. 2005), and is particularly happening fast in the Arctic (Root et al. 2003, IPCC 2007, Parmesan 2007, Rosenzweig 2008, Walsh 2008, Serreze et al. 2010).

The cryosphere is critical though to maintain Earth's conditions and ecosystems; it plays a central role in physical processes, including climate regulation, and is habitat for a wide variety of species (ACIA 2005, McGuire et al. 2009). Most of the cryosphere system is located in the Arctic, Antarctic and the Hindu Kush-Himalaya regions. In this study, these three areas are called the 'Three Poles' region (Huettmann 2012). The Three Poles include fragile and vulnerable ecosystems and species, such as mountain ecosystems with ice and snow dependent species. The Three Poles are also rich in natural resources, such as oil and gas and mine sites, which play a role in international economy and development. Environmental destruction of the Three Poles ecosystems will affect not only local inhabitants, but has major global effects. If the Three Poles melt, and apart from serious watershed impacts, a positive temperature feedback may amplify global warming and other negative effects for people and ecosystems (IPCC 2007, Stern 2007, Serreze et al. 2010, Callaghan et al. 2011, Vincent et al. 2011). Human population growth and the increasing demand of resources are major drivers of ecosystem degradation (Singh 2006), including those at the Three Poles.

It is well documented that economic growth leads to a range of social and environmental impacts and the competition with other species for land and resources (Booth 2004, Stiglitz 2005, Dasgupta 2007, Clausen and York 2008, Czech 2008). It has become one of the major drivers of species extinction (Sodhi and Ehrlich 2010), and subsequently populations are also declining

(Clausen and York 2008, Sodhi et al. 2010). Anthropogenic climate change may catalyze present threats to biodiversity and many species will not be able to adapt as quick as they have to, leading to their reduction and eventual extinction (Hunter 2002, Thomas et al. 2004, Stork 2010). For example, species in the Three Poles that depend on sea ice will have major trouble coping with ice loss because the feature they depend on is simply gone.

Current global environmental and macroeconomic policies tolerate ecosystem destruction such as those in the Three Poles in benefit for growing one-sided businesses (Huettmann 2012). For example, if the Arctic melts, the access to oil, gas and minerals will increase and will in turn again increase transportation opportunities, but leading eventually to ecosystem degradation. Such a growth is based on resources. Due to climate change, access to resources and tourism will increase in the Antarctic pole (Trathan and Agnewa 2010), with assumed consequences such as oil spills, noise and other pressures will increase for ecosystems and species (Ruoppolo et al. 2012). In the Hindu Kush-Himalayan pole, climate change may increase the availability of crop land areas, and many species may lose their habitats (ICIMOD 2009a).

With no effective policies or strategies to protect the Three Poles and ecological services until now, the astounding biodiversity and global processes are at stake. Polar ecosystems and their species will already be affected considerably due to global warming. Since species are interrelated (e.g. trophic web), and birds being one of the most thoroughly studied taxa and good indicators of ecosystems' health, this study here is focused on the investigation of economic growth and socioeconomic effects on bird populations. Most threats to ecosystems are linked to human activities and economic development, including an increasing demand for resources and space (BirdLife 2012). Climate change intensity will further be influenced by population growth, economic growth and technological factors, as well as by the capacity of reducing anthropogenic GHG emissions (Raupach and Fraser 2011). Therefore it is important to know if socioeconomic development is affecting critical areas for Earth system functioning, such as those in the Three Poles and birds as powerful indicators (see Wohler in Humphries and Huettmann 2012).

Data mining is based on machine learning algorithms and well known due to its speed and predictive power to find unexpected trends and signals in messy data (Han et al. 2006, Craig & Huettmann 2009), as well as its flexible modeling process approach (Hastie et al. 2003). This study here uses socioeconomic data from the WDI Data Catalog of The World Bank (World Development Indicators; The World Bank 2012a). Two response variables were selected based on bird distribution maps provided by BirdLife (BirdLife and Nature Serve 2012) and the IUCN RedList categories (IUCN 2012), including those that have a risk of extinction or are in the Least Concern category and with declining populations. A total of 24 models were created based on the Three Poles, primary nations (with territory or claims at the poles) and secondary nations (without territory but with interest at the poles) concept.

While this study deals with birds, it is also an overview of the current environmental problematic in the Three Poles. A description of the Three Poles and its role in global economy and environmental issues is presented, too.

3. Objectives

The main goal of the research presented in this document is to investigate how much anthropogenic impact from economic growth and socioeconomic issues are contributing to bird species declining in the Three Poles region (Arctic, Antarctic and Hindu Kush-Himalaya), using best available data and analysis methods.

To achieve, the specific goals of this study are:

- Use the best available data and analysis methods.
- Learn and apply the fundamental concepts of machine learning software.
- Have an understanding of the use of natural resources and impacts in the Three Poles region.
- Have an understanding of how global anthropogenic issues affect negatively ecosystems in the Three Poles.
- Develop models for analyzing socio-economic information involved in the process of bird population declining.
- Discuss how economic growth and other anthropogenic issues are involved in the process of bird population declining.

4. The Three Poles

The "Three Poles" are the Arctic in North Pole, the Antarctic in the South Pole and the Hindu Kush-Himalaya region in Asia. These regions are the coldest on Earth and have most of the ice and freshwater resources (IPCC 2007). The Three Poles are part of a global system formed by ice and snow called the cryosphere. Components of the cryosphere include sea ice, snow, glaciers, ice sheets, ice shelves, permafrost, and river and lake ice (Walsh 2008). The Three Poles contain 70% of freshwater resources (about 24 million km^2) in the form of ice and permanent snow (http://www.unwater.org/statistics_res.html).

Fossil fuels have been key drivers in recent human development and modern life (Vitousek et al. 1997, National Research Council 2003, Huber 2009, Ayres 2010, Armaroli and Balzani 2011, Li 2011). The top ten countries with the highest fuel consumption are also the world's major economies (Yergin 2008, Li 2011) and are closely related to the Tree Poles regions. Economic growth in virtually all of the Three Poles countries is based on oil, gas and other natural resources (Glomsrød et al. 2009, CIA 2012). Some countries are already extracting poles' resources, while other countries claim to own polar land and exploit natural resources.

4.1 Primary and secondary countries

In this work I defined primary countries as those countries that are partially or fully contained in the Three Poles areas, or have territorial claims (see table 1); and secondary countries as those countries that have an economic and political interest on the Three Poles areas and play an important role on Three Poles' conservation and environmental issues. Nonetheless secondary countries do not have country land, overseas territories or claims at any of the poles (see table 1).

Primary countries of the Three Poles are organized in different ways. For the Arctic, the Arctic Council (http://www.arctic-council.org) has permanent observers that include non-arctic countries (France, Germany, The Netherlands, Poland, Spain, and the United Kingdom). China, South Korea, Japan, Italy and the European Union have tried unsuccessfully to be permanent observers. In the Antarctic, the Antarctic Treaty includes 48 countries (British Antarctic Survey 2012a). From this total, 28 are consultative nations and 20 are observer countries. Eight consultative countries have made claims to Antarctic Territory. Since Antarctic is declared a peaceful place, these claims are a contradiction to the Treaty. Russia and the U.S. do not recognize these claims and have reserved the right to make claims as well. The U.S. has not even signed the United Nations Convention on the Law of the Sea (UNCLOS; http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm) neither Kyoto Protocol. Research stations have been established in the Antarctic region by several countries such as Italy, South Africa, India, Russia, Australia, France, among others (CIA 2012). On the third pole, some aspects of the Himalayan countries are organized through the International Centre for Integrated Mountain Development (ICIMOD). ICIMOD has eight regional board members. Non-Himalayan countries that are part of the independent board members are Germany, Sweden, Canada, Norway and Switzerland (see http://www.icimod.org).

I describe in the next chapter the environmental issues and importance in global economy of the Three Poles.

Table 1: List of primary and secondary countries sorted by pole.

Country Name	Arctic	Antarctic	Himalaya
Afghanistan			1
Argentina		1	
Australia		1	2
Bangladesh			1
Bhutan			1
Brazil	2	2	2
Canada	1	2	
Chile		1	
China	2	2	1
Denmark	1		
Finland	1	2	
France		1	2
Germany	2	2	
Greenland	1		
Iceland	1		
India	2	2	1
Italy	2	2	2
Japan	2	2	2
Korea, South	2	2	2
Malaysia		2	
Mongolia			2
Myanmar			1
Nepal			1
Netherlands	2	2	
New Zealand		1	2
Norway	1	1	2
Pakistan			1
Poland	2	2	
Russian Federation	1	2	2
South Africa		1	
Sweden	1	2	
Switzerland			2
Ukraine		2	
United Kingdom	2	1	2
United States	1	2	2
Uruguay		2	
Peru		2	
Ecuador		2	
Spain		2	

Bulgaria		2	
Czech Republic		2	
Belgium		2	
Romania		2	

1=primary nation for the particular pole
2=secondary nation for the particular pole

5. The Arctic

5.1 General description

The Arctic region, the 1st pole, is located on the northern hemisphere and is situated within the Arctic Polar Circle (Callaghan et al. 2001). Many definitions of 'the Arctic' exist, for example based on the artificial definition of the Arctic Circle, the outer boundary of the tree line, climatic boundaries, and the zone of continuous permafrost on land and sea-ice area on the ocean (Huntington and Weller 2005). In this work, I defined the Arctic region according to the Conservation of Arctic Flora and Fauna (CAFF 2009) by the Arctic Council (http://www.arctic-council.org). The Arctic boundary in Alaska and Europe follows the northern limit of sub-Arctic where the boreal forest begins. The marine parts of this boundary include the marine areas north of the Aleutian Islands, the Bering Sea, Hudson Bay, and parts of the North Atlantic Ocean including the Labrador Sea (CAFF 2008) (Fig. 1).

The Arctic comprises approximately 7% of the Earth's surface including water and land, and holds between 13% (Howard 2009) to 22% of the known petroleum reserves, 30% of gas reserves (Gautier et al. 2009, Lindholt and Glomsrød 2012), rare metals, minerals, and marine resources (Gautier et al. 2009, CIA 2012, Lindholt and Glomsrød 2012). The Arctic plays an important role in global water, CO_2 and CH_4 cycles and weather regulation (Shaver and Jonasson 2001, Macdonald et al. 2005, IPCC 2007, Semiletov et al. 2007, Budikova 2009, Lai 2009, McGuire et al. 2009, Kitidis et al. 2010). The world as we know it today would not be possible without Arctic ecosystem services, and many environmental issues would be catalyzed by reduction in ice cover and snow (see section 8.3) (Serreze et al. 2010).

Figure 1: Arctic boundaries according to CAFF (2006) (Source: CAFF 2009, ESRI 2012).

The Arctic shows one of the most extreme environmental conditions on Earth, and a very high variation in environmental and physical conditions (Callaghan et al. 2001, Nuttall and Callagha 2000, Walsh 2008). The average winter temperature is -34° C and the average temperature in summer is 3-12° C.

Arctic environments comprise about 1-3% of Earth's biodiversity (Matveyeva and Chernov in Nutall and Callaghan 2000, Mace et al. 2005). Best represented groups are lichens (5-6.5% of the global diversity), mosses (5.7-7% of the global diversity) and springtails (7-8% of the global diversity) (Callhahan et al. 2001). The Arctic region includes terrestrial, marine and freshwater ecosystems. It includes mountains such as the Brooks Range in Alaska and Gunnbjørn Fjeld mountain in Greenland; and as well as archipelagos in the Northwest Territories in the Canadian Arctic and on Svalbard in Norway. This region has abundant lakes, rivers, and wetlands that are habitat for species, including migratory wildlife (Vincent and Hobbie 2000; also see http://www.cms.int/).

5.2 Arctic ecosystems

5.2.1 Freshwater resources in the Arctic

Inland waters are a major component of the Arctic landscape. Four of the Earth's ten largest river systems are located in the Arctic, e.g. the Mackenzie, Ob, Yenisei and Lena (Fig. 1) (Forman et al. 2000). Lakes and rivers contribute to the global carbon cycle, transporting organic material to the ocean from terrestrial and aquatic ecosystems (Semiletov et al. 1996, Forman et al. 2000).

Arctic freshwater resources are also present in the form of glaciers, snow and ice sheets (in Greenland), as well as frozen ground and permafrost. Snow covers the Arctic for 8-10 months each year (Callaghan et al. 2011). When snow melts, runoff contributes to water flow in river systems. Sea ice is present in the Arctic Ocean in winter and varies every season from 7-16 million km^2 (see http://earthobservatory.nasa.gov/Features/SeaIce/page3.php). However, unprecedented sea ice losses have been present in summer 2007 (Perovich et al. 2008) and even more extreme in 2012 (NSIDC 2012a, NSIDC 2012b). Ice loses were due to anomalous high temperatures and winds that increased solar heating input to the upper ocean (Comiso et al. 2008, Perovich et al. 2008, Zahng et al. 2008; also see http://nsidc.org/arcticseaicenews/). Soil in the Arctic is characterized by a permanently frozen layer called 'permafrost'. It reaches under land, under mountains as well as partly under the sea. Together with peatlands, areas of permafrost store large amounts of CO_2 and CH_4 (Kvenvolden and Lorenson 1993, McGuire et al. 2009, Nindre et al. 2011, Walter et al. 2012).

Freshwater biodiversity is also important for local people and the whole trophic web, including fish and birds. Fish resources include salmon (*Salmo salar* and *Oncorhynchus spp.*) (Quinn 2005, Verspoor et al. 2007), cod (*Arctogadus glacialis* and *Boreogadus saida*) (Von Dorrien 1991), among other species.

5.2.2 The Arctic Ocean

The Arctic Ocean is the smallest of the Earth's five oceans. It is about 14 million km^2, the average depth is 1,050 m and the deepest point is found north of the Chukchi Sea at 4,441 m (Welsh et al. 1986). Its average productivity is low, but may vary according to the region (Sakshaug 2003). The Arctic Ocean has several high productivity areas that host large fisheries, such as: the Chukchi Sea (Short and Murray 2011), Barents Sea, Bering Sea, Davis Strait and Labrador Sea for instance (Grebmeier et al. 2006, Hunt et al. 2012).

The surface of the Arctic Ocean is covered by an ice layer in winter, but in summer the icepack shrinks by about half of its winter extent. This variation contributes to Arctic Ocean processes such as primary production. Also, polynyas (i.e. water surrounded by sea ice) are very important for

wildlife and ecosystem processes (Grebmeier and Barry 2007). Some seabirds stay all year round in the Arctic using polynyas for feeding and breeding – spectacled eider duck (*Somateria fisheri*), black guillemot (*Cepphus grylle*), northern fulmar (*Fulmarus glacialis*), ivory gull (*Pagophila eburnea*), as well as several geese species such as Canada geese (*Branta canadensis*) in Alaska (Falk et al. 1997, Hatch and Nettleship 1998, Butler and Buckley 2002, Bump and Lovvorn 2004, Gilchrist and Mallory 2005, Gaston et al. 2006, U.S. Fish & Wildlife Service 2010; see Huettmann et al. 2011 for predicted species distribution maps). In general, Arctic water birds include divers (*Gavia stellata, Gavia adamsii*), grebes (*Podiceps auritus, P. grisegena*), ducks (*Somateria spp.*), cranes (*Grus leucogeranus* and *G. americana*), waders (*Philomachus pugnax*), gulls (*Larus argentatus, Larus glaucoides*), skuas (*Stercorarius maccormicki, S. parasiticus, S. pomarinus, S. skua*), and terns (*Sterna paradisaea*) (BirdLife and Nature Serve 2012, Zöckler 2012). Other marine species include krill (*Thysanoessa raschii*) which are at the basis of the marine trophic web, crabs (*Paralithodes camtschaticus*), as well as migratory mammals such as the grey whale (*Eschrichtius robustus*), humpback whale (*Megaptera novaeangliae*), harp seal (*Pagophilus groenlandicus*) and hooded seal (*Cystophora cristata*) among others.

5.2.3 Arctic terrestrial ecosystems

Tundra is the coldest of all ecosystems and it is characteristic of the Arctic (Callaghan et al. 2001). Because of snow thawing, tundra turns into important wetland habitats every year (Woo and Young 2006, Sodhi and Elrich 2010). Vegetation mostly includes low shrubs, grasses, sedges and lichens adapted to live in extreme conditions. Plants are short and usually grouped together, and carry out photosynthesis at low temperatures and low light. Productivity in this ecosystem is low compared to the rest of the world's ecosystems (Shaver and Jonasson 2001, Mace et al. 2005, Arrigo et al. 2008). Typical arctic terrestrial biodiversity includes mammals such as arctic fox (*Alopex lagopus*), caribou (*Rangifer tarandus*), as well as hares (*Lepus arcticus*), squirrels (*Spermophilus parryii* and *Tamiasciurus hudsonicus*) and lemmings (*Dicrostonyx torquatus*) (Callahan et al. 2001). Some seabirds nest in the tundra, like terns, skuas and phalaropes (*Phalaropus fulicarius* and *P. lobatus*). Also bird biodiversity in the tundra include for instance swans (*Cygnus bewickii*), fulmars (*Lagopus lagopus, L. muta*), raptors (*Accipiter gentilis*), pipits (*Anthus cervinus*, *A. rubescens*), among others (USFWS 2010, BirdLife and Nature Serve 2012, Zöeckler in Huettmann 2012).

Some species stay year-round in the Arctic and some others migrate to other regions. Two hundred and seventy-nine species of birds migrate to the Arctic to breed every year from South Africa, Australia, New Zealand and South America (Alerstam et al. 2001, Alerstam et al. 2007, Hohn and Jaakkola 2010, Zöeckler in Huettmann 2012). Arctic ecosystems also support more than half of all shorebird species and 80% of global goose populations in the world (Hohn and Jaakkola 2010, Zöeckler in Huettmann 2012).

5.3 People in the Arctic

In spite of harsh weather conditions, several indigenous people have lived well in the Arctic for thousands of years. They are distributed along the Arctic in Alaska (5 groups), Canada (4 groups), Greenland (2 groups), Fennoscandia and Russia's Kola Peninsula (1 group), as well as the Russian Far North and Siberia (5 groups) (table 2). These groups are classified according to the Arctic Climate Impact Assessment (ACIA) (Nutall 2005) and depend on hunting, herding, fishing and gathering to survive; but also these activities represent their cultural identity (Berman and Kofinas 2004, Nutall 2005, Sale 2009, Reeves et al. 2012).

Table 2: Arctic indigenous groups according ACIA (Nutall 2005).

Country/region	Indigenous group
Alaska	Iñupiat,Yup'ik, Alutiiq, Aleuts, and Athapaskans
Northern Canada	Inuit, Inuvialuit, Dene, and Athapaskans
Greenland	Kalaallit and Inughuit
Fennoscandia and Russia's Kola Peninsula	Saami
Russian Far North and Siberia	Chukchi, Even, Evenk, Nenets, and Yukaghir

The Arctic region has a population of about three-and-a-half million people (Bogoyavlenskiy and Siggner 2004, U.S. Census Bureau 2011). There is a mixture of indigenous and non-indigenous people. In some places indigenous people are the majority (e.g. Nunavut in Canada and Greenland); in contrast, in places such as the Yukon Territory, most people are non-indigenous. In general, Arctic population increased in the middle of the 20th century, especially in Greenland, Alaska and Northern Russia (due to migration since 1930s) (Bogoyavlenskiy and Siggner 2004). Currently, most of the Arctic population lives in Arctic Russia; but the most densely populated areas are Iceland and Arctic Norway.

5.4 Economic activities and environmental issues in Arctic environments

5.4.1 Arctic countries' natural resources and economy

Arctic territories belong to eight countries: the U.S., Canada, Denmark (Greenland), Iceland Norway, Sweden, Finland and Russia. Except for Russia, Arctic nations are high income countries. The gross domestic product (GDP) per capita in high income countries in the Arctic has increased dramatically since the 1970s (Fig. 2). In the 1960s these countries had a GDP per capita of approximately US$2,500; by the 2000s the average of Arctic high income countries was US$41,500 and US$5,900 in Russia (The World Bank 2012b). Part of this economic growth comes from using natural resources that were extracted from the Arctic, and their economies still depend much on natural resources extraction (Glomsrød et al. 2009).

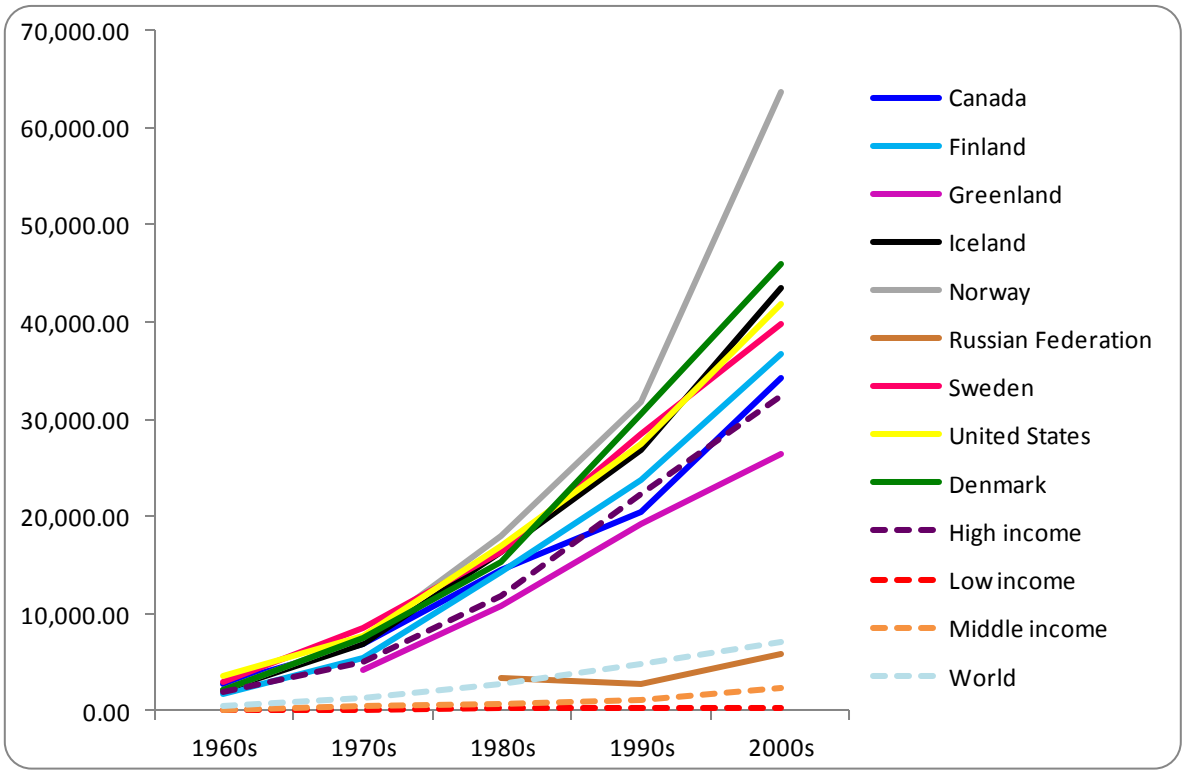


Figure 2: Average GDP per capita and per decade in primary Arctic countries vs. income categories (US$) (The World Bank 2012a).

Economic activities in Arctic countries are diverse, but in some countries extractive resources industry is the most important. Oil and gas extraction, and transportation are the main industries in Alaska (30% of Alaskan Gross State Product) and Arctic Russia (Glomsrød et al. 2009). Alaska is the third largest U.S. oil producer, just after Texas and federal offshore oil (PADD 3), but oil production in both states has been falling since late 1980s (U.S. Energy Information Administration 2012). Oil and gas production is also declining in Canada. Other Arctic countries base their economies on education, health and social work; however extractive resources industries still play an important role in their economies. Extractive activities are mainly fisheries and processing of fish (Greenland, Iceland and Norway), mining (Arctic Finland and Sweden), and energy resources (Arctic Norway) (Glomsrød et al. 2009).

Secondary Arctic countries are also mostly high income countries (Fig. 3). Their interests' in Arctic resources ranges from oil (e.g. Russian oil to Germany; http://af.reuters.com/article/commoditiesNews/idAFL5E8H62ZJ20120606) to whaling (e.g. Japan).

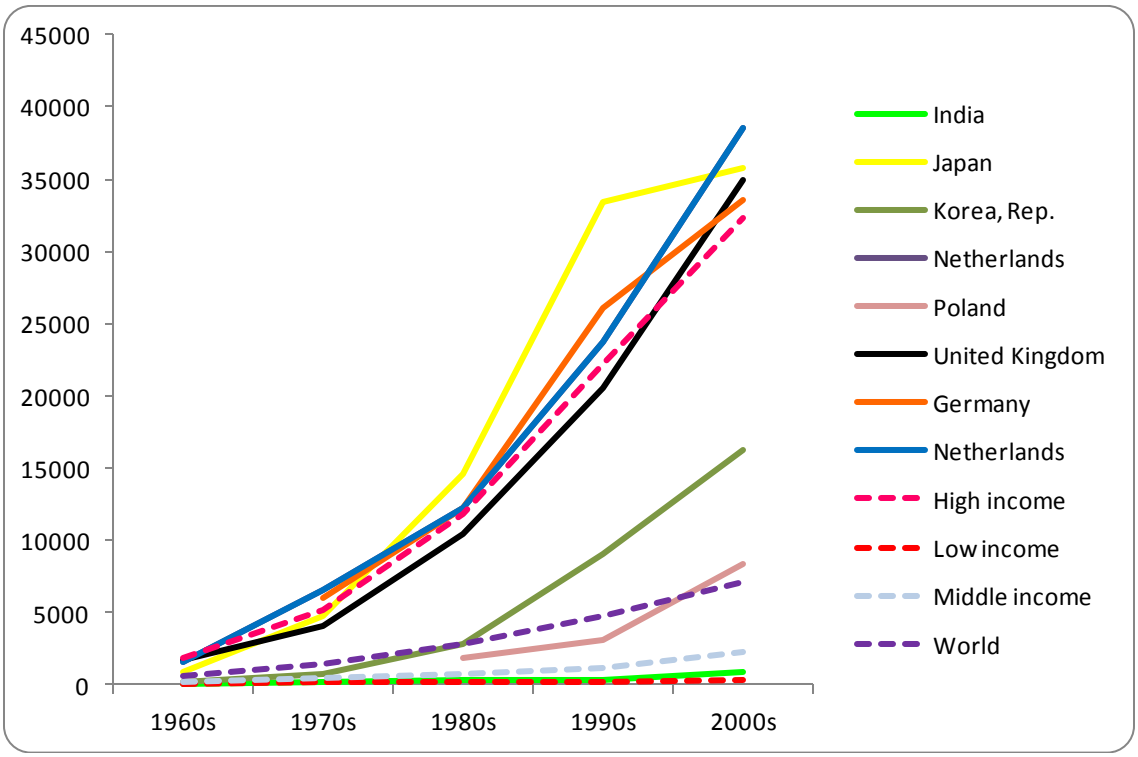


Figure 3: Average GDP per capita and per decade in secondary Arctic countries vs. income categories (US$) (The World Bank 2012a).

Undoubtedly exploitation of natural resources in the Arctic has given some economic and welfare benefits to high income economies (National Research Council 2003). Nonetheless, human activities *in situ* or elsewhere, intensification and new commercial exploitation of living and non-living resources have had a negative impact on the Arctic land- and seascape (National Research Council 2003, Sale 2009, Young and Steffen 2009, Huettmann 2012). Direct and indirect effects represent a serious threat for species, trophic web and ecosystems resilience, and therefore for the whole Earth system as well as the humankind (Hunt et al. 2010, Jernelöv 2010, Humphries and Huettmann 2012). Species are interrelated; the loss or decline of one species can and may affect other species and populations (Stork and Lyal 1993, Koh et al. 2004). Economic activities are affecting bird populations considerably (National Research Council 2003, Gilman 2011, MacMillan and Han 2011, Søndergaard et al. 2011, Zöeckler in Huettmann 2012). A brief description of regional activities and their impacts on birds and other wildlife species is presented as following (see section 8.3 for other impacts):

5.4.1.1 By-catch, overfishing, aqua-farming

Overexploitation has increased in the last decades, with negative effects on many bird species populations (Zöckler 2012 in Huettmann 2012). Fisheries compete with seabirds in the Arctic and negative effects are diverse (Furness 2003). Due to the complex relationships the problem is not only associated with commercial species (Rouyer et al. 2011). By-catch is one of the main causes of marine biodiversity loss, affecting species such as marine mammals and seabirds (Hunt et al. 2010, Gilman 2011, MacMillan and Han 2011). By-catch may decrease seabird populations (see Furness 2003 for albatrosses and petrels). Seabirds may be affected by baits and nets (drowned) or change

in food availability (Tasker et al. 2000). This is an issue, for instance, for Kamchatka waters in Siberia, as well as in Greenland.

Even alternatives such as aquaculture are intensive practices. Intensive activities may damage marine ecosystems through invasive species and pollution that disrupt ecosystems and kill marine life. Selective fisheries based on size or age are also a negative factor that is affecting the structure of populations and the trophic web (CAFF International Secretariat 2010, Rouyer et al. 2011).

5.4.1.2 Oil spills and offshore gas

Arctic local pollution sources include hydrocarbons and waste drilling fluids from oil and gas exploration and production (Thomas et al. 1992). Oil and gas exploration and production is happening intensely throughout the Arctic region: Canadian Beaufort Sea, West Greenland, the Norwegian Sea, the Barent Sea, the West Siberian Basin and the Far East Siberian Basin (Pew Environment Group 2010). These activities require an infrastructure that has several ecological impacts: habitat destruction, death of individuals, fragmentation of migration routes, erosion, pollution, among others (Harrould-Kolieb et al. 2009, WWF 2012). Development of oil and gas in the Arctic is most advanced in Alaska, which is traditionally thought to hold by far the largest portion of Arctic offshore oil (Short and Murray 2011). But gas extraction is also threatening ecosystems in Canada and Russia (Potapov et al. 2008). Offshore development is going on in Northern Norway and Northwest Russia, as well as in regions northeast of Iceland, and the Sea of Okhotks for instance. Oil spills from blowouts, pipeline leaks or shipping accidents are threatening Arctic ecosystems (Jernelöv 2010; Humphries and Huettmann 2012). Recent spills from pipelines have increased due to ruptures and leakages, e.g. Arctic Russia (Committee on Oil in the Sea 2003, Jernelöv 2010). Due to extreme weather, there is currently no effective method known for controlling and cleaning up an oil spill during Arctic winter conditions (Harrould-Kolieb et al. 2009, Pew Environment Group 2010, Humphries and Huettmann 2012). Other spills than oil should also be considered for their impacts, e.g. fresh and salt water spills and leaking transmission fluids as well as other liquids used for pipeline, drilling and machinery. They all add up dramatically to the spill statistics.

The input of current operational discharges from the oil industry into the ocean is increasing and by now exceeds the actual amount of oil released by oil spills in the 1970s (e.g. tank washing with seawater, oil content in ballast water and fuel-oil sludge) (Jernelöv 2010). Many oil and other spill accidents have happened in the Arctic. Prudhoe Bay and Cook Inlet in Alaska have also the highest rates of accidents due to gas (Pew Environment Group 2010). In 1989 the Exxon Valdez spilled 260,000 barrels of oil killing an estimated of 100,000 to 300,000 birds from 90 species, mostly murres (*Uria spp.*) (Piatt et al. 1990, Harrould-Kolieb et al. 2009, Ott 2005 for details). Effects from oil spills can last for decades, even after bioremediation, and sea ice can envelop oil and transport it. Oil can also sink to the seafloor and affect benthic communities (Peterson et al. 2003). Even the operational industry itself predicts oil spills in the Arctic (Huettmann 2012).

Moreover, the search for oil in the Arctic continues in the North of Canada. Consequences include changes in species distribution (Boulanger et al. 2012) habitat destruction (Birtwell et al. 2005) and impact on local people as well (National Research Council 2003, Davison and Hawe 2012).

5.4.1.3 Oil sands

Nations like Canada and the U.S. are now engaged into fracking, as well as into 'oil sands' (Hein 2006). Northern Alberta and British Columbia are among the most advanced provinces in those

businesses, and the impacts of these activities are devastating on many accounts (Kelly et al. 2009, Kelly et al. 2010). They affect directly and indirectly Arctic watersheds and the Arctic overall (Athabasca River), for example by promoting energy consumption, water use and climate change (Charpentier et al. 2009, Kelly et al. 2009, Giesy et al. 2010).

5.4.1.4 Mining

Metal-mining activity is increasing and a big topic (e.g. in Northern Canada). Mine wastes include heavy metals (Thomas et al. 1992), trace elements and other contaminant (Lemly 1994). Threats are however not only due to recent activities. In the past mining waste was directly discharged into the sea, including heavy metals (e.g. Pb and Zn). Even when some mines were already closed, metals were still present in sea sediments and biota in surrounding areas (e.g. seaweeds and blue mussels) (Søndergaard et al. 2011). A classic example can be seen in Fairbanks, Alaska. An old gold mining site is now polluted with arsenic contaminants in virtually all of its groundwater. Many sites in Chuktoak suffer from similar problems. Still, mining is the industry with the highest rate of growth in Alaska (Glomsrød et al. 2009). Mining in Alaska includes in their order of economic importance zinc, gold, lead, and silver.

Mining is also among the largest industries in the Canadian Arctic (e.g. Yukon), and especially the diamond industry is growing (Glomsrød et al. 2009). It started in the 1990s and today Canada is the third largest producer of diamonds in the world (Natural Resources Canada 2011). Today three of four diamond mines in Canada are located in the Arctic region - Ekati (since 1988), Diavik (since 2003) and Snap Lake (since 2007). High and increasing rates of pollutants have been already found in many arctic bird species (Braune et al. 2002, Braune 2007, Choy et al. 2010). Mercury concentration in eggs of thick-billed murres (*Uria lomvia*) and northern fulmars (*Fulmarus glacialis*) has increased in the last decades (1975-2003) (Braune 2007).

5.4.1.5 Tourism

Ecotourism depends heavily on the wildlife and the scenery of the Arctic. Biodiversity in the Arctic includes unique Arctic species that are attractive to visitors. Arctic landscapes such as in Alaska, Russia and the Yukon represent basically a billion dollar business with visitors from all over the globe. Further, aboriginal tourism in the Arctic is resource-based, including hunting ecotourism and cultural tourism (Notzke 1999).

Growing tourism in the Arctic leaves a lasting environmental impact, specifically in the atmosphere and ecosystems. Arctic species already face many different threats, and populations may decline as a result of the current changing conditions (ACIA 2005).

Considering ongoing stresses, sport hunting may become a threat for some species such as muskoxen (*Ovibos moschatus*) and caribou (*Rangifer tarandus*) (both have shown extinct subpopuations in the past). Conflicts between local people and visitors may happen as well (UNEP/GRID Arendal 2011). For instance, polar bear (*Ursus maritimus*) hunting by non-local people have increased in the last thirty years (Freeman and Wenzel 2006). This species is already decreasing and classified as vulnerable (VU) by IUCN (2012); and as extremely vulnerable by IPCC (2007) due to climate change and ice retreat.

5.4.1.6 Other pollutants

The trophic relationships and the food web in Arctic species is complex, and some pollutants may be transferred by species (bioaccumulation) (Blais et al. 2005, Choy et al. 2010). Radioactive fallout

from the 1950s and the 1960s in the Arctic still remains affecting food web (Thomas et al. 1992) and it is widely known for some Russian sites for instance (Smith 2000, Savinov et al. 2003). Nuclear tests were carried out in places such as Guba Chenaya Bay in the 1960s (Savinov et al. 2003). Seabirds may transfer persistent organic pollutants (POPs) to coastal food webs. Snow buntings (*Plectrophenax nivalis*) are reported as being among one of the most contaminated species, with high levels of PCBs (polychlorobiphenyls) and DDT (Dichloro-diphenyl-trichloroethane) (Choy et al. 2010). Northern fulmars (*Fulmarus glacialis*) and arctic terns (*Sterna paradisaea*) present high levels of As, Cd and Hg in musde and liver tissues (Savinov et al. 2003). PCBs and DDT are the most abundant residues in peregrine falcons (*Falco peregrines*) (higher than other terrestrial and marine mammals) (Thomas et al. 1992). Polar bears (*Ursus maritimus*) have further been shown to carry unhealthy loads of such contaminants (St. Louis et al. 2011) Bioaccumulation of radiation, heavy metals and other organic compounds are also affecting local people that ingest them in traditional foods (Strand et al. 2002, Van Oostdam et al. 2005).

Furthermore, plastic debris is affecting marine environments. Seabirds ingest high levels of plastic which has serious negative effects on the health (North Atlantic Ocean in Canadian Arctic) of thick-billed murres (*Uria lomvia*) (Provencher et al. 2009) and northern fulmars (*Fulmarus glacialis*) (Mallory et al. 2006, Mallory 2008).

5.4.1.7 Invasive species

According to Lassuy and Lewis (2010), due to environmental conditions the Arctic has not a severe problem of invasive species. However, some species have been introduced to the Arctic, and currently are having negative effects on the ecosystems. For example, the red king crab (*Paralithodes camtschaticus*) was introduced to the Barent Sea from the North Pacific in order to start a commercial fishery (Falk-Petersen et al. 2011). This species is commercially exploited, but having negative effects on native species, and therefore on other commercial species (Jørgensen and Primicerio 2007, Oug et al. 2011, Falk-Petersen et al. 2011). Up to c. 30% of invasive plants get reported already at different sites in Russia and in Alaska, specifically for industrial sites.

In addition global warming will add more stress to the Arctic and its invasive species. An increase in the accessible maritime routes and the risk of invasive species and diseases will further increase as well (Ruiz and Hewit 2009).

6. The Antarctic

6.1 General description of the Antarctic Pole

The Antarctic, the second pole, is located in the Southern Hemisphere, opposite to the Arctic. According to the Antarctic Treaty (1959), the Antarctic is the area south of the parallel 60° (see http://www.antarctica.ac.uk/about_antarctica/geopolitical/treaty/update_1959.php). The Antarctic includes the Antarctic Circle and the South Pole, the continent of Antarctica (land mass and ice-shelves), as well as the Southern Ocean and surrounding islands. The Antarctic continent has an estimated area of 14 million km^2 (Stonehouse 2002, CIA 2012). It is mostly covered by ice year-round (99.5% or about 14 million km^2) (Convey 2001, British Antarctic Survey 2012b), and the ice there can be up to three miles deep. There are also ice-free areas close to the coast, mostly on the Antarctic Peninsula and the McMurdo Dry Valleys region in southern Victoria Land (Fig. 4).

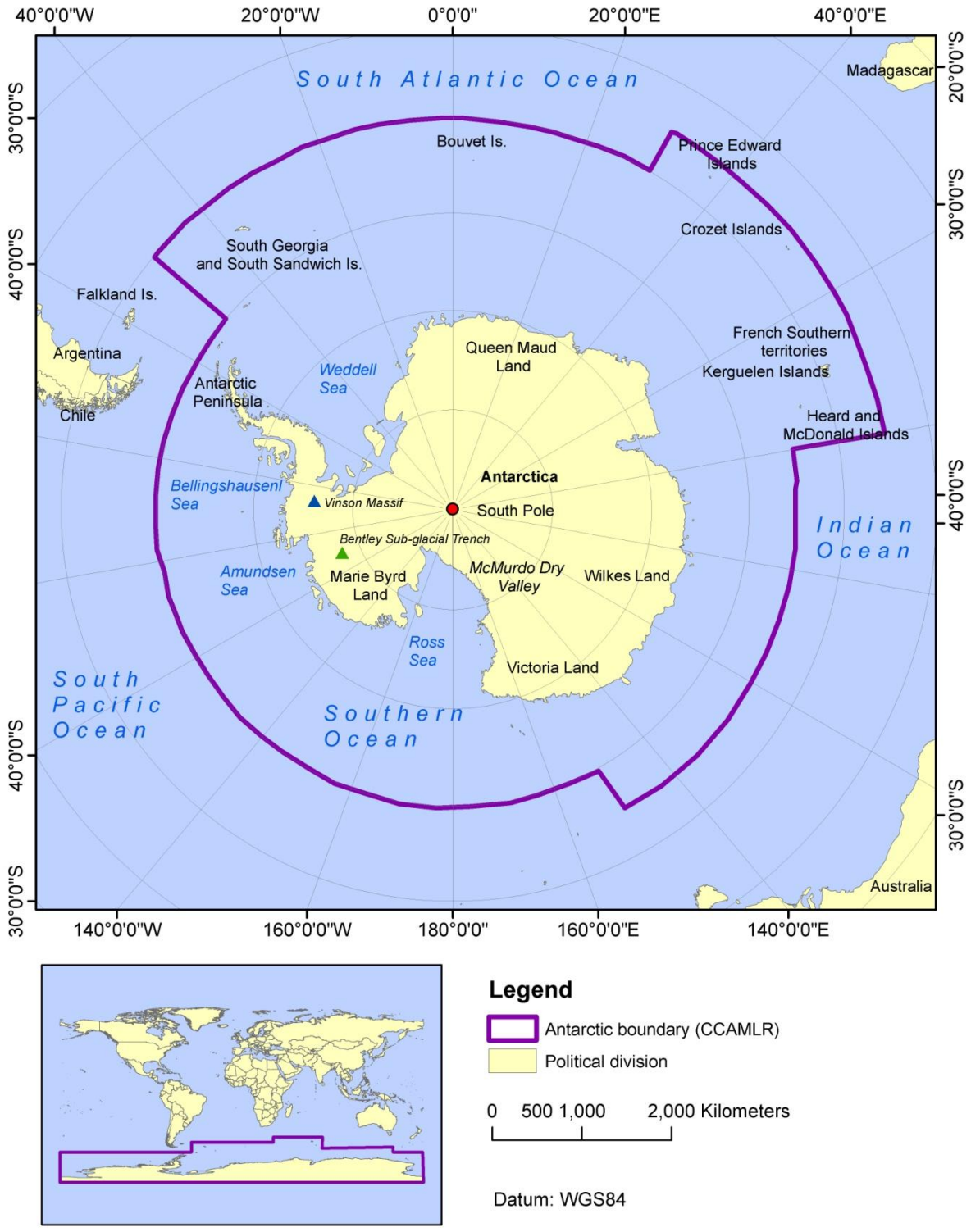


Figure 4: Antarctic region (Source: CCAMLR 2012, ESRI 2012).

The Transantarctic Mountains divide Antarctica. The eastern part is larger and mostly above sea level; whereas the western part is smaller and mostly below sea level. The highest point is the Vinson Massif mountain (4897 meters above sea level) and the lowest is the Bentley sub-glacial

Trench (-2540 meters below sea level) (Fig. 4) (Stonehouse 2002). Antarctica also has several volcanoes, most of them extinct.

In the second pole, cold weather is persistent even during the southern summer. The mean annual temperature in the interior is around -57° C. Snowfall in coastal areas is several meters each year, whereas the interior region is considered the world's biggest snow and ice desert (precipitation is about 5 cm/year) (Convey 2001).

6.2 Antarctic ecosystems

The Antarctic region is divided into three biogeographic regions: Continental Antarctic, Maritime Antarctic and sub-Antarctic. As its name suggests, the Continental Antarctic corresponds to the continental Antarctic landmass. The Maritime Antarctic contains the islands: South Sandwich, South Orkney, South Shetland Islands, Palmer Archipelago, the west coast of the Antarctic Peninsula south of Marguerite Bay, Bouvetøya and Peter 1 Øy. The sub-Antarctic region is the ring of islands surrounding the continent, including: South Georgia, Prince Edward Islands, Îles Crozet, Îles Kerguelen, Heard Island and Macquarie Island (Fig. 4). (Convey 2001, Holdgate 1970 in Terauds et al. 2012).

6.2.1 Terrestrial ecosystems: continental landmass and islands

Continental Antarctic vegetation consists of mosses, liverworts and lichens (Stonehouse 2002). The Maritime Antarctic has a higher floral diversity than the continental region, also including macro-fungus and two species of flowering plants - Antarctic hair grass (*Deschampsia antarctica*) and Antarctic pearlwort (*Colobanthus quitensis*). Sub-Antarctic diversity is even richer than in the other two zones. It is inhabited by mosses, liverworts, lichens, macro-fungus and also ferns, clubmosses and flowering plants (Convey 2001, British Antarctic Survey 2012c). Cook's tussock grass (*Poa cookie*) is a dominant species in various sub-Antarctic islands.

Terrestrial animal biodiversity in Continental Antarctic is low, and it is composed mostly by arthropods (Acari - mites and Collembola - springtails) and earthworms (nematodes, tardigrades and rotifers). These groups are represented by few different species, but populations are usually high in abundance (Convey 2001, Stonehouse 2002). Sub- and maritime Antarctic terrestrial fauna is mostly comprised by arthropods (springtails and mites), earthworms and mollusks. Sub-Antarctic fauna also includes insects and spiders. Due to human activities, non-native mammals and many plant species are present in sub-Antarctic islands as well (British Antarctic Survey 2012c).

6.2.2 The Southern Ocean

The Southern Ocean is delimited by the Antarctic Circumpolar Current (ACC) (Talley et al. 2011) and may be found up to parallel 30° S, further than those limits defined by the Antarctic Treaty. The ACC goes eastward and separates the Antarctic region from warm subtropical waters (Martinson 2012), influencing the Antarctic marine and terrestrial ecosystems (Murphy et al. 2012).

According to the Census of Antarctic Marine Life (CAML) and the Scientific Committee on Antarctic Research Marine Biodiversity Information Network (SCAR-MarBIN), marine biodiversity is made up of about 8,100 species (De Broyer and Danis 2011). Marine fauna includes krill (*Euphasia superba*), seals (*Arctocephalus gazella, Ommatophoca rossii*), fish (*Dissostichus mawsoni*), whales (*Balaenoptera bonaerensis*, *B. acutorostrata*), squid (*Mesonychoteuthis hamiltoni*), and many

seabird species (Stonehouse 2002). Other marine organisms such as holothuroids (sea cucumbers) are diverse (O'Loughlin et al. 2011) and calanoids (copepods) are abundant (Arndt and Swadling 2006).

The Wilson's Storm Petrel (*Oceanites oceanicus*) is the most abundant bird in the world (about 12,000,000 – 30,000,000 individuals), and is breeding in Antarctica and sub-Antarctic islands (Brooke 2004). Penguins (*Aptenodytes spp., Eudyptes spp., Pygoscelis spp.*) and other seabirds such as albatrosses (*Thalassarche spp.*), petrels (*Thalassoica spp.*), fulmars (*Pachyptila spp.*), gulls (*Larus dominicanus*), terns (*Sterna vittata*) among others are very abundant as well (Stonehouse 2002, BirdLife and Nature Serve 2012). However, some populations are decreasing (IUCN 2012). The seabirds feed mainly on fish, squid and other crustaceans (e.g. copepods. They usually nest in sub-Antarctic islands, and only a few species are adapted to breeding on Antarctic coastal areas or even inland (e.g. snow petrel *Pagodroma nivea*, emperor penguin *Aptenodytes forsteri* and Adélie penguins *Pygoscelis adeliae*) (Convey 2001). Interesting in this context is the taxonomic status, which has been driven by European explorers and their taxonomic standards, but now has to be revised more and more showing cryptic and other species definitions which throw off traditional estimates and classifications dramatically.

6.2.3 Freshwater ecosystems

Antarctic ice holds 90% of the world's ice and 75% of fresh water (Shum et al. 2008, British Antarctic Survey 2012c, National Science Foundation 2012).

Lakes are seasonally or permanently covered by ice, and some of them are hypersaline and anoxic (Convey 2001). Ice streams account for 10% of the ice sheet, and may be hundreds of kilometers in length and up to 50 km wide (British Antarctic Survey 2012c).

Most of these resources are covered in the Madrid Protocol, which outlines the use and protection of Antarctic resources. Worthwhile in these legislations is the emphasize on aesthetic landscape values (see Summerson in Huettmann 2012), and that the oceanic part of Antarctica is covered by the Convention on the conservation of Antarctic Marine Living Resources (CCAMLR) which favors use of resources schemes (see Ainley et al. in Huettmann 2012). The CCAMLR is one of the three international agreements under the Antarctic Treaty, and is about krill (*Euphasia superba*) fisheries (see section 6.4.2.3.).

6.3 People in the Antarctic

Extreme weather and remoteness have limited human presence in Antarctica. There is no indigenous population in the area (Stonehouse 2002). Human presence is usually limited to tourists and staff from research stations (see sections 6.4.2.1 and 6.4.2.2).

6.4 Economic activities and environmental issues in Antarctic environments

6.4.1 Antarctic countries, natural resources and economy

The Antarctic region is protected under the Antarctic Treaty (1959).This isolated territory of the Antarctic region is virtually unmanaged and conserved through the Antarctic Specially Protected Areas system (see http://www.antarctica.gov.au/environment/protecting-and-managing-special-areas). However, there is hardly an oversight, nor an Antarctic police, nor a real court or punishment system in place. At least seven countries (Argentina, Australia, Chile, France, New

Zealand, Norway and the United Kingdom) claim Antarctic territories. There are overlaps in claimed territories between Argentina, UK and Chile, but there are no armed disputes known.

Except for Argentina and Chile, the countries involved are high income countries (Fig. 5). It is to be stated though that Argentina, Brazil and Chile are so called ABC nations which are among the political powerhouses in South America. Brazil also is part of the BRIC nations, linked with India, Russia, China, and since 2011 South Africa. Together with ownerships of nudear power and satellites, such alliances should not be ignored when Antarctic claims are discussed. Most of these countries have built their economies based on so-called free market and free trade agreements (CIA 2012). Their economic performances vary; however have increased since the 1970s.

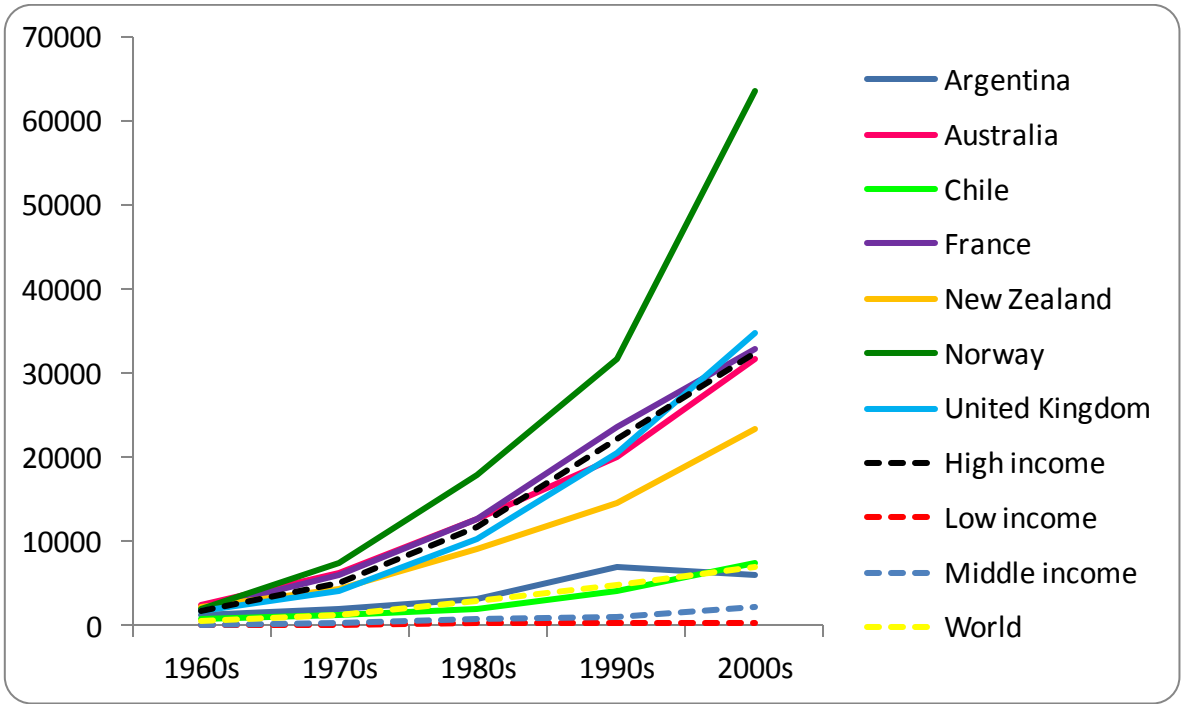


Figure 5: Average GDP per capita and per decade in primary Antarctic countries vs. income categories (US$) (The World Bank 2012a).

By now, many other nations try to claim territory on Antarctica and its terrestrial and marine resources, namely Russia, China, South Korea, Japan, Ukraine and Malaysia. This reflects on the global resource hunger and pressures on the poles. Many countries have established year-round research stations in Antarctic territories, for example Ukraine, Russia, India, Italy and South Africa have research stations (CIA 2012), and maintain claims or presence that way. Secondary Antarctic countries are mostly high income countries, but also major players in the global economy (Fig. 6).

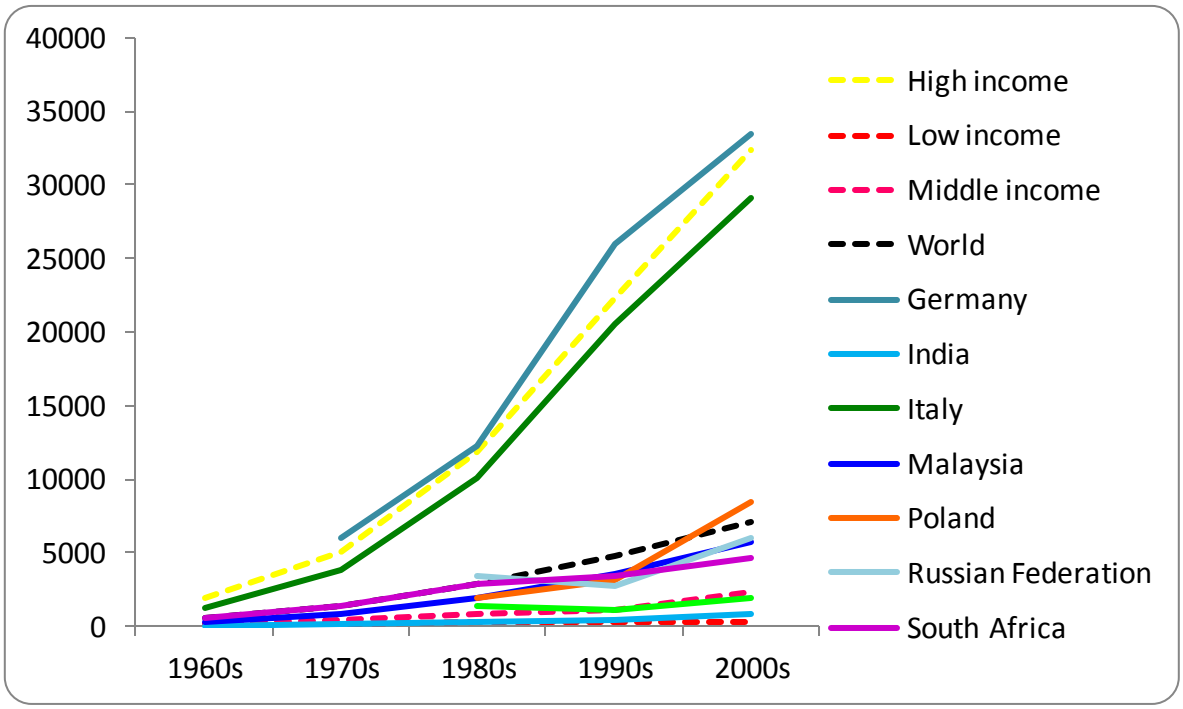


Figure 6: Average GDP per capita and per decade in secondary Antarctic countries vs. income categories (US$) (The World Bank 2012a).

Nowadays, in spite of its uniqueness, remoteness and very harsh climate, Antarctic has already suffered severe impacts from human activities. Aware of the existence of natural resources in Antarctica, several countries have permanent presence in the area. Moreover, it is described that science has been used as an excuse to explore and exploit natural resources in the Antarctic. By some people it might be considered a pristine area, but global and local anthropogenic impacts have reached the Antarctic already for decades (for example the Ozone hole), changing the landscape and affecting ecosystem processes and species (Riddle 2009). A short description of regional human activities and impacts are described in the next section.

6.4.2 Economic activities threatening Arctic ecosystems

6.4.2.1 Tourism

Antarctic tourism started in the mid-1960s. Today the impact of tourists is growing (Aronson et al. 2011, Farreny et al. 2011, Liggett et al.2011, IAATO 2012) with 30,000 - 40,000 people visiting each year (IAATO 2012). Most tourists visit the Antarctic on cruise ships (70%), but also a small number of private expeditions arrive, including researchers. Much of the touristic industry comes from the western world, mainly the U.S. (U.S. Department of State 2012), Germany, UK, and Australia (IAATO 2012). More than one third of all cruise ships come from the U.S. (IAATO 2012, U.S. Department of State 2012). It is important to realize that Antarctic tourism has one of the highest carbon footprints globally possible (Bas and Machiel 2007, Aronson et al. 2011, Farreny et al. 2011). It is estimated at an average of 5.44 ton CO_2 per passenger (Farreny et al. 2011). Secondly, it brings invasive species and general disturbance such as waste issues, noise and light pollution (Frenot et al. 2005, Bargagli 2008, Aronson et al. 2011). Boat accidents and rescue efforts have been reported (Liggett et al. 2011). Recently, Australia piloted a public airplane transport to

Antarctica and its station. A proposal to build a hotel was also entertained. With the rise of Antarctica as a tourist destination and promotion, it is expected that regular tourist business and its problems reach levels such as those known from the Arctic or Hindu Kush-Himalaya.

Visitors may also have a significant impact on Antarctic nature. Careless people may walk over the fragile vegetation. Disturbing seabird breeding colonies, parenting birds may leave chicks or eggs momentarily, putting them at risk (Erize 1987) (see Summerson in Huettmann 2012).

6.4.2.2 Research activities

People doing research in Antarctica and on the ground vary from about 4,400 in summer to 1,100 in winter (CIA 2012). Research development is affecting the Antarctic continent for instance through fuel combustion for transportation and energy production, accidental oil spills (e.g. Bahía Paraíso spilled 600,000 L of diesel in 1989), waste incineration and sewage (Bargagli 2008, Aronson et al. 2011). Pollution and contamination from daily activities in the stations have been reported in the vicinity of these sites (Cripps 1992, Hughes and Thompson 2004). Nonetheless, the protocol on Environmental Protection to the Antarctic Treaty (EPAT) or Madrid Protocol (1991) has improved good environmental practices in Antarctica, e.g. all wasted must be removed, open burning of waste is banned and past waste-disposal sites must be cleaned up (Aronson et al. 2011). Nevertheless, the lack of policing in the Antarctic on such issues results into serious oversights and problems (see references and chapters within Huettmann 2012).

6.4.2.3 Fisheries

Due to fisheries industrialization, since the 1900s commercial fishing fleets have arrived to Antarctic waters. Fisheries in the Antarctic make for one of the most remote fishery on Earth, and thus, cannot truly operate on the free open market, unless supported through subsidies, e.g. by governments or by large industries and seen as rewarding investment projects. By the late 1970s some fish populations collapsed (British Antarctic Survey 2012d). The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) (1982) has helped to recover some fish stocks in the last few decades (Constable et al. 2000). However, since the 1980s, fisheries for krill (*Euphausia superba*) prevail, but also for fish such as mackerel icefish (*Champsocepahlus gunnari*) and the arctic toothfish (*Dissostichus mawsoni*). Toothfish are fished by using trawling and long-lines that increase mortality of albatrosses and petrels as bycatch. Krill fisheries are also of serious conservation concern because it is the bases of the food chain and ecological service.

Krill is a major item in the diet of many seabird species (e.g. penguins), but also a critical component of the food web and its species, e.g. fish and squid are important for many seabirds (Murphy et al. 2012). Antarctic krill (*Euphausia superba*) has a heterogeneous circumpolar distribution in the Southern Ocean. The ACC and sea-ice are critical for early life stages, food and shelter (Thorpe et al. 2007). A decline in krill populations may affect many species, e.g. seabirds and seals (Forcada et al. 2012). Most of the commercial Antarctic krill fishing is carried out by Japan, Ukraine and Poland. An average of 130,000 ton/year in the last decade has been taken from the Southern Ocean (FAO Fishery Statistics 2012). The use of krill for direct human consumption and animal feeds (aquaculture products) is increasing. Expansion of krill fisheries have to be careful, otherwise population might collapse (Nicol and Foster 2003). New technology has been introduced recently to increase the amount of krill harvested (Schiermeier 2010).

6.4.2.4 Sealing and whaling

Antarctic seals and whales have been exploited by humans since the 19th century (Stonehouse 2002, Riddle 2009). The International Convention for the Regulation of Whaling (1946) and the Antarctic Treaty (1961) came into force to protect the Antarctic and its species. In 1996 zero catch limits for commercial whaling were established, but since then special permits for whaling have been issued as "scientific permits". According to the International Whaling Comission (IWC 2012) Japan has taken more than 10,000 whales from the Antarctic (two-thirds of scientific permits 1986-2010) and the number of scientific permits is increasing (Sand 2008, International Whaling Commission 2012). By-products from scientific Japanese whaling are sold, and utilized in different ways, e.g. meat and blubber (Endo and Yamao 2007). Antarctic mink whales are the most often caught whales for scientific purposes. The IUCN (2012) classifies *Balaenoptera bonaerensis* as Data Deficient, whereas *Balaenoptera acutorostrata* is classified as least concern (LC). However, both species are listed by the Convention on Intenational Trade in Endangered Species of Wild Fauna and Flora CITES in the Appendix I as threatened with extinction (see Sand 2008).

Due to commercial exploitation, the Antarctic fur seal (*Arctocephalus gazella*) was already on the brink of extinction by 1830 (Australian Government Antarctic Division 2012). Currently, seals are protected by the Convention on the Conservation of Antarctic Seals (CCAS) (1972) (see http://www.antarctica.ac.uk/about_antarctica/geopolitical/treaty/update_1972.php). Catch limits have been established for crabeater seals (*Lobodon carcinophagus*), leopard seals (*Hydrurga leptonyx*) and weddell seals (*Leptonychotes weddelli*). Full protected species are Ross seals (*Ommatophoca rossi*), southern elephant seals (*Mirounga leonine*) as well as the genus *Arctocephalus*. According to the CCAS, catch permits "are subject to review in the light of scientific assessments". The IUCN (2012) has not assessed these species or has no reliable information whereas CITES (2012) includes elephant seals and the *Arctocephalus* genus in Appendix II.

6.4.2.5 Exotic species

Many exotic species have been introduced to the Antarctic, especially to the sub-Arctic region (Croxal 1987, Frenot et al. 2005, Bargagli 2008), most of them are European species (Frenot el al. 2005). Fungi, microbes, plants and animals, for example rats, mice, fish, rabbits, cats (Croxall 1987) are having negative impacts on native species (predation of bird eggs, competing for food, alteration of habitat structure, etc.) (Convey 2001).

In the sub-Antarctic, about 108 alien vascular species occur; *Poa annua* is present on all main islands. Regarding invertebrates, diptera, hemiptera and coleoptera are the most common. Reindeer and rabbits are impacting sub-Antarctic native vegetation. The Îles Kergulen Islands, French overseas territories, are the most affected by invasive species in the Antarctic region (see Frenot el al. 2005).

6.4.2.6 Pollution and Contamination

Metals, pesticides and other persistent organic pollutants (POPs) have been found in air, snow, mosses, lichens and marine species (Bargagli 2008). Their origin can be natural or anthropogenic sources, even from remote sources (Sanchez-Hernandez 2000, Convey 2001, Bargagli 2008). Contaminants come from countries and population centers in the Southern Hemisphere (Bargagli 2008) – for example polycyclic aromatic hydrocarbons (PAHs) and PCBs from Africa, South America and Australia (Klánová et al. 2008). These pollutants may be found in eggs and adults of different bird species (Luke et al. 1989, Metcheva et al. 2006, Jerez et al. 2011) and also accumulate through the food web in top predators (Nygard et al. 2001, Goerke et al. 2004). Dichloro-diphenyl-

trichloroethane (DDT) is one of the main pollutants together with PCBs. Many Antarctic species (penguins, petrels, fishes, plankton) hold considerable levels of DDT and it is present in the food web (Sumich and Morrisey 2004). Metal levels are higher in areas with major human presence (Jerez et al. 2011). Concentrations of POPs and other pollutants are expected to increase (Bargagli 2008, Knowles and Diggle, Schiavone et al. 2009).

6.4.2.7 Mining

Antarctic natural resources include iron ore, chromium, copper, gold, nickel, platinum and other minerals (CIA 2012). Mining in the Arctic is currently banned for 50 years until the year 2048 by the Protocol on Environmental Protection from the Antarctic Treaty (1991). The aim of the Protocol on Environmental Protection is related to possible environmental damages and the lack of profitability (Cullen 1994). However, terrestrial and offshore mining is still a potential threat for the Antarctic, and with the global shortage and strong demand of such resources elsewhere, the current mining closure will likely be loosened up soon or later. In reality, and seen from a global perspective, the mining closure in Antarctica will put pressures on the existing resources and even make them profitable, boosting prizes for the suppliers such as Australia, Russia or China.

7. The Himalayas

7.1 General description

The Hindu Kush-Himalayan (HKH) region is a group of mountain ranges located in the tropical latitudes of Southeast Asia, including the Karakórum, Hindu Kush and Himalayas ranges (Fig. 7) (ICIMOD 2012). The area was named the "the third pole" by the explorer Marcel Kurz in 1933, and years later by Günter Oskar Dyhrenfurth in 1955 (Dyhrenfurth 1955). The HKH encompasses the world's highest peaks with elevations over 8,000 meters including Mount Everest (*Sagarmāthā* in Nepali and *Zhūmùlǎngmǎ Fēng* in Chinese) as the highest (8848 meters above sea level) (ICIMOD 2012). The region is surrounded by rather flat land, includes a high plateau (Tibet) and extends 3,500 km through eight countries: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan (ICIMOD 2012).

The third pole is a densely populated area, of outermost complexity. Himalayan landscapes include abundant rivers and streams, slopes; and a large diversity of cultures and rich traditions of indigenous communities, languages and economies (Singh 2006). The HKH region includes two Global Biodiversity Hotspots (Myers et al. 2000), six UNESCO (United Nations Educational, Scientific and Cultural Organization) Natural World Heritage Sites, 30 Ramsar sites, 488 protected areas, 330 Important Bird Areas (IBAs), and 53 Important Plant Areas (IPAs) for medicinal plants (ICIMOD 2009b).

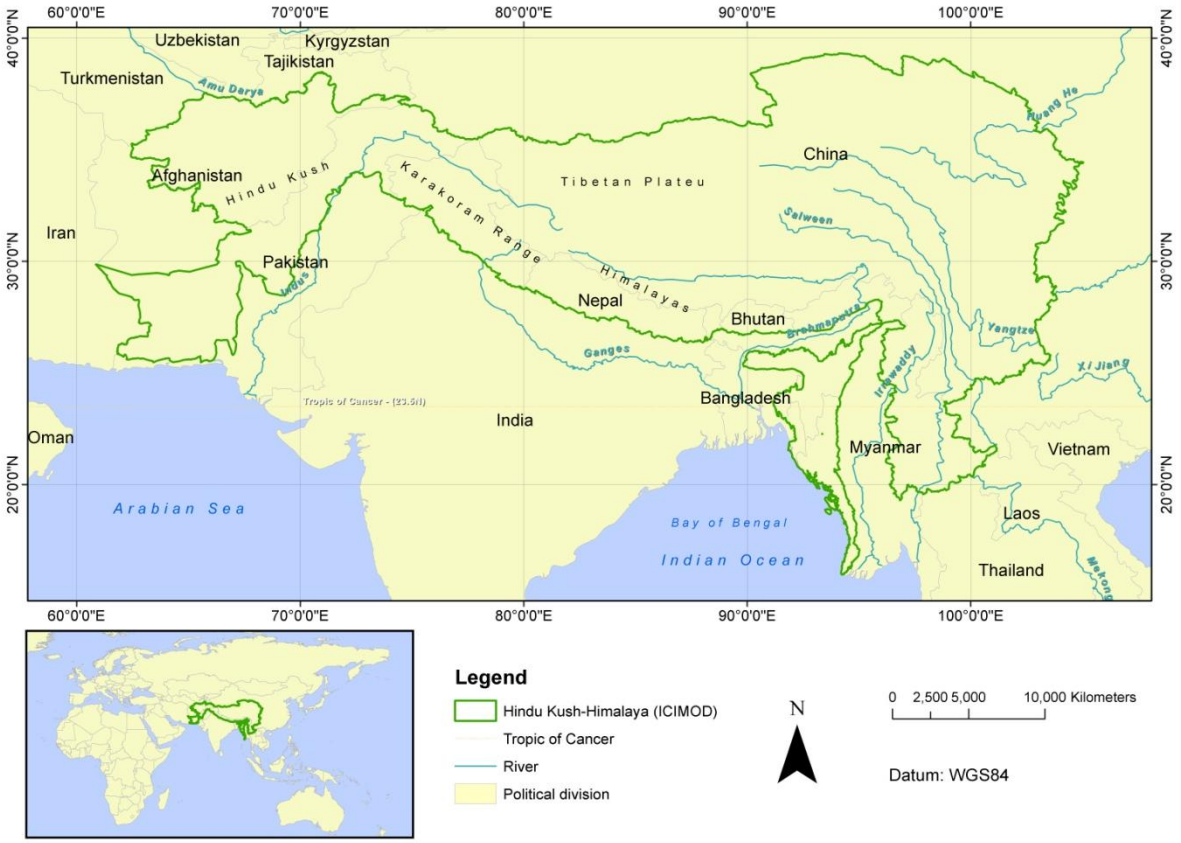


Figure 7: The Hindu Kush-Himalaya region map (Source: ICIMOD 2008, ESRI 2012)

Weather and vegetation vary according to elevation and other factors, showing an heterogeneous landscape. The Himalayas are the geographical boundary for the summer monsoon and winter westerlies. Sun exposure is rather different between northern and southern slopes. Northern slopes receive sun only for a few hours per day, whereas southern slopes are warmer and have the most sun exposure. The highest elevations show snow and ice all year-round (Tyagi 1991).

7.2 HKH ecosystems

7.2.1 Freshwater resources in the Himalayas

The Himalayan mountain system has the world's highest concentration of snow and glaciers outside the Arctic and Antarctic poles. Approximately 1.4% of the region is glaciated and it is estimated that 54,000 glaciers cover an area of 60,000 km^2 (Bajracharya and Shrestha 2011). Glaciers play a role in the water cycle and world climate as a cooling mechanism (Bolch et al. 2012). Some of the major Himalayan glaciers are in Mustang and Khumbu in Nepal, and Gangotri in India. Runoff from snow and glaciers feed the ten largest river systems in Asia (i.e the Amu Darya, Indus, Ganges, Brahmaputra, Irrawaddy, Salween, Mekong, Yangtze, Yellow and Tarim). Freshwater resources from glaciers provide water, food, power and jobs for more than 1.3 billion (app 1/6th of the world) people as well as habitat for many species living in the area (Barnet et al. 2005, ICIMOD 2012). Glaciers also have a cultural value for people and tourism.

7.2.2 Terrestrial ecosystems

Biodiversity at the third pole, the HKH region, is higher than at the other two poles, including 5,562 plant species for example (see Himalayan Uplands Plant –HUP– database, Nemitz et al. in Huettmann 2012).

Vegetation in the Himalaya is driven by a combination of factors such as climate, altitude, topography, slope, aspect, soil and latitude (Negi 2000, see Global Observation Research Initiative in Alpine Environments http://www.gloria.ac.at/). Broadly speaking, ecosystems of the Himalaya include subtropical forests at the lower parts (up to 1,200 m), where the dominant tree is sal (*Shorea robusta*). The temperate forests are broad-leaved evergreen trees and conifer forests (1200-1800 m), including chir pine (*Pinus roxburghii longifolia*), oak trees (*Quercus lamellosa, Q. fenestrate, Q. lauginosa*, etc.) and firs (*Abies delavayi* and *A. densa*). The alpine and sub-alpine zones are the highest parts (up to 4,500 meters). The lower part of the sub-alpine zone is dominated by oak trees (e.g. *Quercus incana, Q. dilatata* and *Q. semicarpifolia*). The higher part of the sub-alpine zone from 2,000 to 3,000 meters is dominated by cypress (*Cupressus torulosa*), blue pine deodar (*Cedrus deodara*), pine (*Pinus excelsa*), silver fir (*Abies pindrow*), spruce (*Picea morinda*) and birch (*Betula utilis*). The Alpine zone includes shrubs in the northern part and temperate grasslands up to the snowline (4,500 meters) in the south. Dominant grass species include the genera *Pao*, *Glyceria* and *Festuca* (Hajra and Rao 1990). By now, human activities have modified and have had an impact on the vegetation up to the highest altitudes (e.g. black carbon, air pollution and climate change; see Huettmann 2012 for review).

The wildlife set up varies according to the type of vegetation, altitude and rainfall (Negi 2000). The Hindu Kush-Himalaya ecosystems are habitat for species listed in threatened IUCN categories such as elephants (*Elephas maximus*), rhinos (*Rhinoceros unicornis*), buffalos (*Bubalus arnee*), and tigres (*Panthera tigris*) (ICIMOD 2012, IUCN 2012). There are also birds such as quails (*Ophrysia superciliosa*), tits (*Parus major, Melanochlora sultanea*), robins (*Copsychus malabaricus*) and raptors (*Gyps bengalensis, G. tenuirostris*) (BirdLife and Nature Serve 2012). The temperate zone is also inhabited by red pandas (*Ailurus fulgens*), wild goat (*Capra aegagrus),* and sheep (e.g. thar, *Hemitragus jemlahicus*; markhor *Capra falconeri cashmiriensis* and nayan *Ovis ammon hodgsoni*), as well as black bears (*Ursus thibetanus*) (ICIMOD 2012). Birds include cheer pheasants (*Catreus wallichi*) The snow leopard (*Panthera uncia*) may be found on higher elevations. Birds there include pheasants (*Lophophorus impejanus*), tragopans (*Tragopan melanocephalus, T. satyra*), and snowcocks (*Tetraogallus himalayensis, T. tibetanus*) (BirdLife and Nature Serve 2012).

7.3 Economic activities and environmental issues in the Himalayan environment

7.3.1 The Himalayan countries, natural resources and economy

According to The World Bank classification (2012b), all HKH countries are developing countries. Low-income economies ($1,025 or less) include Afghanistan, Bangladesh, Myanmar and Nepal; the subdivision lower-middle income ($1,026-4,035) includes Bhutan, India and Pakistan; the upper-middle income economies ($4,036-$12,475) include China (Fig. 8). Besides, the United Nations lists Afghanistan, Bangladesh, Myanmar, Nepal and Bhutan as least developing countries (LDCs) (see http://www.un.org/special-rep/ohrlls/ldc/list.htm) (table 3). LDCs have special conditions such as extreme poverty, political instability or social conflicts. The economy in most of these countries is based on agriculture and forestry (e.g. Nepal, Bhutan, Pakistan), and a high number of its population live below the poverty line (CIA 2012). International assistance has tried to help these

countries to improve their economy, which helped India and China. However they are still extremely poor, and social conflicts and violence are still going on (see section 8.1).

Table 3: HKH countries by income (The World Bank 2012b).

Country	Income category
Afghanistan	Low*
Bangladesh	Low
Buthan	Lower-middle*
China	Upper-middle
India	Lower-middle
Myanmar	Low income*
Nepal	Low income*
Pakistan	Lower-middle

*Least developing country according United Nations.

Since the late 1970's China and India have grown economically, at an average of 9% and 6% respectively. China became the world's largest exporter and the second largest world economy (The World Bank 2012a), whereas India is by now the world's third economy. However, this fails to capture the true picture because poverty, overpopulation, corruption and environmental degradation still remain. India for instance runs a cast system (known for its inequities), and the rural population in China is infamous by now for its poverty too.

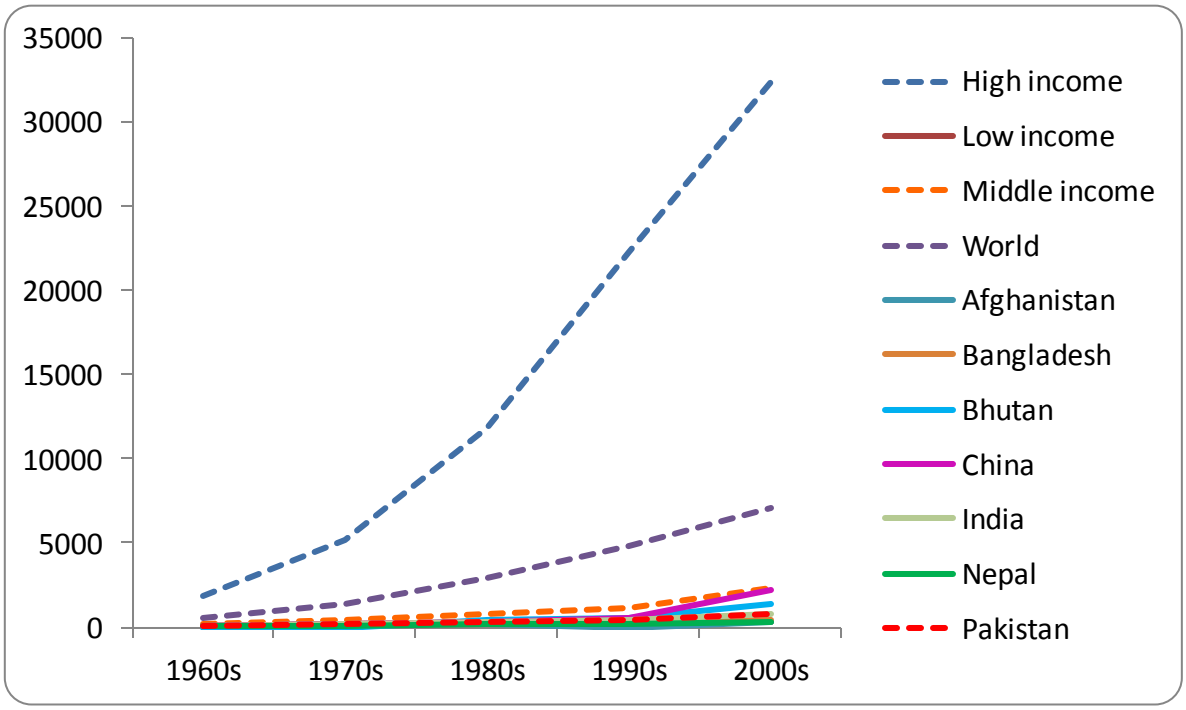


Figure 8: Average GDP per capita and per decade in primary HKH countries vs. income categories (US$) (The World Bank 2012a).

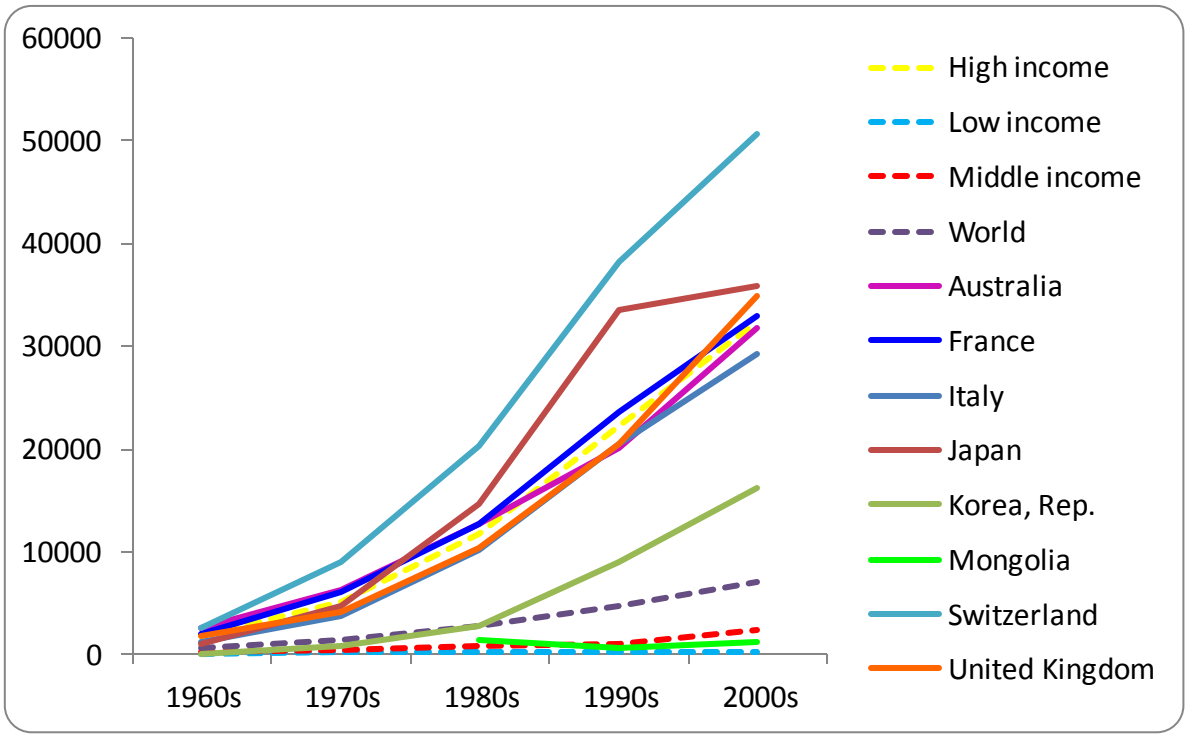


Figure 9: Average GDP per capita and per decade in secondary HKH countries vs. income categories (US$) (The World Bank 2012a).

Except for Mongolia the secondary countries have a good economic performance since the 1970s and are high income countries today (Fig. 9). Mongolia is a lower-middle income economy (The World Bank 2012b) that is having right now a mining boom and boosting its economy with the support of, and demand by, foreign countries such as China, Russia, Canada, the U.S., the E.U. and Germany.

Socioeconomic issues have limited the capacity of these countries to protect important and rich ecosystems (Joshi 2009). Growing population and poverty have forced governments to focus on economic growth and development (Dudgeon 2005). Today the HKH region faces many environmental issues as a result of local development, and from the increasing global demand for resources. A short explanation is presented in the next section, which is on the various pressures that affect the HKH.

7.3.2 Economic activities threatening ecosystems at the HKH Pole

7.3.2.1 Increasing tourism increases pressure on HKH ecosystems

The touristic industry is growing fast in the Himalayas. Some places are visited by about 1000 people per day (e.g. Shingba Rhododendron Sanctuary in India) (Acharya et al. 2010). Pressure on ecosystems and therefore bird species (e.g. resident birds breeding sites) is intense in some areas. Most of the tourism comes from the U.S. and the E.U. In the last few decades alpine ecosystems have been damaged by uncontrolled tourism, for example Sagarmatha National Park (Mt. Everest) in Nepal (Byers 2005). Deforestation for timber, firewood and construction material is reported in some touristic areas (e.g. Mt. Everest and Yumthang valley) (e.g. Laiolo 2004, Byers 2005). Tourism

also increases energy consumption; for example in 2007 tourists consumed 6.06% and 14.18% of the total energy consumption in Qinghai and Tibet (both China) respectively (Ping et al. 2011).

7.3.2.2 Land use change and overexploitation of resources due to human population growth in the HKH region

The increasing demand for resources is driven by changes in population, values, policies and economy in the HKH region (Singh 1999, Xu et al. 2008). Land use change is mostly due to agriculture expansion (Upadhyay et al. 2006, Qasim et al. 2011); for example slash-and burn shifting cultivation, one of the prevailing types of agriculture that have caused forest cover loss. In Swat, Pakistan, forest cover in some areas has decreased by 47.9% in the last 40 years (Qasim 2011). Moreover, deforestation, due to commercial harvesting and mismanagement by governments, is responsible for about 30% of deforestation in the last three decades (Ali et al. 2005). Clearing vegetation also causes desertification (Yang et al. 2004) – for example grasslands in the Tibet. Some non-timber plants are also locally extinct due to overuse (Singh 1999, Joshi 2009).

Besides, land-use change to make space for industrial and urban uses is happening fast (Allen et al. 2010). Infrastructure construction deforests large areas for the economic and social development, and produces soil erosion on the steep slopes (Ma et al. 2012) – for example in Nadid village, Dharamsala in India.

Deforestation is threatening endemic species, including birds (Pandit et al. 2007). Loss of habitat is the most important threat for birds in sub-tropical and temperate forests in the Himalayans (Crosby 1996). Habitats for birds are severely threatened by human activities and species richness as well as diversity is lower in heavily utilized forests (Laiolo 2004). Loss of breeding habitat is one of the most important features (Acharya and Vijayan 2010). Deforestation also increases run-off and floods, soil erosion, CO_2 global emissions, and water conservation (Zhang et al. 2011).

7.3.2.3 Pollution and contamination (heavy metals)

Many rivers in the HKH region are polluted (e.g. the Ganga and Brahmaputra rivers) (Dudgeon 2006). Development and population growth have contributed to water pollution (Karn and Harada 2001, Ha and Pokhrel 2001, Babel and Wahid 2008). Reasons include sewage, industrial effluents and agrochemicals (Kannel et al. 2007, Allen et al. 2010). Some of the rivers and their issues are not well resolved due to cultural and religious reasons; for example the Bagmati River in Kathmandu, Nepal is used as a burial site after cremation of dead bodies and according to Hindu beliefs (Ha and Pokhrel 2001), but it is also the sewage run-off for million-citizen cities like Kathmandu.

7.3.2.4 Overfishing and intensification of fishing practices

Bangladesh, China and India account for some of the largest fisheries in the world (FAOSTAT 2012). Local communities in countries like Myanmar, Bangladesh, India, Nepal and Buthan also depend upon rivers and wetlands (Allen et al. 2010). The Mekong, fed from Himalayan glacier water, is one of the longest rivers in Southeast Asia and supports the largest fishery system in the world (Dugan et al. 2010). Approximately 2.1 million tons of fish are caught per year, including species such as the Mekong giant catfish (*Pangasianodon gigas*) a critically endangered species mainly due to overfishing (Dudgeon 2005). Species like the gharial (*Gavialis gangeticus*) and the Ganges river dolphin (*Platanista gangetica*) live in such rivers but are threatened too. The river systems, directly linked to glaciers, make for watershed issues that are also linked with pelagic as well as coastal ocean issues. For instance, sea level rise is partially attributed to melting glaciers,

and marine mixing processes enriching coastal regions are often driven by a freshwater inflow and run-off.

Ancient but sustainable practices are disappearing, and instead overexploitation and intensification take over. Overexploitation and by-catch have led to declining fresh water fish populations (e.g. lower West Bengal in India) (Patra et al. 2005). Some fish populations have already collapsed (Dudgeon 2006). Other harmful fishing practices include blast, poison, bottom trawling and electro-fishing. Noteworthy are the hydro-dam problems in the Himalayan region (see next section).

7.3.2.5 Infrastructure

Some water engineering projects have resulted into a destructive situation for biodiversity (Dudgeon 2005). Dam construction for hydropower development is a major problem (WWF cited in Huettmann 2012) and is likely to increase in number. Some rivers still have a high potential for hydropower development, and there are some plans to develop a large number of dams in the region (e.g. India, Myanmar, Bhutan) (CIA 2012). Negative effects for species result in the disruption of migratory routes and breeding patterns (Dudgeon 2005) affecting the trophic web overall (see Baral in Huettmann 2012 for waterbirds in Kushi Ramsar Site in Nepal).

8. The world and the Three Poles

8.1 Global economic growth

The modern approach of global economy relies mostly on neoclassical economics, and which got promoted by virtually all institutions (see Perkins 2004). It is based on the idea that a country and its population and consumption can grow virtually unlimited. It is promoted that competition makes for an efficient allocation of resources and maximization of profits (Sherman et al. 2008). This conventional view defines economic growth as the sustained increasing capacity of the economy to produce goods and services, and it is considered to be a way to create wealth (Polèse 2010, McEachern 2011), happiness, to reduce global poverty and cure all sorts of human problems. Technology has been perceived as a key driver for economic growth (Nelson 2000) but other mechanisms to achieve it exist, such as the economy of scale and wars.

"Economy of scale" occurs when industrial production of a good or service increases on a larger scale and costs are reduced. This system may include labor specialization, forcing workers to carry on only one specific task to boost productivity (Mankiw and Taylor 2006). A clear example is Wal-Mart (Holmes 2011) that is now even present in the poorest and remotest areas of the world as a sign of development and having implications for local communities (Reardon et al. 2003) and ecosystems. Wal-Mart alone is responsible for 15% of the U.S. imports of consumer goods from China. Within just 25 years China grew 90-fold and U.S. imports from China increased 30-fold (Basker and Pham 2008). China is the global growth engine, stimulating economic growth also at the Three Poles. China's economy has been increasing even more than the economy of current high income countries. Today China is the third largest world's economy but its average GDP per capita in the last decade was only $2,294 (The World Bank 2012a), and thus very far away from rich economies. Extreme poverty, environmental and management issues are spread all over the country. During the process of developing its economy, China has been polluting its ecosystems and has lost millions of hectares of natural vegetation (See Elvin 2004). At present, many species are at risk of extinction, including 86 threatened bird species (BirdLife 2012). China has lost many

goods and services provided by nature, and its quality of life has been considerably diminished (Jun 2007, He 2009), a strong gradient between poor and rich occurs now and due to this growth policy. This new economical power is leading to Chinese demands that have a negative degradation impact on ecosystems worldwide and also on the Three Poles. China and other foreign mining companies are now extracting resources from Tibet, one of China's least-developed regions and part of the HKH pole. Mining and other industrial activities have polluted the environment and water resources of Tibet over the last 20 years (Huang et al. 2010).

"Economy of wars" - Historically, wars have had a complex influence on economic growth and technological development (Goldstein 2003). Conflicts are usually about limited resources such as water, oil or minerals (Gleditsch 1998). In some cases, war and conflicts impede development and shock economies (e.g. Afghanistan), and in some cases effects are long term (e.g. Russia). Nonetheless, in some other countries war has increased economic growth and innovation (e.g. the postwar economic boom also known as the Golden Age of Capitalism). In all cases wars have had negative environmental consequences, including pollution (Gerges 1993, Husain 1998), environmental degradation and long-lasting effects (Dudley et al. 2002). Environmental effects derived from a war may also be long-term (Westing 2011). No relevant armed conflicts have taken place directly in the Antarctic territory, yet. Nonetheless Japanese research vessels have been attacked by non-governmental organizations to stop whaling activities (i.e. Sea Shepherd Conservation Society) as part of a resource conflict presented to the global public (Japan Fisheries Agency 2010). Regarding the Arctic the Lapland War (1944-1945) took place during the Second World War between Finland and Germany. During the cold-war, many disputes were fought about the poles. Territory disputes about boundaries exist between countries of the HKH pole in Afghanistan and Pakistan, China and Bhutan, as well as China and India, and India and Pakistan. A military territory conflict for instance exists in Kashmir (China, India and Pakistan) (CIA 2012). There are many disputes in Tibet among minorities; in India the Naxalite-Maoist insurgency and the Indian government are in an ongoing conflict; and Nepal is in political turmoil and partly even lacked a constitution in 2012 (Hanson et al. 2009, CIA 2012).

Environmental and social consequences of the current ways to achieve economic growth may be irreversible, especially in the Three Poles regions. Countries promoting the classical concept of economic growth are mostly rich economies interested in keeping and improving their lifestyles and on the cost of others (Czech 2008, Rosales 2008). In doing so, they have created a number of international institutions and councils to promote their macroeconomic policies.

8.2 A selection of major stakeholders

Several organizations and groups of countries exist worldwide to promote security and human well-being. They usually include in their goals: Environment, wildlife and sustainable development. By now, it is known that the current economic growth scheme is not compatible with sustainability (Martinez 2009) and stands in direct conflict with it (Czech 2008, Daly and Farley 2010; also see http://steadystate.org/).

8.2.1 OECD

The Organization for Economic Co-operation and Development (OECD) (http://www.oecd.org) promotes policies to achieve economic growth, global development and social well-being. It is also stated that the OECD looks for an environmentally friendly "green" and sustainable growth. The OECD has 34 member countries, including the world's "most advanced countries" and some emerging economies (e.g. Chile, Mexico Turkey). Besides, the OECD is also working with countries

such as Russia, China, India and Brazil (the so called BRIC countries group) as well as Indonesia and South Africa. Some of these emerging economies have at the same time the highest environmental impact, overuse of natural resources, high levels of emissions and a high number of threatened species (Bradshaw et al. 2010).

8.2.2 United Nations Security Council

The five permanent members of the United Nations Security Council (since 1946, see http://www.un.org/Docs/sc/) are Russia, France, the United Kingdom, China and the U.S. Other nations are given a temporary observer status, e.g. Germany, India and Brasil. The council's responsibility is the maintenance of world's peace and security as well as armament regulation. However these countries have a number of international disputes for territory and natural resources going on, including the military conflict in Kashmir (located in the Three Poles region and considered the world's largest and most militarized territorial dispute) where China is involved (CIA 2012). In addition, the same countries are the largest exporters of weapons in the world (Stockholm International Peace Research Institute 2012), and which is known to fuel many economies.

8.2.3 Banks

The market for green investment is growing fast. Multilateral development banks and international financial institutions aim to help developing countries to pursue environmentally sustainable economic growth. According to the Brundtland Report (WCED 1987), multilateral development banks are an important source of funding for developing countries. The responsibility of accomplishing this relies on The World Bank and the International Development Association. Banks call themselves the "key promoters and financiers of *environmental* upgrading in the developing world" and they look for economic development and poverty alleviation (The World Bank 2012a). On the other hand, the promotion of economic growth and the way banks are funding environmental projects are putting pressure on the environment. The Basel Accord is an agreement on ethical banking (see http://www.bis.org/bcbs/index.htm). These institutions have been criticized for poor environmental and social performance, including massive deforestation and increasing use of resources, contribution to excessively high levels of debt in developing countries and unsuccessful poverty reduction (Rich 1994, Gutner 2002, Pentzlin et al. 2012). Organizations like The World Bank and the International Monetary Fund (IMF) financed projects from the 1980s to the early 2000s that resulted in the destruction of the rainforests in the Amazon, South East Asia and West Africa (e.g. Rondonia Forest in Brazil http://www.worldbank.org/projects/P006454/rondonia-natural-resources-management-project?lang=en) affecting global climates, and thus the cryosphere. Any GHG emissions and land use change (LUC) contribute to current global warming that influence the Three Poles negatively.

8.2.4 Non governmental organizations (NGOs)

Environmental non-governmental organizations such as The World Wildlife Fund (WWF) and Greenpeace have been working for the conservation of individual poles. WWWF has specific programs to protect each of the Three Poles and specifically works at international policies level. In the Arctic pole, WWF has conservation planning and protected areas management (WWF 2012). In the Antarctic one the goals is the establishment of marine protected areas to protect Antarctic species from illegal or unregulated fisheries (http://wwf.panda.org/what_we_do/where_we_work/project/projects/?uProjectID=AU0083).

In the Hindu Kush-Himalaya, the WWF looks to connect landscapes and reduce human-wildlife conflicts (see http://wwf.panda.org/what_we_do/where_we_work/eastern_himalaya/). The major presence of WWF at the Three Poles is in the Arctic. In all cases climate change adaptation is mentioned; but so far the progress is rather little, if at all (see missed biodiversity and Kyoto goals).

Greenpeace actions are mostly though protests and awareness campaigns. Greenpeace has been one of the most significant critics on nuclear waste, oil drilling and fisheries in the Arctic and of Japanesse whaling in the Antarctic. In the Hindu Kush-Himalaya pole Greenpeace has documented glacier retreat and ecosystem degradation (Greenpeace USA 2007). However the Antarctic and the Hindu Kush Himalaya poles are not mentioned in the annual report (Greenpeace International 2011). The Sea Sepherd Conservation Society mentions that they have not seen Greenpeace in the Southern Ocean since 2007 (http://sea-shepherd.tumblr.com/post/20354681145/greenpeace-finally-finds-the-japanese-whaling-fleet). As a general stragegy against climate change, Greenpeace is advocating for an energy revolution using renewable energies (Greenpeace International 2012). The most important program for the Three Poles protection is called "Save the Arctic" (http://www.savethearctic.org/). Greenpeace has offices in six of the eight Arctic countries (Greenpeace USA 2011).

There are other international NGOs, such as The Wilderness Society in Alaska (http://wilderness.org/), and the Nature Conservancy that has an office in China and many projects, and of them four are included in the Hindu Kush-Himalaya area. In addition, the Nature Conservancy recognizes an area in the HKH as a priority conservation area (PCA) (see http://www.nature.org/ourinitiatives/regions/asiaandthepacific/china/explore/multimedia-china.xml).

Many other stakeholders exist promoting similar values and ideas, such as the World Trade Organization (WTO), the United Nations Environment Programme (UNEP) and the Food and Agriculture Organization (FAO). Also, international economic treaties are threatening the Three Pole conservation, such as the North American Free Trade Agreement (NAFTA), the Free Trade Areas in Europe and the General Agreement on Tariffs and Trade (GATT).

Think tanks are also playing a role in the Three Poles. Examples for the Arctic are the Stockholm International Peace Research Institute (SIPRI) and the Norwegian Nansen Institute (http://www.fni.no/); for the HKH the World Resources Institute (http://www.wri.org/) and Climate Change Network Nepal (CCNN) (http://ccnn.org.np/). See also http://thinktankmap.iccgov.org.

8.2.5 International agreements

There are a number of international and regional agreements that are concerned with the conservation of the Three Poles and global climate change (see: http://sedac.ciesin.columbia.edu/entri/; for Arctic see reviews in Huettmann et al. 2011, Huettmann 2012). Differences among them are evident (extent, strategies, goals, etc.) and each of them operate autonomously. Each country has signed a different number of treaties and agreements creating institutions to comply the commitments. There are also cases in which some countries do not ratify an important agreement, and therefore have no obligation. For example, the U.S., the second largest CO_2 emitter (The World Bank 2012a), has ignored most of the international agreements. On the contrary, China did it but it is the world's largest emitter and it

still is increasing its CO_2 emissions. Likely, this will go on for many more years even. Global CO_2 emissions are also increasing (Fig. 10); nonetheless countries that have ratified the Kyoto Protocol tend to make their production processes more efficient (Feroz et al. 2009). This is important even in countries that have not such a significant GHG emission such as Nepal, but a high black carbon emission. This represents an opportunity to develop alternative sources of energy (Pokharel 2007). It is also important that rich countries contribute to minimizing emissions in developing countries (i.e. deforestation) in order to produce commodities for rich countries. Instruments such as the Carbon Finance of The World Bank (http://wbcarbonfinance.org/) and the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD) are available for developing countries (http://www.un-redd.org/). These initiatives are giving a market value to the carbon stored in forests; however, the drivers of deforestation, and the individual reality, politics and corruption of these countries still remain (Sunderlin and Atmadja 2009, Karsenty and Ongolo 2012).

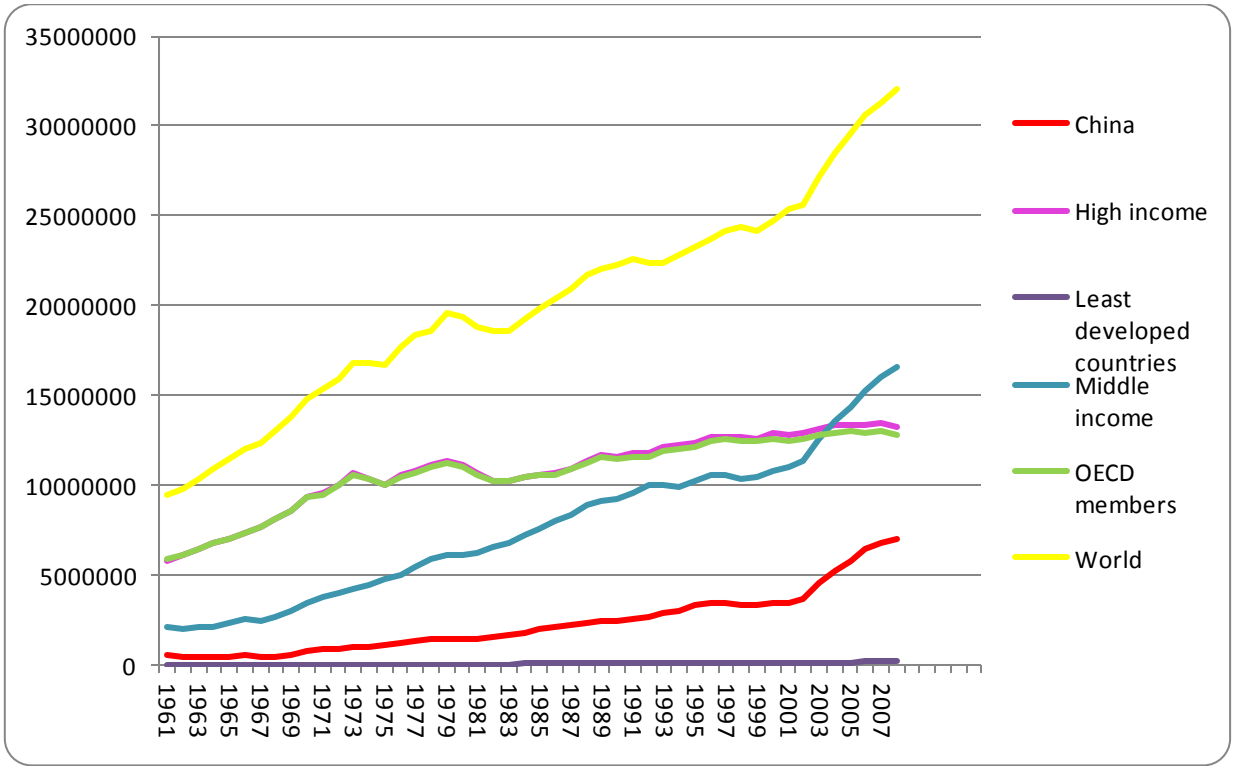


Figure 10: A comparison of CO_2 emissions (kt) by country income, stakeholders and China (The World Bank 2012a).

8.3 Climate change and other anthropogenic impacts on the Three Poles

8.3.1 Global Green House Gas (GHG) emissions and climate change

The development of a country is usually related to the energy sources it uses and therefore the amount and type of GHG emissions it releases into the atmosphere. Only a few countries account for 61% of all the GHG emissions worldwide, and most of them have been maintaining high levels

of emission throughout their history (Baumert et al. 2004). In developed countries for instance, CO_2 emissions come mostly from fossil fuels (81%), whereas in developing countries fossil fuels make only for 41% of the emissions. Sources of black carbon can be for instance fuel wood and dung for heating. The countries that emit the most are: China, United States, the EU, India and Japan (World Bank 2012). Oil and gas is produced in c. 90 countries, but only a few have an important production (over 100 million tons/year), including the Three Pole countries Russia, the U.S., China, Canada and Norway (Li 2011). These nations have already been referred to as 'petrol states'.

Deforestation may reduce Earth's capacities to sink anthropogenic emissions as well as to cool down local climate. CO_2 emissions from land use change (LUC) are the highest in developing countries (Baumert et al. 2004). Clearing forests to convert them into plantations releases large amounts of carbon to the atmosphere. For example Brazil (1,830 $MtCO_2e$) and Indonesia (1,459 $MtCO_2e$) account for 60% of emissions from LUC (Climate Analysis Indicators Tool 2012). Neoliberal governments have facilitated the conversion of natural ecosystems into industrial plantations to supply the growing demand of resources in the world (McCarthy and Cramb 2009). In this viewpoint, the role of oceans (2/3 of the globe) should not be forgotten though.

Fossil fuel capitalism is the dominant system, fueled by consumerism and the search for any economic growth (Storm 2009), for example with the stock market and online sales. The size of a country's economy is directly proportional to the degradation of natural resources (Rosales, 2008). A similar relation exists between the GHG emissions of a country and the size of the economy. Current macroeconomic policies are designed to foster economic growth (Lawn 2008) and these policies mainly privilege powerful interests (Rosales 2008). It is clear that several three pole countries are highly contributing to GHG emissions and are also important producers of fossil fuels. In addition, emerging economies are deforesting important areas and releasing large amounts of stored CO_2 and methane that used to be in plants and the soil. To supply the international demand, unsustainable trade and consumption are contributing to climate change and increasing GHG emissions all over the globe. However, the effects of climate change are more pronounced in certain areas of the world (e.g. ocean acidification in the Arctic) (Serreze et al. 2010).

8.3.2 Effects of climate change on the Three Poles

Climate change is happening faster at the Three Poles than in any other region (IPCC 2007), and particularly in the Arctic (Root et al. 2003, IPCC 2007, Parmesan 2007, Rosenzweig 2008, Walsh 2008, Serreze et al. 2010) and in the general cryosphere. Effects of climate change on the Three Poles include: decreases in snow cover (Serreze et al. 2010), reduction in annual duration of lake and river ice (Magnuson et al. 2000, Prowse et al., 2001), shrinkage of glaciers and reduction in sea ice-extent and thickness (IPCC 2007, Sodhi and Elrich 2010, Serreze and Stroeve 2008, Serreze et al. 2010). In addition, predicted changes in temperature may be a major driver for future, deteriorating conditions such as the thawing of permafrost (Arctic Climate Impact Assessment 2005, McGuire et al. 2006) and sea ice (e.g. the collapse of the West Antarctic ice sheet), changes in precipitation, changes in sea level, changes in the oceanic and atmospheric circulation (e.g. the shutdown of the North Atlantic thermohaline circulation) (ACIA 2005, Walsh 2008). Ozone level changes in the Arctic (e.g. the Bering/Chukchi Seas) (Walsh 2008) and Antarctic may derive into reproductive problems for many species, including fish and phytoplankton and therefore cause food chain disruptions (Björn and McKenzie 2008) affecting then for instance bird populations.

Glaciers are threatened locally by increasing populations and use of resources, pollution and ecosystem modification (Dudgeon 2006, Upadhyay et al. 2006, Qasim et al. 2011). Tropical glaciers, such as those in the Himalayas are among the most threatened due to the relatively small area they cover (Fankhauser et al. 2001). Many glaciers in the Eastern Himalayas like others around the world are reducing in volume, but some others are gaining mass (e.g. Karakoram) (Bolch et al. 2012). The estimated retreating rate of glaciers is approximately 10 to 60 m/year and many glaciers <0.2 km^2 in area have already disappeared (Bajracharya 2008). Retreating glaciers will increase the risk of floods with ecological, cultural and economic implications (Barnett et al. 2005, IPCC2007). Glacial lakes will also form and expand, increasing the risk of glacial lake outburst floods (GLOFs) (Bolch et al. 2008). In recent times, GLOFs have added to big problems in mountain villages, including many deaths (Richardson and Reynolds 2000, Pradhan and Shrestha 2007, Gardelle et al. 2011). For example Ngozumpa Glacier, west of Mount Everest in Nepal, has formed a lake that is growing fast and has the risk of GLOF (Benn et al. 2012, Thompson et al. 2012).

Alterations in the global physical system will therefore have consequences on biodiversity. Some species may have benefits and others may be harmed by climate change and environmental impacts. These shifts are currently having impacts in species abundance, changes in species distribution, phenology (Parmesan 2007), migration times and many others. Climate change may also produce long-term impacts with some of them being irreversible, such as species extinction (Thomas 2004, Secretariat of the Convention on Biological Diversity 2009). However, some organisms may have the ability to adapt to climate change too.

In marine ecosystems physical and chemical changes have been associated with climate change and with other anthropogenic effects (e.g. ocean warming and acidification). These changes already have effects on species and on the trophic food web. The Arctic cod (*Arctogadus glacialis*), a key species for many seabirds (e.g. black guillemot*, Cepphus grylle*), lives close to the ice; therefore if the ice is retreating, birds have to fly longer distances to obtain food and in some point the bird colony may fail (Link et al. 2008, Stempniewicz et al. 2007, Moir 2012). Another example is the movement of plankton populations to northern areas, affecting bird species (Stempniewicz et al. 2007).

Several marine bird species forage at sea and transport nutrients from the sea to terrestrial ecosystems such as the tundra. Climate change is predicted to change ocean conditions and therefore plankton communities (Richardson 2009, Brander 2010, Patara et al. 2012). As a consequence the changes in the trophic food web will directly affect seasonally plankton-eating seabirds (e.g. little auk, *Alle alle*) and seabirds that feed on plankton-eating fish (e.g. guillemots *Uria sp*.) (Stempniewicz et al. 2007). Moreover climate change threatens specialist species such as the little auk (Karnovsky et al. 2003), as well as other species depending on ice areas such as ivory gulls.

Moreover, some bird species migrate long distances, interconnecting their ranges with other species (Watson et al. 2011), and are multi-function species, providing services in different ecosystems and having different niches (Semmens et al. 2011). Migratory species challenge natural threats traveling along several countries, such as predators and weather; they also have to deal with other human impacts along their life cycle. The Arctic tern (*Stema paradisaea*) usually spends the summer breeding in the high Arctic and the winter in Antarctica (Hatch 2002, Egevang et al. 2010). Breeding habitat of this species, the arctic tundra, is projected to decrease in area due to increasing CO_2 scenarios of climate change (BirdLife 2012). Some bird species in the Hindu Kush-

Himalaya have altitudinal migration and may be affected by climate change effects (e.g. *Ficedula subrubra and Anser indicus*).

8.3.3 Feedback loops and climate change impacts in other parts of the world

The Three Poles Regions are critical for maintaining the Earth's processes and stability. Dangerous positive feedback loops may contribute to accelerating global warming (Serreze et al. 2010, Callaghan et al. 2011, Vincent et al. 2011). For example, the Arctic stores 200-400 billion tons of carbon and approximately 1,000 billion tons of methane are stored in permafrost soil (UNEP 2012). If permafrost thaws it will release the otherwise stored gas and accelerate climate change. Boreal forests may also replace tundra (Walsh 2008) which would help to store carbon, but then increase heat absorption. A reduction of ice area will increase heat absorption contributing to a warming of the Earth as well (McGuire et al. 2006, McGuire et al. 2009).

Warming in tropical regions is expected to be less severe than in the Three Poles regions (Root et al. 2003, IPCC 2007, Parmesan 2007, Rosenzweig et al. 2008). However, different tropical ecosystems that are playing important roles in ecological, cultural and socio-economic contexts are threatened by climate change (Badjeck et al. 2010, Cinner et al. 2012). For example, coral bleaching due to changes in oceanic temperature is probably the most severe threat for coral reefs (McCormick et al. 2010), affecting global cycles and biodiversity. It is noticeable that these resources are located mostly in developing countries where economic growth plays a major role in the political agenda (e.g. Coral Triangle in South East Asia).

Ice sheets (in Greenland and Antarctica) are located in extreme and remote environments; however they are not away from human impacts such as climate change. Ice sheets (Vaughan 2009) and small glaciers (IPCC 2007, Jenkins and Holland, 2007) have the potential to raise sea-levels. In the Amundsen Sea embayment of West Antarctica the ice sheet has been thinning at rates of a few centimeters per year (interior) and meters per year near the coast. Sea level rise has been linked to human activities and GHG emissions (Gehrels 2009, Zecca and Chiari 2012), and is considered one of the major indicators of ongoing global changes (0.06 m per decade) (Gehrels 2009). Sea level rise may have serious effects on coastal areas, including ecosystems, people and economy (Vaughan 2009), especially in South East Asia and Pacific Islands (Gehrels 2009). For instance, sea-level rise due to climate change represents a serious threat for mangrove ecosystems (e.g. Sundarbans in the Ganges–Brahmaputra Delta). This will bring changes in salinity distribution and inundate mangroves (IPCC 2007).

8.3.4 Other effects of climate change considered "positive" for global economy

Environmental changes and the shrinking of the sea-ice cover will improve the accessibility of the Arctic Ocean to shipping and exploration of natural resources (e.g. fisheries, oil and gas) (Sale 2009). The melting Arctic ice cap will allow new trade routes and potential economic benefits for countries. Non-Arctic countries already started showing interest in the region (e.g. East Asia). China may create a new marine route for transportation industry (Hong 2012). That will increase the anthropogenic pressure on the Arctic ecosystems and confrontation risk over rights of way (Howard 2009).

A moderate climate warming in the Arctic may also be positive for fisheries (Schrank 2007). There is still a lot of uncertainty about climate change effects (e.g. trophic relations, fish stock productivity) (IPCC 2007). Global changes added to local pressures increase the uncertainty of consequences (Nurse 2011).

9. Methods

To carry out this thesis, a meta-analysis technique (Glass 1976), the Geographic Information System (GIS) software ESRI ArcGIS 10.1, and the machine learning software Salford Predictive Modeler Builder® v.6.6 were used. Meta-analysis is a formal quantitative method to combine and compare results for their general trends from independent but similar studies including those with contradictory results (Fernández-Duque and Valeggia 1994, Harrison 2011). Meta-analyses have been widely used in social sciences as well as in clinical medicine, and are now utilized more frequently in several fields of biology and in ecology (Stewart 2010, Worm and Myers 2003). In this work here, a meta-analysis was used to compare native birds of the Three Poles included in the IUCN Red List and linked with socioeconomic data from the WDI Data Catalog of The World Bank (World Development Indicators) for primary and secondary countries (The World Bank 2012a).

From the list of countries of the world (The World Bank 2012a), a subset of countries was selected for each of the Three Poles and classified as primary or secondary (for criteria and definitions of primary and secondary countries see section 4.1 and table 1). Primary nations are the countries that are directly linked with the poles. Results from their analysis should be the strongest due to inference on causation, but they are weak in sample size. The secondary nations are not directly linked in space with the poles, but show correlations and as a group; they have a higher sample size which is most likely the reason for better model performance. The combined set is an approach to find and confirm general trends, and with statistical interactions. This set is a mix of data quality but has the highest sample size.

A list of primary and secondary countries for each pole was created. These lists included a total of eight countries classified as primary and 13 as secondary for the Arctic; eight primary and 24 secondary countries for the Antarctic; and eight primary and 13 secondary countries for the HKH region. Moreover, spatial information on the distributions of bird species from the institution BirdLife was analyzed in ArcGIS 10.1® software to select birds' distributions along the Three Pole regions (Fig. 11).

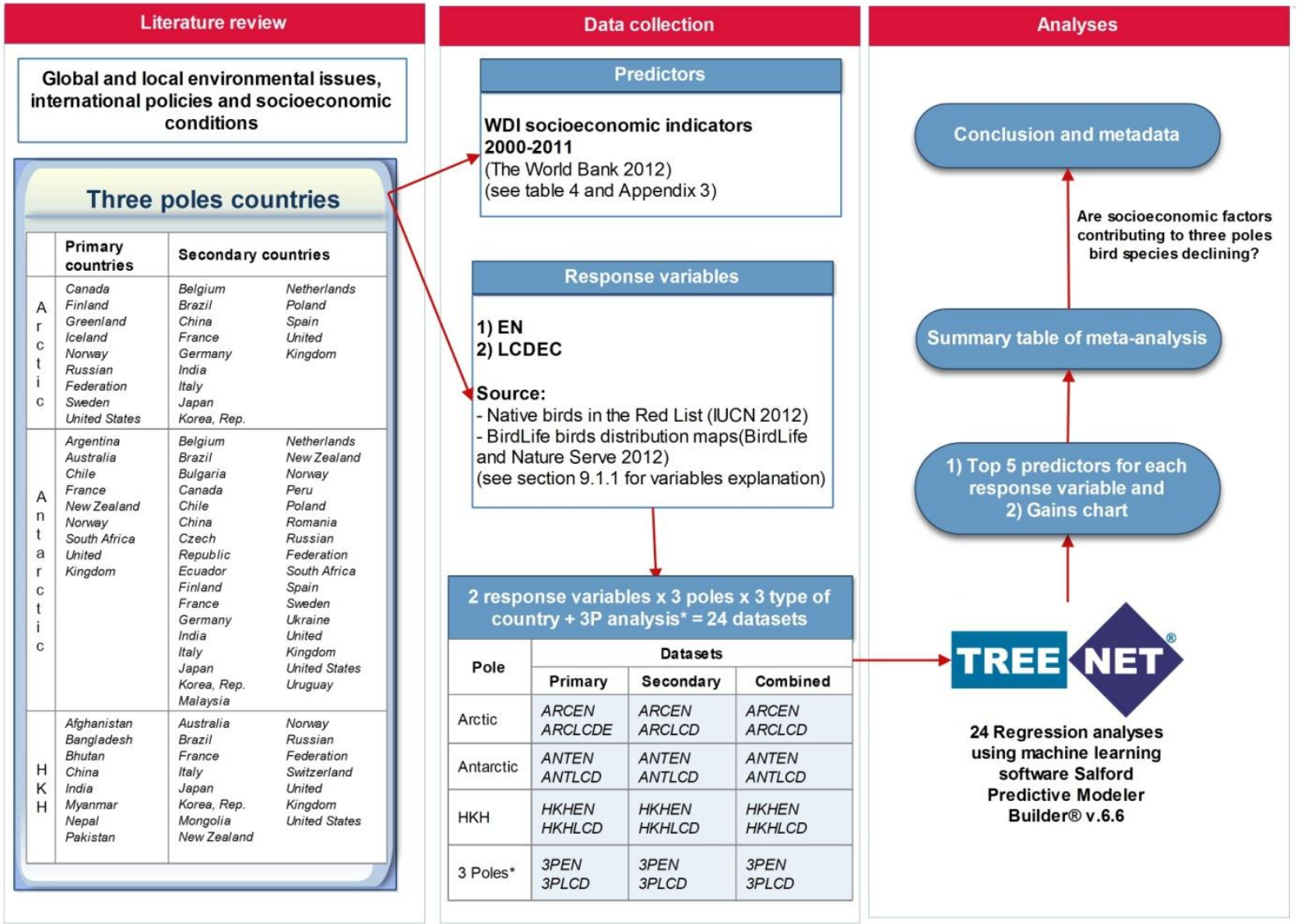


Figure 11: A Flowchart describing the analytical process.

Primary and secondary countries were identified for each pole according to the literature. Data from the IUCN RedList (IUCN 2012) and BirdLife (BirdLife and Nature Serve 2012) was used to create the variables EN and LCD (EN= birds in critically endangered, endangered, vulnerable, near threatened category of IUCN; LCD= Least concern decreasing bird species). Predictors were selected from the World Development Indicators (WDI) (The World Bank 2012a) (see section 9.1).A total of 24 datasets were created and analyzed in TreeNet (Salford Systems L. 2003) (see section 9.2). The results were evaluated according to the top five predictors and the gains charts, and presented in summary tables (see section 9.3).

9.1 Data collection

9.1.1 Response variables

The values of a response variable can usually be explained by many predictors using modeling techniques. Predictors are assumed to cause an effect on the response variable and in a meaningful fashion. In this work the response variables used were continuous numbers; thus the information was analyzed using a tree-based regression method (classification tree is used when categorical data are used).

Response variables were defined according to the available information in the IUCN Red List (http://www.iucnredlist.org/) and the bird species distribution maps of the world provided by BirdLife (BirdLife and Nature Serve 2012). Bird distribution maps were provided in a geodatabase file (GDB). An example of a distribution map for Sooty shearwater (*Puffinus griseus*) is presented in figure 12. This species is widely distributed around the world, but currently is classified as “near threatened” by the IUCN (IUCN 2012). The Sooty shearwater populations are declining due to long-line fisheries, the harvesting of juvenile birds (“muttonbirding”) and climate change (Brooke 2004, Clucas et al. 2008, BirdLife International 2012). The protection measures for this species clearly have to be carried by many countries.

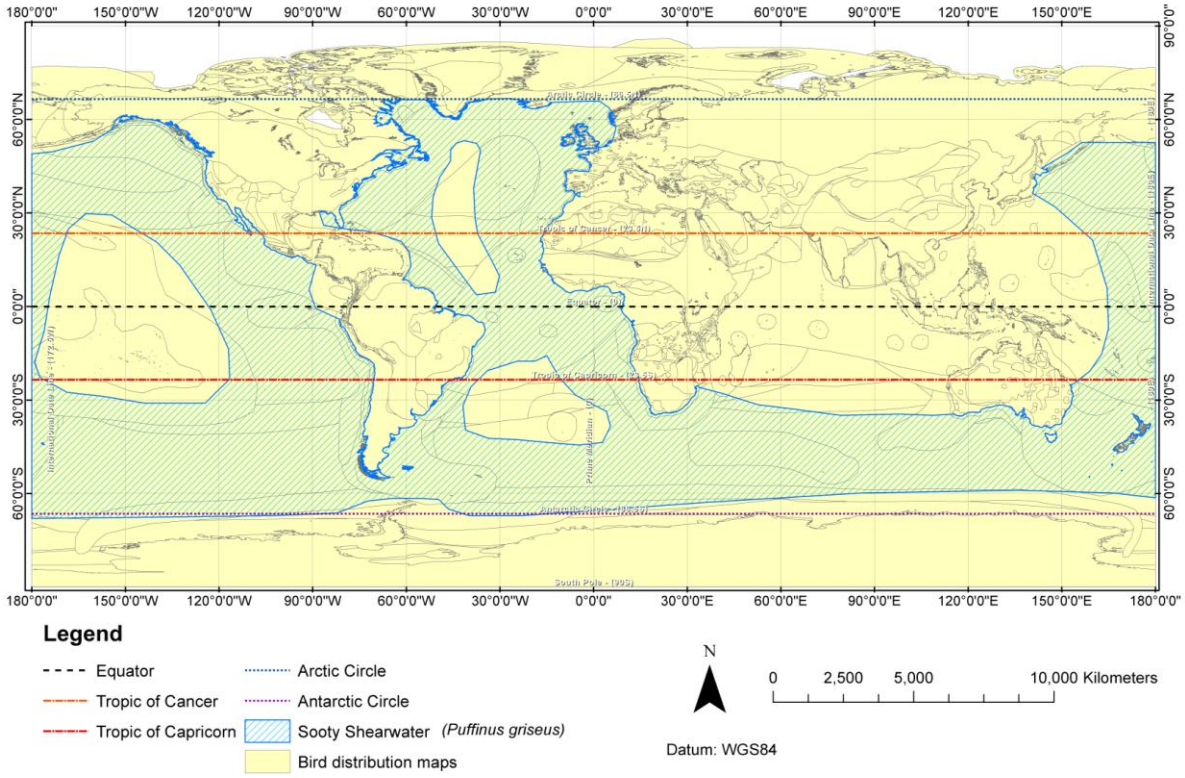


Figure 12: The complete data provided by BirdLife and the sooty searwater distribution as an example (Source: BirdLife and Nature Serve 2012, ESRI 2012).

Two response variables were created for each pole, and included all IUCN categories of bird species decreasing in number:

- EN: Percentage of bird species in the critically endangered (CR), endangered (EN), vulnerable (VU), and near threatened (NT) categories of IUCN with regard to the total of species in a country (IUCN 2012).
- LCD: Percentage of bird species in the least concern category of IUCN which populations are decreasing with regard to the total of species in a country (IUCN 2012).

The total of birds for each variable was calculated using two different methods using the *GIS* software ArcGIS 10.1 from ESRI®:

a) For primary countries bird distributions were selected for each pole from the global information contained in the GDB file provided by BirdLife and Nature Serve (2012). The following boundary definitions were used to delineate the poles: 1) CAFF boundary from the Arctic Council (http://arcticdata.is/index.php?option=com_phocadownload&view=file&id=98:caff-boundary&Itemid=156) was used to define the Arctic pole, 2) CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) boundaries provided by the Australian Antarctic Data Center (2012) (http://data.aad.gov.au/aadc/portal/drill_down.cfm?id=35), was used to define the Antarc pole and 3) the HKH outline polygon from ICIMOD

(http://geoportal.icimod.org/downloads/Download.aspx?ID=3) was used to define the HKH region. Bird distributions for primary and secondary countries were selected by location for each pole (Fig. 13).

b) Secondary countries were selected from the shapefile GIS Data for Countries (state of the art: 2007) from ESRI (http://edcommunity.esri.com/arclessons/lesson.cfm?id=393). Bird distributions were selected for secondary countries at each pole from the global information contained in the GDB provided by Bird Life and Nature Serve (2012). However, species that are resident to secondary countries and are therefore never at the pole are not of concern here and were therefore deleted from the data (also see section 4.1). We are not aware of better data for such an analysis.

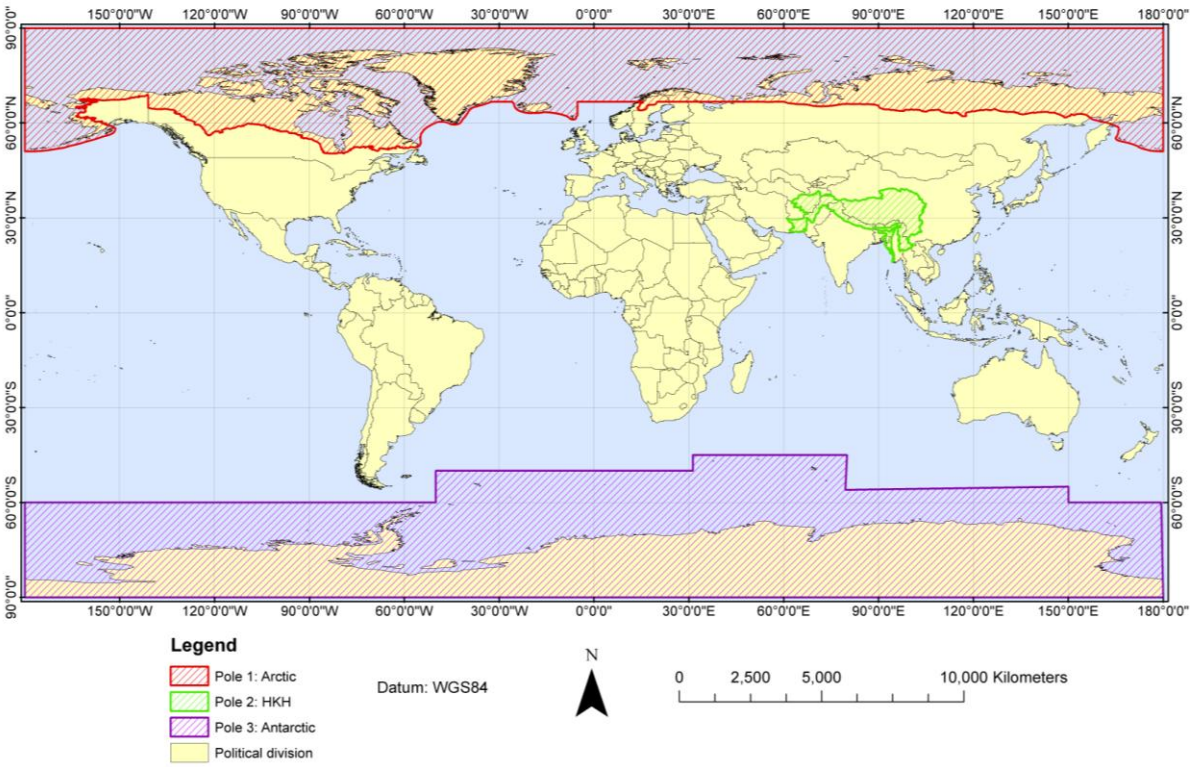


Figure 13: Map of the study area (Sources: CAFF 2009, CCAMLR 2012, ICIMOD 2008, ESRI 2012).

In both cases, total bird species for each response variable and country were calculated. Eight datasets were created, one for each response variable and for each pole, as well as for the Three Poles dataset. The Three Poles dataset (3P) consists of primary and secondary country datasets pooled together in one dataset for each variable and country. The 3P dataset may include the same country several times, but with different information regarding response variables. A short name was assigned to each response variable in order to identify them during the phase of analyses. The names of the response variables correspond to abbreviations of their definitions:

- ARCEN: Is the the percentage of bird species included in the critically endangered (CR), endangered (EN), vulnerable (VU), and near threatened (NT) categories of IUCN with regard to the total of species in a country the Arctic.
- ARCLCD: Is the percentage of bird species in the least concern category of IUCN which populations are decreasing with regard to the total of species in a country in the Arctic.

- ANTEN: The percentage of bird species included in the critically endangered (CR), endangered (EN), vulnerable (VU), and near threatened (NT) categories of IUCN with regard to the total of species in a country the Antarctic.
- ANTLCD: Percentage of bird species in the least concern category of IUCN which populations are decreasing with regard to the total of species in a country in the Antarctic.
- HKHEN: Percentage of bird species included in the critically endangered (CR), endangered (EN), vulnerable (VU), and near threatened (NT) categories of IUCN with regard to the total of species in a country the HKH region.
- HKHLCD: Percentage of bird species in the least concern category of IUCN which populations are decreasing with regard to the total of species in a country in the HKH region.
- 3PEN: Percentage of bird species included in the critically endangered (CR), endangered (EN), vulnerable (VU), and near threatened (NT) categories of IUCN with regard to the total of species in each country of the Three Poles.
- 3PLCD: Percentage of bird species in the least concern category of IUCN which populations are decreasing with regard to the total of species in a country in the Three Poles regions.

9.1.2 Predictors and final datasets

A set of social and economic predictors derived from The World Bank was collected in a Microsoft Office Excel® 2007 table for further analysis. The data set included a total of 180 socioeconomic predictors. The values of the predictors were pooled over time. Each predictor was averaged for the time between 2000 and 2011. Then it was determined which predictors could be used based on the availability and coverage for the different countries. Not all predictors were available for all countries, and predictors with no information were excluded from the database. Therefore, 33 predictors were used for the Arctic dataset, 94 for the Antarctic dataset, 63 for the HKH dataset and 27 for the Three Poles dataset (table 4). The complete list of predictors used in the analyses is presented in Appendix 3.

Table 4: List of predictors used in the analyses and sorted by pole.

Code	Predictor name	Antarctic	Arctic	HKH	3 Poles
AGLNCR	Permanent cropland (% of land area)	x		x	
AGLND	Agricultural land (% of land area)	x	x	x	x
AGMEEM	Agricultural methane emissions (% of total)	x			
AGNIEM	Agricultural nitrous oxide emissions (% of total)	x			
AGVAAD	Agriculture, value added (% of GDP)	x		x	
AGYLDCREL	Cereal yield (kg per hectare)	x		x	
ALNUEN	Alternative and nuclear energy (% of total energy use)	x			
ARLAPER	Arable land (hectares per person)	x		x	
ARLND	Arable land (% of land area)	x		x	
BIRACRU	Birth rate, crude (per 1,000 people)	x	x	x	x
C02ADJSAV	Adjusted savings: carbon dioxide damage (% of GNI)	x	x		

CO2DAM	Adjusted savings: carbon dioxide damage (current US$)	x	x	x	x
CO2EMI	CO_2 emissions (metric tons per capita)	x	x	x	x
CO2FCONS	CO_2 emissions from gaseous fuel consumption (kt)	x			
CO2FCPER	CO_2 emissions from gaseous fuel consumption (% of total)	x			
CO2IND	CO_2 emissions from manufacturing industries and construction (million metric tons)	x			
CO2KGGDP	CO_2 emissions (kg per 2005 PPP $ of GDP)	x			
CO2KT	CO_2 emissions (kt)	x	x	x	x
CO2LIQU	CO_2 emissions from liquid fuel consumption (kt)	x	x	x	x
CO2LIQPER	CO_2 emissions from liquid fuel consumption (% of total)	x	x	x	x
CO2OTHERS	CO_2 emissions from other sectors, excluding residential buildings and commercial and public services (million metric tons)	x			
CO2SOLIDFC	CO_2 emissions from solid fuel consumption (kt)			x	
CO2RES	CO_2 emissions from residential buildings and commercial and public services (million metric tons)	x			
CO2TRANSP	CO_2 emissions from transport (million metric tons)	x			
DERACRU	Death rate, crude (per 1,000 people)	x	x	x	x
DIESPC	Road sector diesel fuel consumption per capita (kt of oil equivalent)	x			
EGUSEKT	Energy use (kt of oil equivalent)	x			
ELPOCO	Electric power consumption (kWh per capita)	x			
EMPORA	Employment to population ratio, 15+, total (%)	x		x	
ENIMP	Energy imports, net (% of energy use)	x			
ENPROD	Energy production (kt of oil equivalent)	x			
ENUSE	Energy use (kg of oil equivalent per capita)	x			
ENUSKT	Energy use (kt of oil equivalent)	x			
EXPORT	Exports of goods and services (% of GDP)	x		x	

FERATO	Fertility rate, total (births per woman)	x	x	x	x
FODINV	Foreign direct investment, net inflows (BoP, current US$)	x		x	
FODPR	Food production index (1999-2001 = 100)	x	x	x	X
FORAR	Forest area (% of land area)	x	x	x	x
FORKM	Forest area (km^2)	x	x	x	x
FOSENC	Fossil fuel energy consumption (% of total)	x			
GASPC	Road sector gasoline fuel consumption per capita (kt of oil equivalent)	x			
GDP	GDP (current US$)	x	x		
GDPGRW	GDP growth (annual %)	x	x	x	x
GDPPC	GDP per capita (current US$)	x	x		
GEFBIO	GEF benefits index for biodiversity (0 = no biodiversity potential to 100 = maximum)	x	x	x	x
GNIPC	GNI per capita, PPP (current international $)	x		x	
GRCAFO	Gross capital formation (% of GDP)	x		x	
HEEXPC	Health expenditure per capita (current US$)	x		x	
INFCOPR	Inflation, consumer prices (annual %)			x	
IMPORT	Imports of goods and services (% of GDP)	x		x	
INFGDPD	Inflation, GDP deflator (annual %)	x	x	x	x
INMISTK	International migrant stock, total	x	x	x	x
INVALAD	Industry, value added (% of GDP)	x		x	
IWATSO	Improved water source, rural (% of rural population with access)			x	
LAFOTO	Labor force, total	x		x	
LAPART	Labor participation rate, total (% of total population ages 15+)	x		x	
LIEXBIR	Life expectancy at birth, total (years)	x	x	x	x
LIVPRO	Livestock production index (1999-2001 = 100)	x	x	x	x
LNDAR	Land area (km^2)	x	x	x	x
LPRFE	Labor participation rate, female (% of female population ages 15+)	x		x	
LPRMA	Labor participation rate, male (% of male population ages 15+)	x		x	
MERTRD	Merchandise trade (% of GDP)	x	x		

METEM	Methane emissions (kt of CO_2 equivalent)	x			
MILEXP	Military expenditure (% of GDP)	x			
MORA	Mortality rate, under-5 (per 1,000)	x		x	
MOTVEH	Motor vehicles (per 1,000 people)	x		x	
NATRESDEPPER	Adjusted savings: natural resources depletion (% of GNI)	x			
NETMIG	Net migration	x		x	
OGHGEM	Other greenhouse gas emissions, HFC, PFC and SF6 (thousand metric tons of CO_2 equivalent)	x			
PASCAR	Passenger cars (per 1,000 people)			x	
PEDAMSAV	Adjusted savings: particulate emission damage (current US$)	x			
PEDAMSAVPER	Adjusted savings: particulate emission damage (% of GNI)	x		x	
PLGCIT	Population in the largest city (% of urban population)	x	x		
PM10	PM10, country level (micrograms per cubic meter)	x		x	
POP014	Population ages 0-14 (% of total)	x		x	
POP1564	Population ages 15-64 (% of total)	x		x	
POP65	Population ages 65 and above (% of total)	x		x	
POPGRW	Population growth (annual %)	x	x	x	x
POPTOT	Population, total	x	x	x	x
PRDIES	Pump price for diesel fuel (US$ per liter)	x		x	
PRGAS	Pump price for gasoline (US$ per liter)	x		x	
RDENCOM	Road sector energy consumption (% of total energy consumption)	x			
REFORI	Refugee population by country or territory of origin	x		x	
RENWAS	Combustible renewables and waste (% of total energy)	x			
RNWFW	Renewable internal freshwater resources per capita (cubic meters)	x	x	x	x
RNWFWM	Renewable internal freshwater resources, total (billion cubic meters)	x	x	x	x
RUPOPER	Rural population (% of total population)	x	x	x	
RURPOP	Rural population	x	x	x	x
SENRPRE	School enrollment, preprimary (% gross)	x		x	

SENRPRI	School enrollment, primary (% gross)	x		x	
SENRSEC	School enrollment, secondary (% gross)	x		x	
SEVALAD	Services, etc., value added (% of GDP)	x		x	
TAXPAY	Tax payments (number)	x			
TORES	Total reserves (includes gold, current US$)	x			
TOTTAX	Total tax rate (% of commercial profits)	x			
UNEMTO	Unemployment, total (% of total labor force)	x	x		
URBPOP	Urban population	x	x	x	x
URPOPR	Urban population (% of total)	x	x	x	x

For each country, the socioeconomic predictors were linked to the corresponding response variables in an Excel table. A total of eight tables were exported to comma-separated values (CSV) files. These tables were divided into three subsets to perform the analyses in the Salford Predictive Modeler Builder software (Salford Systems, L. 2003):

- Primary countries model: only primary countries
- Secondary countries model: only secondary countries
- Combined model (primary + secondary countries): the combined model groups primary and secondary countries data in the same dataset.

9.2 The analyses

9.2.1 Models and Machine Learning

Machine learning is based on advanced multiple regression methods and is capable of learning and capturing patterns and trends in data. It can be used to find the major signals in lower-quality data. The resulting model explains the data, and when generalizing well, they can be used to predict, diagnose, validate or simulate variables for instance. As one kind of data mining, machine learning can obtain useful information to solve a problem from potentially messy and otherwise constrained data sets (Han et al. 2006, Craig & Huettmann 2009). These technologies have many applications in professional disciplines like banking, industry, ecology, economy, and many others (Kononenko and Kukar 2007), and are widely used there already. They were ignored in ecology for long time, but nowadays data mining and machine learning algorithms are applied to a variety of research questions (e.g., Kononenko and Kukar 2007, Craig & Huettmann 2009, see Huettmann et al. 2011 for seabirds, Schmid 2012).

Data mining based on machine learning algorithms was chosen here for this project as a method of choice because of its speed and known power to find unknown trends and robust signals in messy data without having to rely on linear relationships and presumptive p-value statistics. In comparison to p-value statistics that rely on many *a priori* assumptions (Breiman 2001), the modeling process in data mining is much more flexible (Hastie et al, 2003). Thus, machine learning is a rather flexible approach, can account for variation in ecological data sets, is capable of

handling interactions (Cutler et al. 2007, Elith et al. 2008, Hochachka et al. 2007) and especially in complex policy and real-world data, as used here.

Machine learning algorithms such as TreeNet and RandomForest, and their underlying mathematics have been described very well in the literature (see Friedman 1999, Breiman 2001, Cutler et al. 2007, Hochachka et al. 2007, Elith et al. 2008, Craig and Huettmann 2009, Oppel and Huettmann 2010). A machine learning algorithm consists of several iterations that repeat the analysis cycle and find the best mathematical solution to describe the data with the least variance possible. The algorithm receives data and describes the pattern until it finds the best summarizing quantitative model, according to the input settings and optimizations. The modeling process is based on a computerized learning process that implies improvements, using information to learn from the outcome to improve the result next time. Therefore the initial performance is changing progressively and tends to become more efficient with each run. Patterns inherent in the data are learned by this intelligent algorithm and get expressed mathematically.

For this study, the machine learning software Salford Predictive Modeler Builder® v.6.6 was used to run the models (http://www.salford-systems.com/). There are several applications combined in this software that can be used and that are based on different algorithms. For each response variable (EN, LCD) a classification and regression trees analysis was performed in TreeNet (see Salford Systems TreeNet™ manual) (see section 9.2.2).

Over 100 different models and model settings were tried out for each response variable using the predictors listed in table 4 and described in the Appendix 3. Appendices 1a, 1b and 1c include the final settings of the best TreeNet models that are then further explained in the results section. This was very helpful to understand the data and the analysis process, and the strengths and weaknesses of machine learning algorithm overall. Models can be tested quickly in such machine learning software.

In the Treenet analysis, the predictors were ordered according to their contribution to the model, where contribution was measured as variable importance from Treenet and Random Forests results. The top five variables were selected to be presented in the results (see Appendices 2a and 2b).

9.2.2 The Random Forests analyses

Due to the small sample size in Arctic and Antarctic primary countries datasets, an additional classification analysis was performed using the Random Forests application to identify important predictors. Random Forest is another machine learning application incorporated in the Predictive Modeler Builder® (see https://www.salford-systems.com/en/products/randomforests and Cutler et al. 2007). Like TreeNet, Random Forests is also tree-based and tends to achieve better classification and predictions than Treenet and for smaller datasets. A random set of variables is used at every node of a tree from a bootstrap sample of the data. The algorithm prevents over fitting, is robust to outliers, and can handle a large number of categorical and continuous variables (Cutler et al., 2007). I ran Random Forests using the default number of 500 trees per model. The response information was classified as “high” and “low” for each country. For the variable EN, countries with values higher than 10% of bird species classified as EN, were classified as “high”; and countries with values lower than 10% of bird species classified as EN, were classified as “low”. For the variable LCD, countries with values higher than 40% of bird species classified as LCD, were

classified as “high”; and countries with values lower than 40% of bird species classified as LCD were classified as “low”.

9.3 Presentation of results

There are different performance parameters in tree-based algorithms such as the mean absolute error curve, the cumulative gains chart, and partial dependency plots. They are presented for each response variable in the results section and explained here.

First, in the cumulative gains chart, the model performance is measured by the area between the lift curve and the baseline (Fig. 14). The larger the area, the better the model (see Salford Systems TreeNet™ manual). See Appendix 4.

Figure 14: Cumulative Gains Chart.

Second, the mean absolute error curve shows the total number of trees and the optimal model (green line). If the train (in blue) and test (in red) curves are decreasing together, this is indication of a good model (see Salford Systems TreeNet™ manual) (Fig. 15). See Appendix 4.

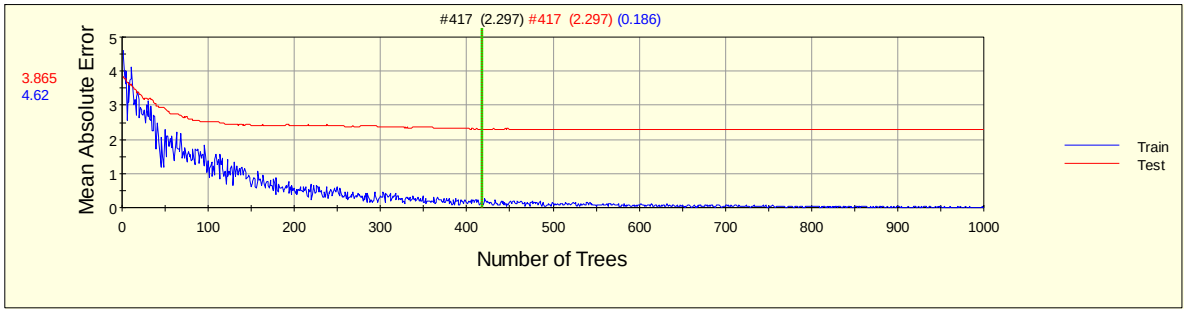


Figure 15: Mean absolute error curve.

Third, the top five predictors were selected from the models. For each predictor a partial dependence plot was presented (Fig.16): Partial dependence plots show the effect of a single predictor on the predicted response, and in the context of the overall multivariate setup. Partial dependence plots are a kind of Resource Selection Functions (RSF; Manly et al. 2002, also see https://www.salford-systems.com/en/blog/dan-steinberg/item/454-reading-treenet-partial-dependency-plots). Moreover, partial dependence plots show the functional non-linear

relationships of single predictors in the context off the pooled set of predictors. The X axis is the range of values of the predictor. Y-axis is the indexed response and corresponds to the prediction outcome of the model. Data from WDI (The World Bank 2012a) was used to interpret the top five response curves for each variable.

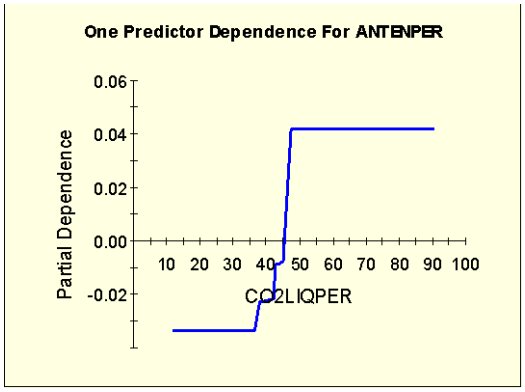
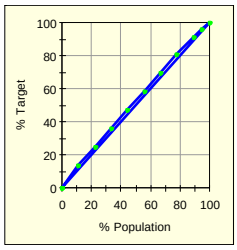


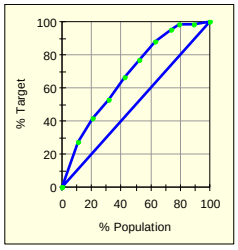
Figure 16: Partial dependence plot.

Fourth, the results from the 24 datasets were integrated in Appendices 2a and 2b. Table 5 shows the results for Cumulative Gains Charts classification:

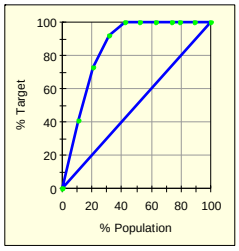
Table 5: Cumulative gains chart classification used as a quality measure for models.



TYPE 1: The area under the lift curve is almost imperceptible, it seems to be flat but some bins are present. The lift curve shows a minimal growth at the beginning, and then stays constant and falls at the end over the baseline. In this work this is considered a fair model.



TYPE 2: The area under the lift curve is small. The lift curve has a moderate growth at the beginning, and then stays constant and falls at the end over the baseline. For this work this is considered a good model.



TYPE 3: The area under the lift curve is clearly larger than the other two types of graphs. The lift curve has a steep growth until some bins reach the top of the upper part of the graph. For this work this is considered the best model possible.

10. Results

In this section I will present the results for the 24 datasets that were analyzed. The corresponding gains categories to evaluate model performances as described in the method section (see table 5) are presented in table 6.

Two ways for organizing the results were chosen according to the relative importance and contribution of predictors to the models: 1) top predictors by pole; 2) top predictors by type of country (primary, secondary and the combined models).

The first part (section 10.2) is an overview of the results. This section is organized according to the model categories Arctic (ARC), Antarctic (ANT), Hindu Kush-Himalayan (HKH) and Three Poles (3P).

The second part of the results (section 10.3, table 7) is organized in two parts: “endangered birds” (EN) models and “least concern decreasing” (LCD) models. Each part is divided into three sections: First I show the results for primary countries; second I show the secondary countries; and third, I show the combined model (primary + secondary countries). Partial dependence plots were created for the five most important predictors of each of the 24 models, and are shown in order of importance.

The results are summarized in Appendices 2a and 2b which show all the most important predictors.

For more detailed gains charts and absolute mean error curves of each model see Appendix 4.
An abstract of the metadata is presented in Appendix 5.

10.1 Models performances and gains charts

According to the Gains chart classification presented in table 5 of methods, model performances by type of country were best for secondary countries. Regarding poles, model performances were generally best for the Three Poles (3P) models. No gains charts were possible for primary Arctic countries (10.3.1.1.1 and 10.3.1.1.2) and primary Antarctic countries (10.3.2.1.1 and 10.3.2.1.2) (table 6).

Table 6: Gains classes for the different models sorted by response variable, country and pole.

Response variable	Country	Pole	Section	Model	Gains class
10.3.1 EN: Critically endangered, endangered, vulnerable and near threatened birds (IUCN 2012)	10.3.1.1 Primary	Arctic	10.3.1.1.1	ARCEN	NE
		Antarctic	10.3.1.1.2	ANTEN	NE
		HKH	10.3.1.1.3	HKHEN	1
		Three Poles	10.3.1.1.4	3PEN	2
	10.3.1.2 Secondary	Arctic	10.3.1.2.1	ARCEN	3
		Antarctic	10.3.1.2.2	ANTEN	3
		HKH	10.3.1.2.3	HKHEN	2
		Three Poles	10.3.1.2.4	3PEN	3
	10.3.1.3 Combined	Arctic	10.3.1.3.1	ARCEN	2
		Antarctic	10.3.1.3.2	ANTEN	1
		HKH	10.3.1.3.3	HKHEN	1
		Three Poles	10.3.1.3.4	3PEN	3
10.3.2 LCD: Least concern birds, and decreasing (IUCN 2012)	10.3.2.1 Primary	Arctic	10.3.2.1.1	ARCLCD	NE
		Antarctic	10.3.2.1.2	ANTLCD	NE
		HKH	10.3.2.1.3	HKHLCD	1
		Three Poles	10.3.2.1.4	3PLCD	2
	10.3.2.2 Secondary	Arctic	10.3.2.2.1	ARCLCD	1
		Antarctic	10.3.2.2.2	ANTLCD	2
		HKH	10.3.2.2.3	HKHLCD	1
		Three Poles	10.3.2.2.4	3PLCD	2
	10.3.2.3 Combined	Arctic	10.3.2.3.1	ARCLCD	1
		Antarctic	10.3.2.3.2	ANTLCD	1
		HKH	10.3.2.3.3	HKHLCD	1
		Three Poles	10.3.2.3.4	3PLCD	2

NE = No Evaluated using Treenet. For these models was used Random Forests to identify the top five predictors (see section 9.2.2).

10.2 An overview of the results grouped by pole

Here I present the general results for each pole, including Arctic, Antarctic, Hindu Kush-Himalaya (HKH) and Three Poles models.

10.2.1 Arctic (ARC) models

The total international migrant stock and GDP were most often selected as top predictors and are therefore most important in the Arctic model.

10.2.2 Antarctic (ANT) models

The most important predictors for Antarctic models according to how often they were selected in the analyses showing a high contribution were related to emissions: CO_2 emissions from gaseous fuel consumption (% of total), CO_2 emissions from liquid fuel consumption (% of total), agricultural methane emissions (% of total), the predictor named other greenhouse gas emissions, HFC, PFC (perfluorochemicals) and SF6 (Sulfur hexafluoride) thousand metric tons of CO_2 equivalent.

10.2.3 Hindu Kush-Himalaya (HKH) models

There is no clear trend towards a most important predictor that is present in HKH models. Nonetheless, school enrolment primary and school enrolment secondary were most often selected as top predictors and are therefore most important for the models (primary and combined model).

10.2.4 The Three Poles (3P) models

The GDP growth and food production index were most often selected as top predictors and are therefore most important for the Three Poles (3P) model.

10.3 The results in detail and grouped by type of country

Here I present the results grouped by the response variables "endangered birds" (EN) (section 10.3.1) and "least concern decreasing" (LCD) (section 10.3.2), and divided into the types of country: primary, secondary or combined (primary + secondary). Each type of country is then divided into Arctic (ARC), Antarctic (ANT), Hindu Kush-Himalaya (HKH) and the Three Poles models. See table 7 for an index of this section.

Table 7: Index of the different models, sorted by response variable, country and pole.

Response variable	Country	Pole	Section	Model
10.3.1 EN: Critically endangered, endangered, vulnerable and near threatened birds (IUCN 2012)	10.3.1.1 Primary	Arctic	10.3.1.1.1	ARCEN
		Antarctic	10.3.1.1.2	ANTEN
		HKH	10.3.1.1.3	HKHEN
		Three Poles	10.3.1.1.4	3PEN
	10.3.1.2 Secondary	Arctic	10.3.1.2.1	ARCEN
		Antarctic	10.3.1.2.2	ANTEN
		HKH	10.3.1.2.3	HKHEN
		Three Poles	10.3.1.2.4	3PEN
	10.3.1.3 Combined	Arctic	10.3.1.3.1	ARCEN
		Antarctic	10.3.1.3.2	ANTEN
		HKH	10.3.1.3.3	HKHEN
		Three Poles	10.3.1.3.4	3PEN
10.3.2 LCD: Least concern birds, and decreasing (IUCN 2012)	10.3.2.1 Primary	Arctic	10.3.2.1.1	ARCLCD
		Antarctic	10.3.2.1.2	ANTLCD
		HKH	10.3.2.1.3	HKHLCD
		Three Poles	10.3.2.1.4	3PLCD
	10.3.2.2 Secondary	Arctic	10.3.2.2.1	ARCLCD
		Antarctic	10.3.2.2.2	ANTLCD
		HKH	10.3.2.2.3	HKHLCD
		Three Poles	10.3.2.2.4	3PLCD
	10.3.2.3 Combined	Arctic	10.3.2.3.1	ARCLCD
		Antarctic	10.3.2.3.2	ANTLCD
		HKH	10.3.2.3.3	HKHLCD
		Three Poles	10.3.2.3.4	3PLCD

10.3.1 Model EN

For the model "endangered birds" (EN), predictors showing the highest contribution to the model were food production and rural population. Other important predictors were agriculture land, CO_2 emissions, GDP, GDP growth and land area.

10.3.1.1 Primary countries

10.3.1.1.1 Arctic

The top five predictors for the "Arctic – endangered birds (ARCEN) primary countries" model were: a) rural population; b) land area (km^2); c) GEF benefits index for biodiversity; d) Population in the largest city (% of urban population); and e) GDP (current US$) (Appendix 2a). No partial dependence plots were created for the ARCEN model (for details see section 9.2.2).

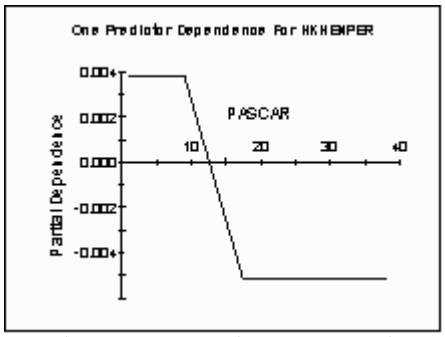
10.3.1.1.2 Antarctic

The top five predictors for the "Antarctic – endangered birds (ANTEN) primary countries model" were: a) adjusted savings: particulate emission damage (current US$); b) Agriculture, value added (% of GDP); c) School enrollment, preprimary (% gross); d) Food production index (1999-2001 = 100); and e) School enrollment, secondary (% gross) (Appendix 2a). No partial dependence plots were created for the ANTEN model (for details see section 9.2.2).

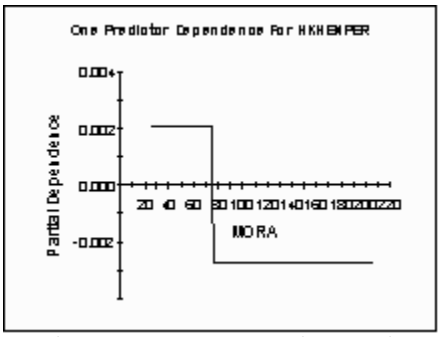
10.3.1.1.3 HKH

The top five predictors for the "Hindu Kush-Himalaya – endangered birds (HKHEN) primary countries" model were: a) passenger cars (per 1,000 people); b) mortality rate, under 5 (per 1,000); c) motor vehicles (per 1,000); d) permanent cropland (% of land area); and e) school enrollment, primary (% gross) (Appendix 2a). The relationships shown in the partial dependence plots indicate a negative correlation for passenger cars (Fig. 17-a) and mortality rate (Fig. 17-b) predictors. The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for motor vehicles (Fig. 17-c), permanent cropland (Fig. 17-d) and school enrolment (Fig. 17-e). The effect on the model was higher in the highest values of these predictors. Nepal, India and Myanmar had the highest impact on the model. Partial dependence plots for the five most important predictors of the HKHEN model are presented in figure 17.

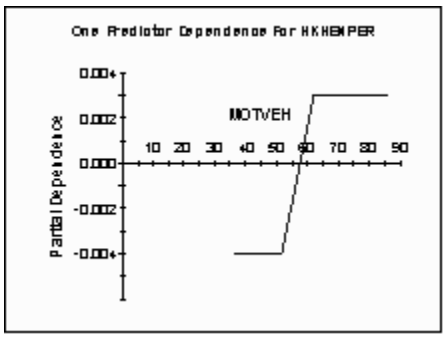
Figure 17: Partial dependence plots for the primary countries of the HKHEN model.



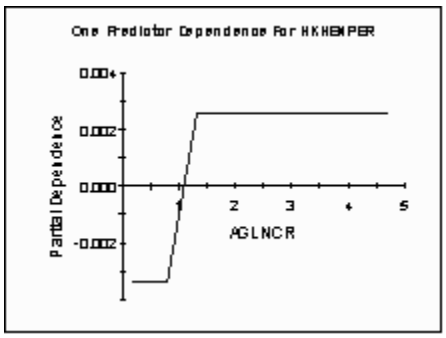
a) Passenger cars (per 1,000 people)



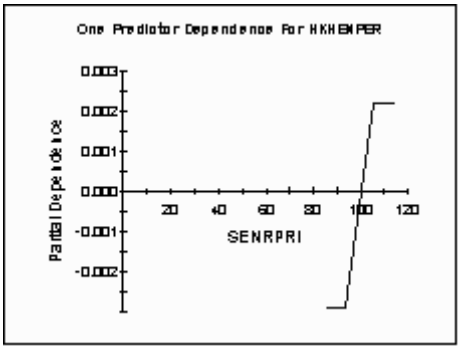
b) Mortality rate, under-5 (per 1,000)



c) Motor vehicles (per 1,000 people)



d) Permanent cropland (% of land area)

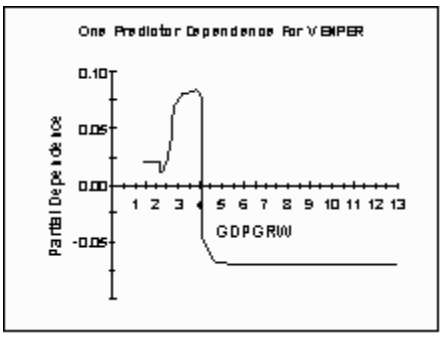


e) School enrollment, primary (% gross)

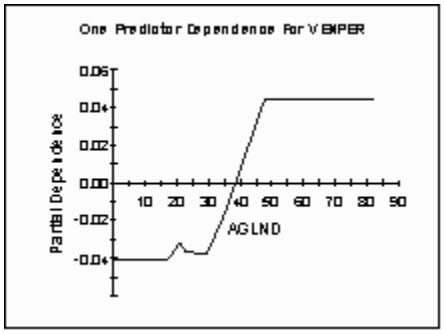
10.3.1.1.4 Three Poles

The top five predictors for the "Three Poles – endangered birds (3PEN) primary countries" model were: a) GDP growth (annual %); b) agricultural land (% of land area); c) forest area (km^2); d) GEF benefits index for biodiversity; and e) food production index (Appendix 2a). Partial dependence plots for the five most important predictors of the 3PEN model are presented in figure 18. The relationships shown in the partial dependence plots indicate a negative correlation for forest area (Fig. 18-c). The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for agricultural land (Fig. 18-b) and GEF benefits index for biodiversity (Fig. 18-d). The effect on the model was higher in the highest values of these predictors. The predictors GDP growth (Fig. 18-a) and food production index (Fig. 18-e) do not show a clear trend. Australia, China, UK and South Africa had the highest impact on the model.

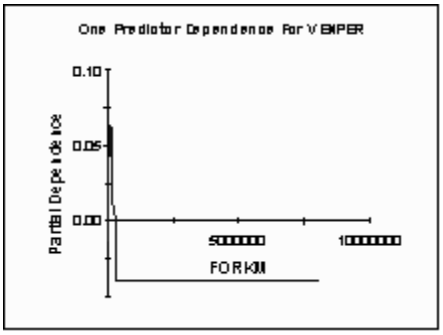
Figure 18: Partial dependence plots for the primary countries of the 3PEN model.



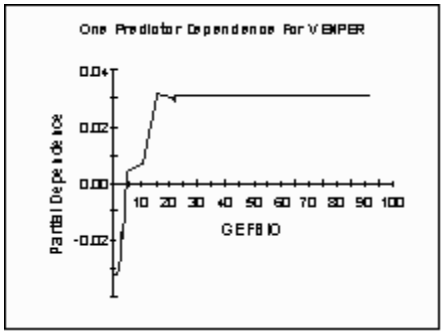
b) GDP growth (annual %)



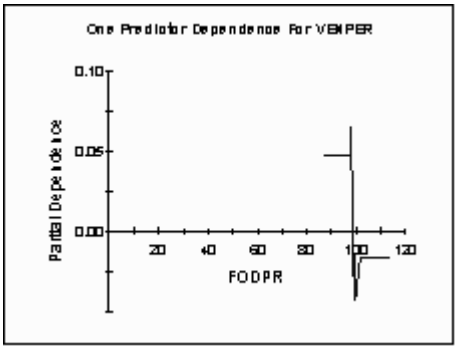
a) Agricultural land (% of land area)



c) Forest area (km^2)



d) GEF benefits index for biodiversity (0 = no biodiversity potential to 100 = maximum)



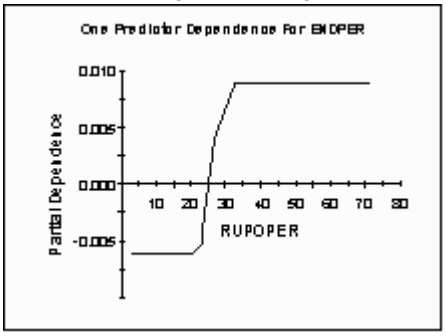
e) Food production index (1999-2001 = 100)

10.3.1.2 Secondary countries model

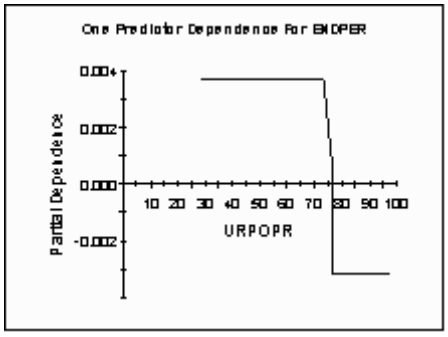
10.3.1.2.1 Arctic

The top five predictors for the "Arctic – endangered birds (ARCEN) secondary countries" model were: a) rural population (% of total population); b) urban population (% of total); c) total international migrant stock; d) population growth (annual %); and e) GDP (current US$) (Appendix 2a). Partial dependence plots for the five most important predictors of the ARCEN model are presented in figure 19. The relationships shown in the partial dependence plots indicate a negative correlation for urban population (Fig. 19-b), total international migrant stock (Fig. 19-c) and population growth (Fig. 19-d) predictors. The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for rural population (Fig. 19-a) and GDP (Fig. 19-e). The effect on the model was higher in the highest values of these predictors. Japan, China, Poland and Germany had the highest impact on the model.

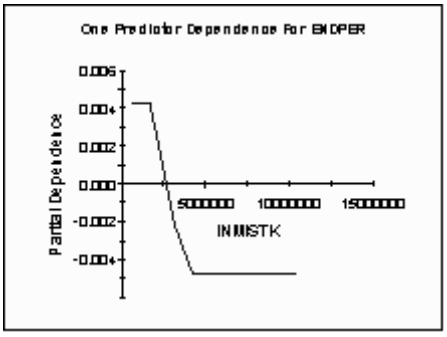
Figure 19: Partial dependence plots for the secondary countries of the ARCEN model.



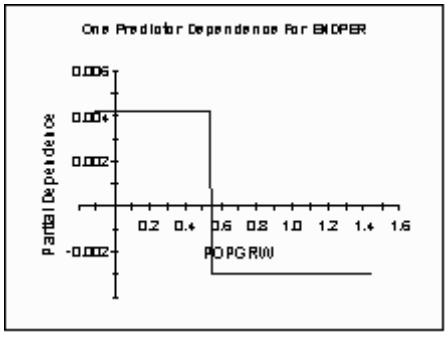
a) Rural population (% of total population)



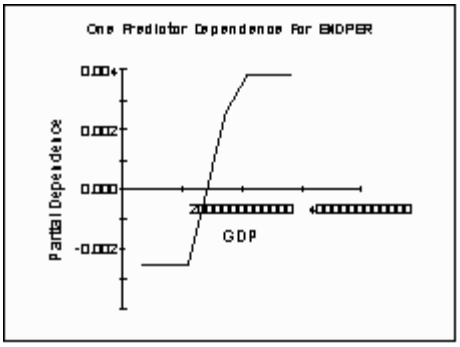
b) Urban population (% of total)



c) International migrant stock, total



d) Population growth (annual %)

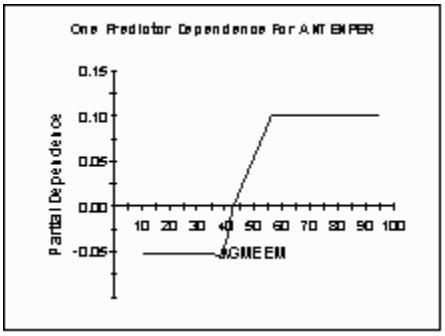


e) GDP (current US$)

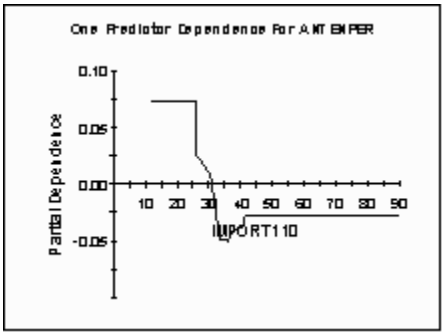
10.3.1.2.2 Antarctic

The top five predictors for the "Antarctic – endangered birds (ANTEN) secondary countries" model were: a) agricultural methane emissions (% of total); b) imports of goods and services (% of GDP); c) permanent cropland (% of land area); d) CO_2 emissions from liquid fuel consumption (% of total); and e) tax payments (number) (Appendix 2a). Partial dependence plots for the five most important predictors of the ANTEN model are presented in figure 20. The relationships shown in the partial dependence plots indicate a negative correlation for permanent cropland (Fig. 20-c) predictor. The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for agricultural methane emissions (Fig. 20-a) and CO_2 emissions from liquid fuel consumption (Fig. 20-d). The effect on the model was higher in the highest values of these predictors. The predictors imports of goods and services (Fig. 20-b) and tax pay (Fig. 20-e) do not show a clear correlation.Japan, Brazil, Peru, as well as Uruguay and Spain had the highest impact on the model.

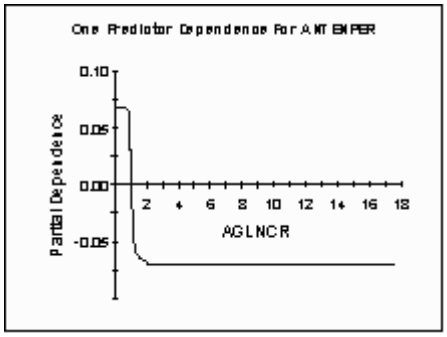
Figure 20: Partial dependence plots for the secondary countries of the ANTEN model.



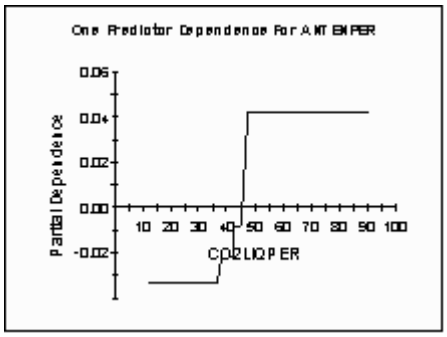
a) Agricultural methane emissions (% of total)



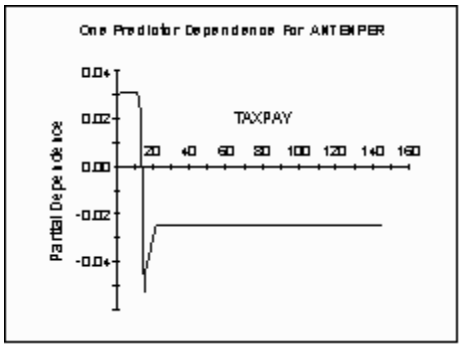
b) Imports of goods and services (% of GDP)



c) Permanent cropland (% of land area)



d) CO_2 emissions from liquid fuel consumption (% of total)

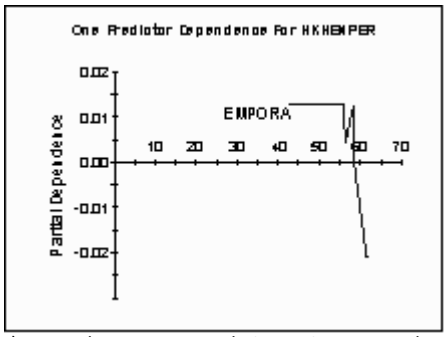


e) Tax payments (number)

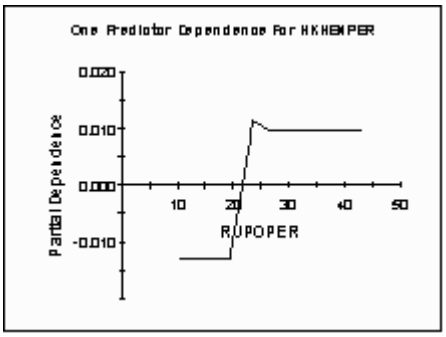
10.3.1.2.3 HKH

The top five predictors for the "Hindu Kush-Himalaya – endangered birds (HKHEN) secondary countries model" were: a) employment to population ratio, 15+, total (%); b) rural population (% of total population); c) gross capital formation (% of GDP); d) industry, value added (% of GDP); and e) CO_2 emissions from liquid fuel consumption (% of total) (Appendix 2a). Partial dependence plots for the five most important predictors of the HKHEN model are presented in figure 21. The relationships shown in the partial dependence plots indicate a positive correlation for rural population (Fig.21-b), gross capital formation (Fig. 21-c) and industry, value added (Fig. 21-d). The effect on the model was higher in the highest values of these predictors. The predictors employment to population ratio (Fig. 21-a) and CO_2 emissions from liquid fuel consumption (Fig. 21-e) do not show a clear relationship. Japan, South Korea, Mongolia and the Russian Federation had the highest impact on the model.

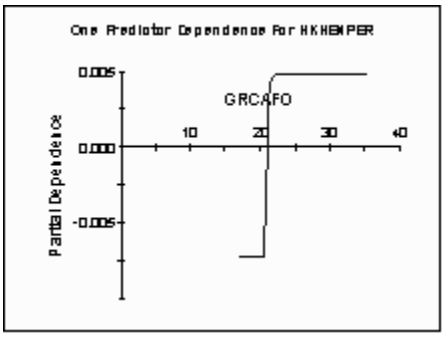
Figure 21: Partial dependence plots for the secondary countries of the HKHEN model.



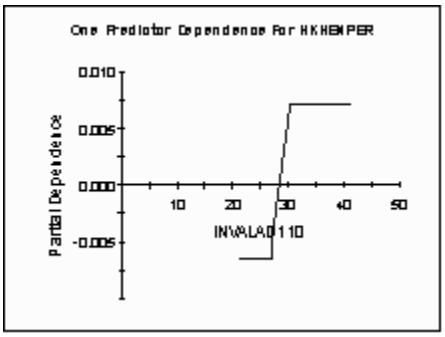
a) Employment to population ratio, 15+, total (%)



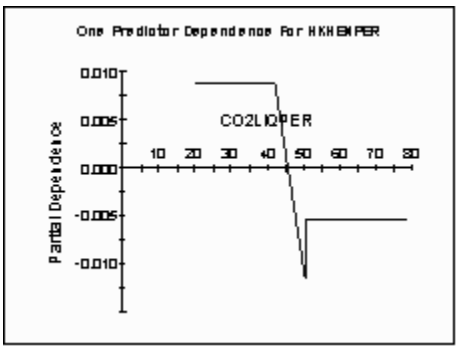
b) Rural population (% of total population)



c) Gross capital formation (% of GDP)



d) Industry, value added (% of GDP)

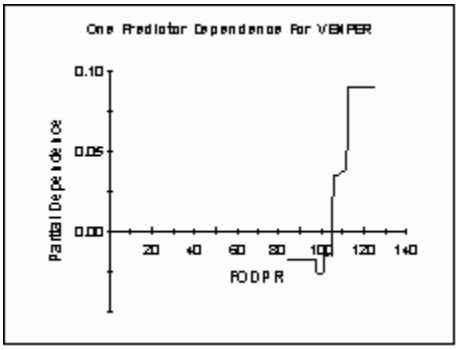


e) CO_2 emissions from liquid fuel consumption (% of total)

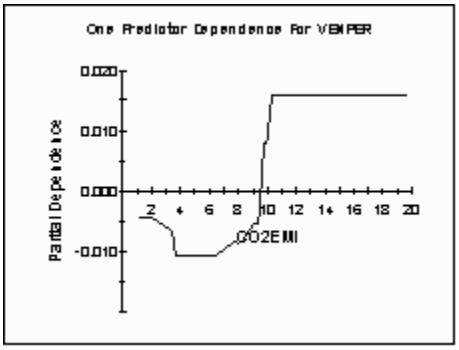
10.3.1.2.4 Three Poles

The top five predictors for the "Three Poles – endangered birds (3PEN) secondary countries" model were: a) Food production index; b) CO_2 emissions (metric tons per capita); c) GDP growth (annual %); d) life expectancy at birth, total (years); and e) agricultural land (% of land area) (Appendix 2a). Partial dependence plots for the 3PEN model for the five most important predictors are presented in figure 22). The relationships shown in the partial dependence plots indicate a negative correlation for predictors GDP growth (Fig. 22-c) and agricultural land (Fig. 22-e). The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for food production index (Fig. 22-a) and life expectancy at birth (Fig. 22-d). The effect on the model was higher in the highest values of these predictors. The predictor CO_2 emissions (Fig. 22-b) does not show a clear direction. Nepal, Norway, Canada, Japan, the U.S. and the Netherlands had the highest impact on the model.

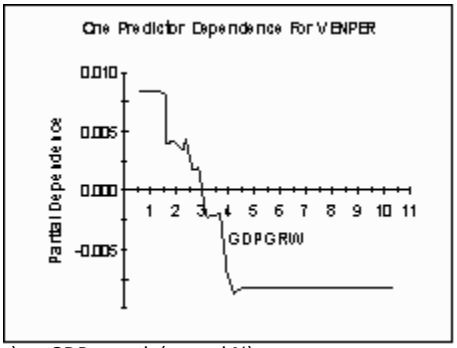
Figure 22: Partial dependence plots for the secondary countries of the 3PEN model.



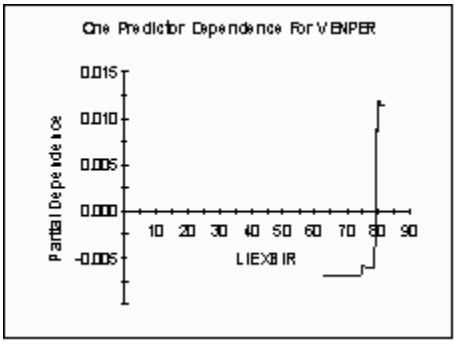
a) Food production index (1999-2001 = 100)



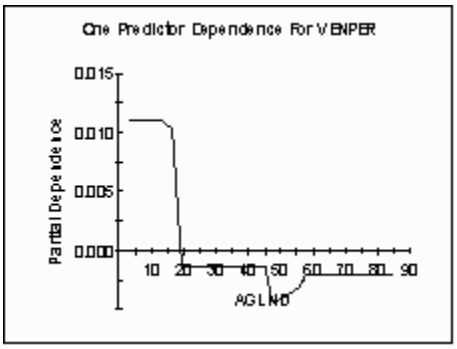
b) CO_2 emissions (metric tons per capita)



c) GDP growth (annual %)



d) Life expectancy at birth, total (years)



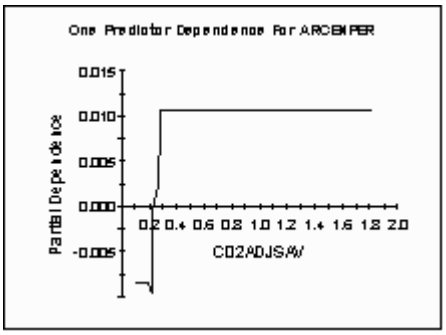
e) Agricultural land (% of land area)

10.3.1.3 Combined models

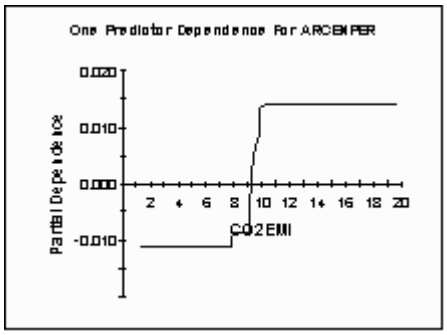
10.3.1.3.1 Arctic

The top five predictors for the "Arctic – endangered birds (ARCEN) – combined (primary + secondary) countries" model were: a) adjusted savings: carbon dioxide damage (current US$); b) CO_2 emissions (metric tons per capita); c) total international migrant stock; d) GDP (current US$); and e) land area ($km^2$) (Appendix 2a). Partial dependence plots for the five most important predictors of the ARCEN model are presented in figure 23. The relationships shown in the partial dependence plots indicate a positive correlation for all predictors in this model (Figs. 23-a, 23-b, 23-c, 23-d and 23-e). The effect on the model was higher in the highest values of these predictors. The U.S., Canada and the Russian Federation had the highest impact on the model.

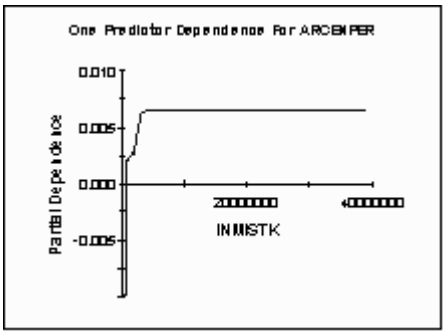
Figure 23: Partial dependence plots for the combined model (primary + secondary countries) of the ARCEN model.



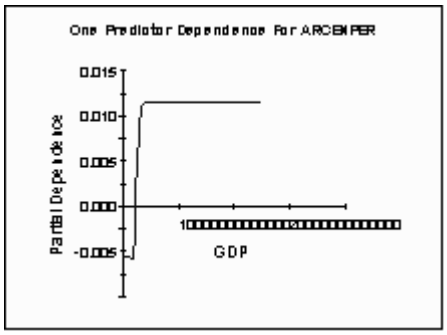
a) Adjusted savings: carbon dioxide damage (current US$)



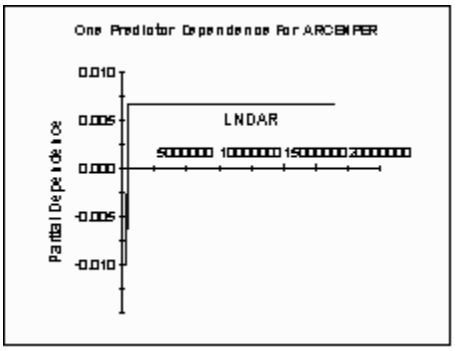
b) CO_2 emissions (metric tons per capita)



c) International migrant stock, total



d) GDP (current US$)

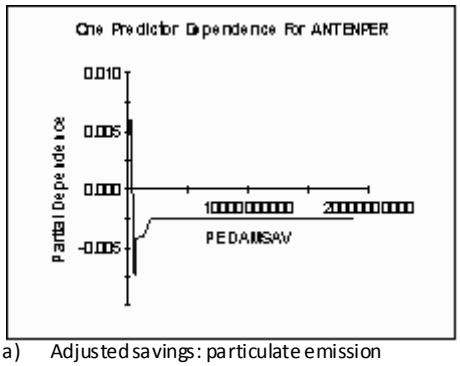


e) Land area (km^2)

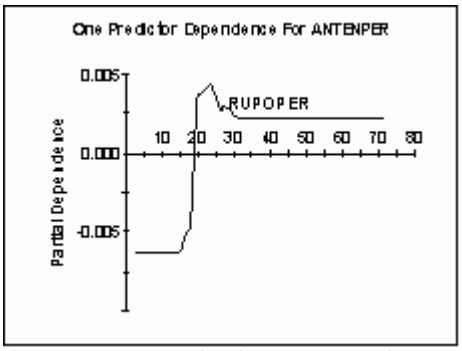
10.3.1.3.2 Antarctic

The top five predictors for the "Antarctic – endangered birds (ANTEN) – combined (primary + secondary) countries model" were: a) adjusted savings: particulate emission damage (current US$); b) rural population (% of total population); c) CO_2 emissions from gaseous fuel consumption (% of total); d) permanent cropland (% of land area); and e) population in the largest city (% of urban population) (Appendix 2a). Partial dependence plots for the five most important predictors of the ANTEN model are presented in figure 24. The relationships shown in the partial dependence plots indicate a negative correlation for CO_2 emissions from gaseous fuel consumption (Fig. 24-c). The effect on the model was higher in the lowest values of the predictor. The predictors adjusted savings: particulate emission damage (24-a), rural population (24-b), permanent cropland (24-d) and population in the largest city (24-e) do not show a clear direction. Norway, France, Bulgaria, South Africa, Czech Republic and Spain had the highest impact on the model.

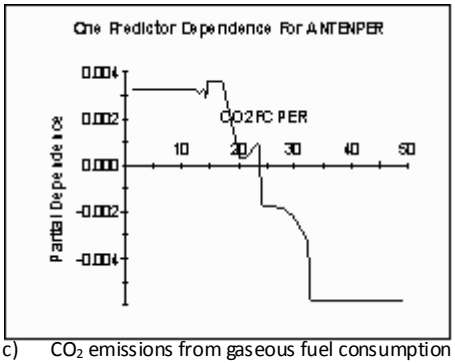
Figure 24: Partial dependence plots for the combined model (primary + secondary countries) of the ANTEN model.



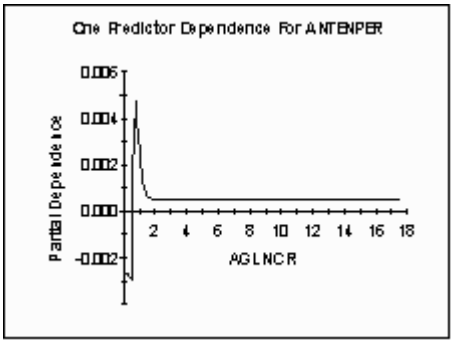
a) Adjusted savings: particulate emission damage (current US$)



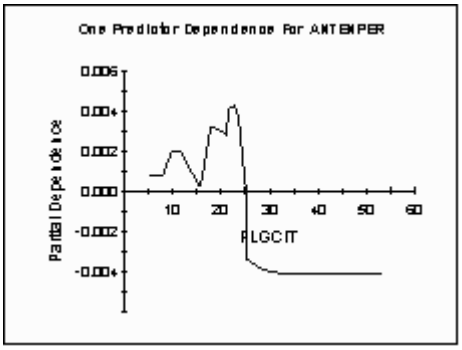
b) Rural population (% of total population)



c) CO_2 emissions from gaseous fuel consumption (% of total)



d) Permanent cropland (% of land area)

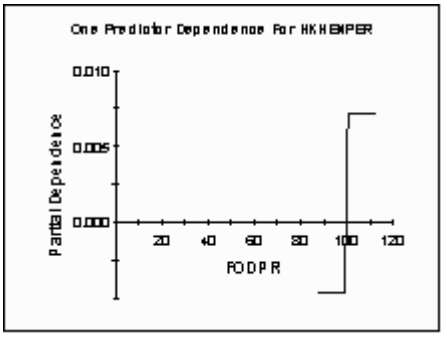


e) Population in the largest city (% of urban population)

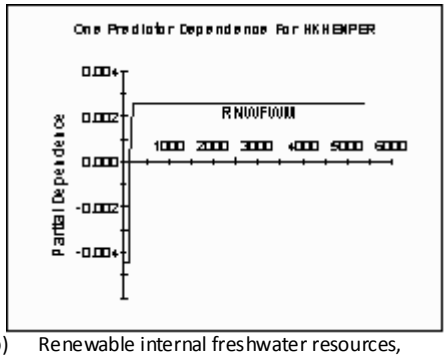
10.3.1.3.3 HKH

The top five predictors for the "Hindu Kush-Himalaya – endangered birds (HKHEN) – combined (primary + secondary) countries" model were: a) food production index; b) renewable internal freshwater resources, total (billion cubic meters); c) school enrollment, primary (% gross); d) pump price for diesel fuel (US$ per liter); and e) land area (km^2) (Appendix 2a). Partial dependence plots for the five most important predictors of the HKHEN model are presented in figure 25. The relationships shown in the partial dependence plots indicate a negative correlation for pump price for diesel fuel (Fig. 25-d) and land area (Fig. 25-e) predictors. The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for food production index (Fig. 25-a), renewable internal freshwater resources (Fig. 25-b) and school enrollment, primary (Fig. 25-c). The effect on the model was higher in the highest values of these predictors. India, Australia, the Russian Federation and Myanmar had the highest impact on the model.

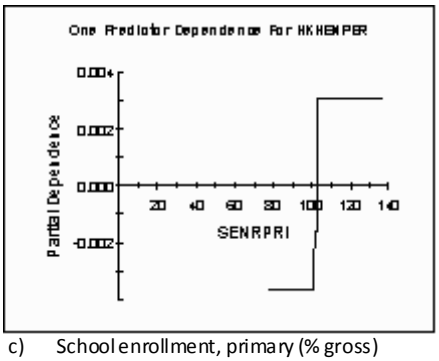
Figure 25: Partial dependence plots for the combined model (primary + secondary countries) of the HKHEN model.



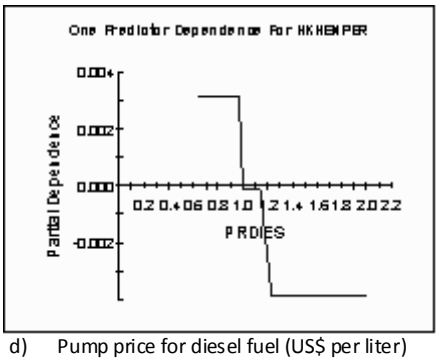
a) Food production index (1999-2001 = 100)



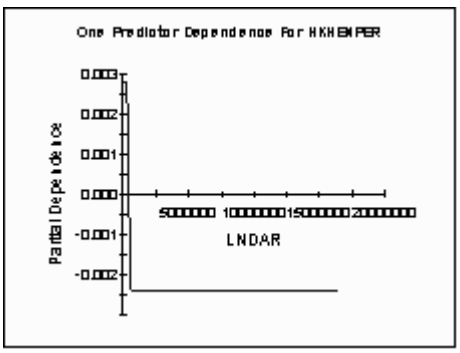
b) Renewable internal freshwater resources, total (billion cubic meters)



c) School enrollment, primary (% gross)



d) Pump price for diesel fuel (US$ per liter)

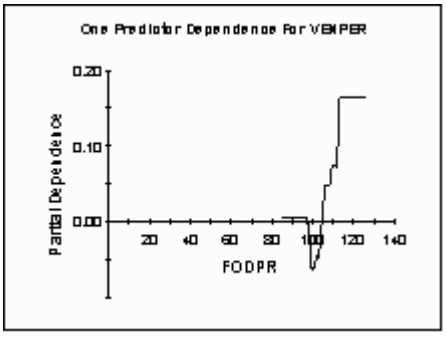


e) Land area (km^2)

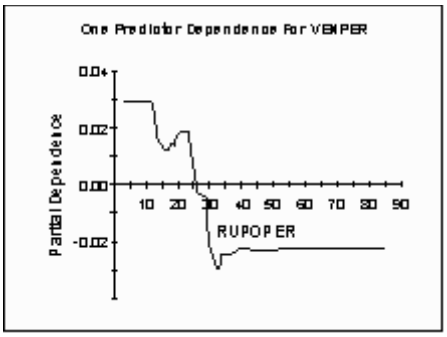
10.3.1.3.4 Three Poles

The top five predictors for the "Three Poles – endangered (3PEN) - combined (primary + secondary) countries" model were: a) food production index; b) rural population (% of total population); c) CO_2 emissions (metric tons per capita); d) GDP growth (annual %); and e) livestock production index (Appendix 2a). Partial dependence plots for the five most important predictors of the 3PEN model are presented in figure 26. The relationships shown in the partial dependence plots indicate a negative correlation for rural population (Fig. 26-b) and GDP growth (Fig. 26-d) predictors. The effect on the model was higher in the lowest values of the predictor. The predictors food production index (Fig. 26-a), CO_2 emissions (Fig. 26-c) and livestock production index (Fig. 26-6) do not show a clear direction. UK, the U.S., Canada, New Zealand and Germany had the highest impact on the model.

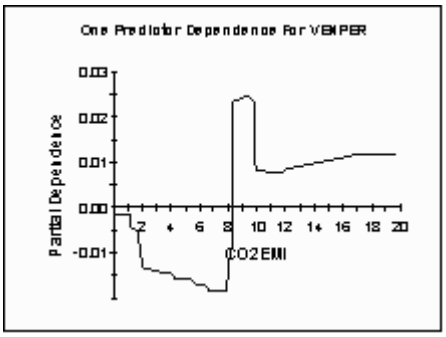
Figure 26: Partial dependence plots for the combined model (primary + secondary countries) of the 3PEN model.



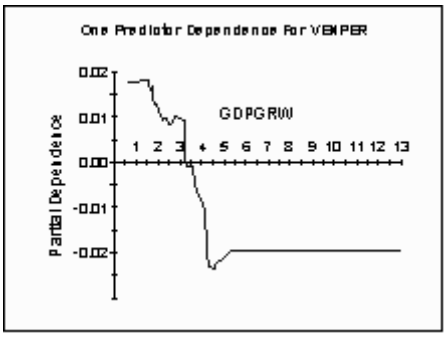
a) Food production index (1999-2001 = 100)



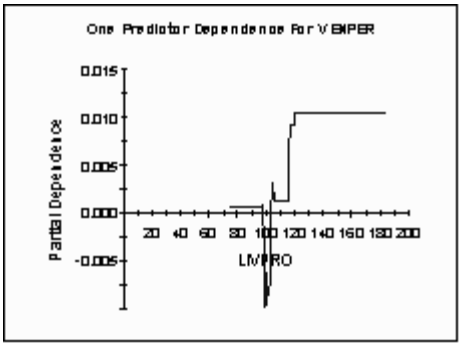
b) Rural population (% of total population)



c) CO_2 emissions (metric tons per capita)



d) GDP growth (annual %)



e) Livestock production index (1999-2001 = 100)

10.3.2 Model LCD

For the model least concern decreasing birds (LCD) the predictor with the highest contribution to the model was food production. Other predictors were GDP, GDP growth, agriculture land, forested area and international migration stock.

10.3.2.1 Primary countries models

10.3.2.1.1 Arctic

The top five predictors for the "Arctic – endangered birds (ARCLCD) – primary countries" model (Appendix 2b) were: a) livestock production index; b) total international migrant stock, total; c) agricultural land (% of land area); d) GDP (current US$); and e) adjusted savings: carbon dioxide damage (current US$). No partial dependence plots were created for the ARCLCD model (for details see seccion 9.2.2).

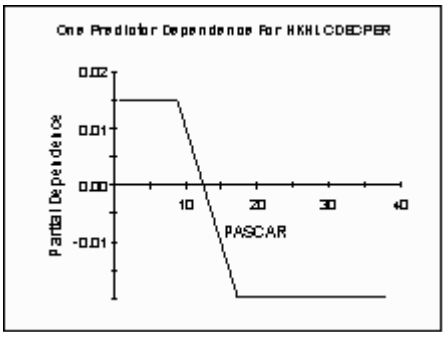
10.3.2.1.2 Antarctic

The top five predictors for the ANTLCD primary countries model (Appendix 2b) were: a) renewable internal freshwater resources, total (billion cubic meters); b) population in the largest city (% of urban population), total; c) adjusted savings: carbon dioxide damage (current US$); d) rural population; and e) gross capital formation (% of GDP). No partial dependence plots were created for the ANTLCD mode (for details see seccion 9.2.2).

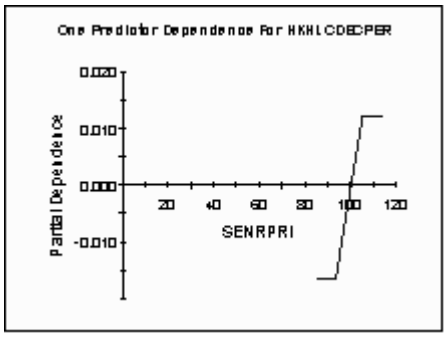
10.3.2.1.3 HKH

The top five predictors for the "Hindu Kush-Himalaya – least concern decreasing bird species (HKHLCD) primary countries" model were: a) passenger cars (per 1,000 people); b) school enrollment, primary (% gross); c) forest area (% of land area); d) CO_2 emissions from solid fuel consumption (kt); and e) school enrollment, secondary (% gross) (Appendix 2b). Partial dependence plots for the five most important predictors of the HKHLCD model are presented in figure 27. The relationships shown in the partial dependence plots indicate a negative correlation for passenger cars (Fig. 27-a) and CO_2 emissions from solid fuel consumption (Fig. 27-d) predictors. The effect on the models was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for school enrollment, primary (Fig. 27-b), forest area (Fig. 27-c) and school enrollment, secondary (Fig. 27-e) predictors. The effect on the models was higher in the highest values of these predictors. Bangladesh, India and Nepal had the highest impact on the model.

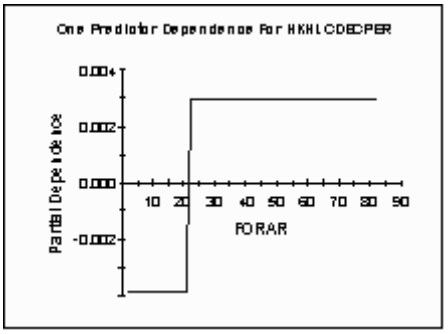
Figure 27: Partial dependence plots for the primary countries of the HKHLCD model.



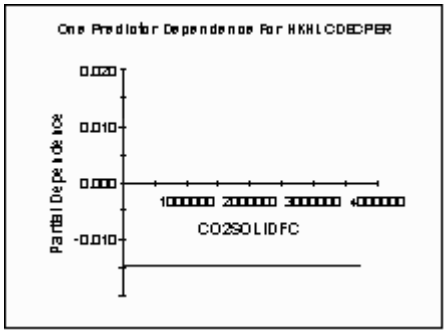
a) Passenger cars (per 1,000 people)



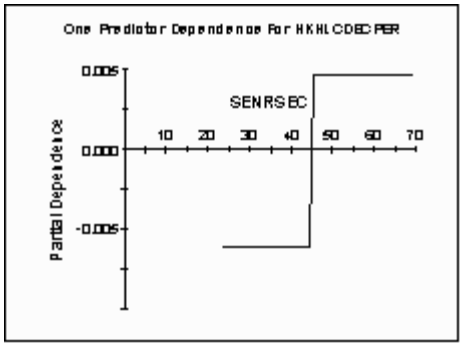
b) School enrollment, primary (% gross)



c) Forest area (% of land area)



d) CO_2 emissions from solid fuel consumption (kt)

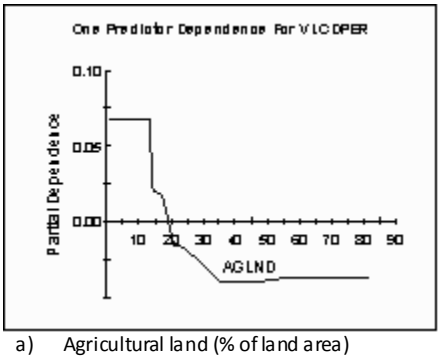


e) School enrollment, secondary (% gross)

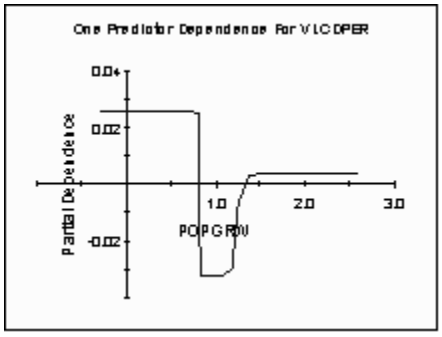
10.3.2.1.4 Three Poles

The top five predictors for the "Three Poles – least concern decreasing bird species (3PLCD) primary countries" model were: a) agricultural land (% of land area); b) population growth (annual %); c) food production index; d) GEF benefits index for biodiversity; and e) GDP growth (annual %) (Appendix 2b). Partial dependence plots for the five most important predictors of the 3PLCD model are presented in figure 28. The relationships shown in the partial dependence plots indicate a negative correlation for agricultural land predictor (Fig. 28-a). The effect on the model was higher in the lowest values of the predictor. Predictors that do not show a clear direction were: population growth (Fig. 28-b), food production index (Fig. 28-c), GEF benefits index for biodiversity (Fig. 28-d) and GDP growth (Fig. 28-e). Greenland, Finland, Sweden and Norway had the highest impact on the model.

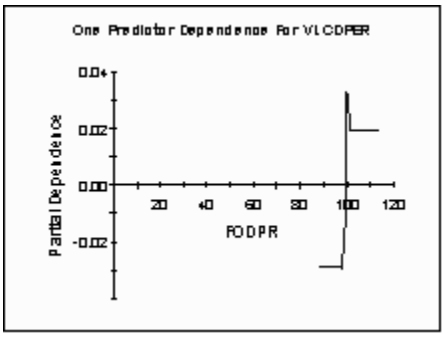
Figure 28: Partial dependence plots for the primary countries of the 3PLCD model.



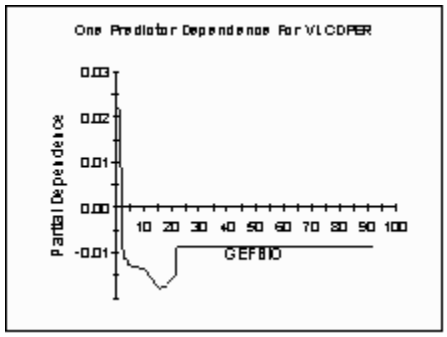
a) Agricultural land (% of land area)



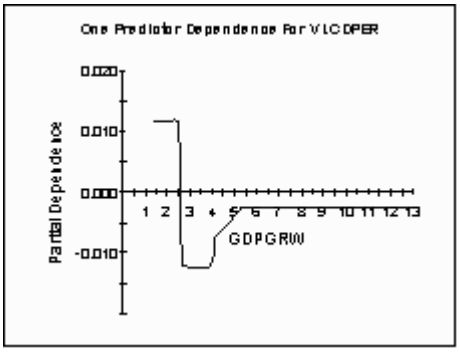
b) Population growth (annual %) area)



c) Food production index (1999-2001 = 100)



d) GEF benefits index for biodiversity (0 = no biodiversity potential to 100 = maximum)



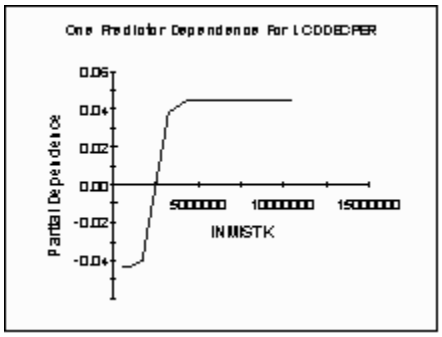
e) GDP growth (annual %)

10.3.2.2 Secondary countries model

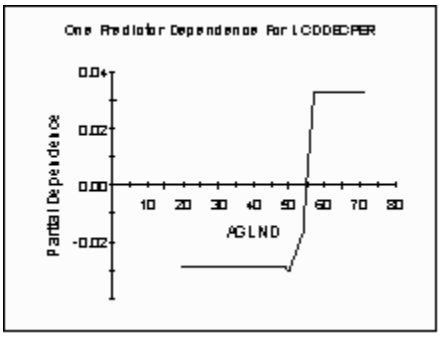
10.3.2.2.1 Arctic

The top five predictors for the "Arctic – least concern decreasing bird species (ARCLCD) secondary countries" model (Appendix 2b) were: a) total international migrant stock; b) agricultural land (% of land area); c) population, total; d) life expectancy at birth, total (years); and e) death rate, crude (per 1,000 people). Partial dependence plots for the five most important predictors of the ARCLCD model are presented in figure 29. The relationships shown in the partial dependence plots indicate a negative correlation for the predictor total population (Fig. 29-c). The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for international migrant stock (Fig. 29-a), agricultural land (Fig. 29-b) and life expectancy at birth (Fig. 29-d). The effect on the model was higher in the highest values of these predictors. The predictor crude death rate (Fig. 29-e) does not show a clear direction. UK, France and Spain had the highest impact on the model.

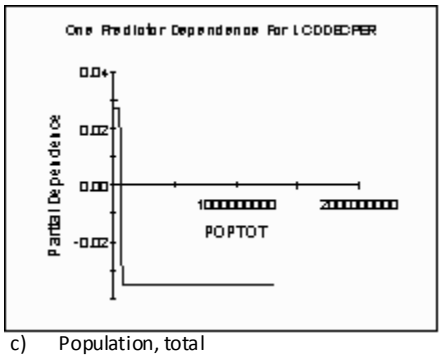
Figure 29: Partial dependence plots for the secondary countries of the ARCLCD model.



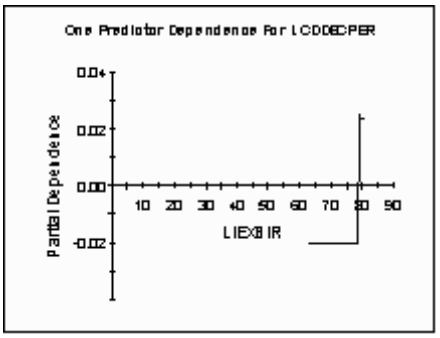
a) International migrant stock, total



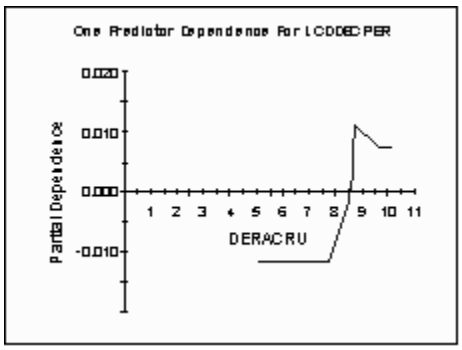
b) Agricultural land (% of land area)



c) Population, total



d) Life expectancy at birth, total (years)

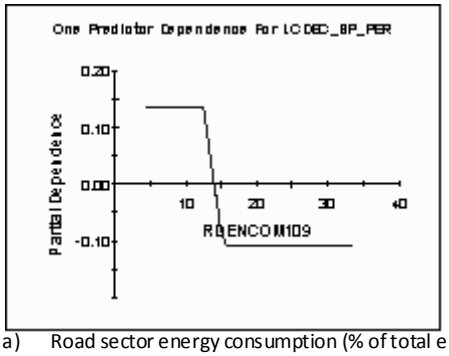


e) Death rate, crude (per 1,000 people)

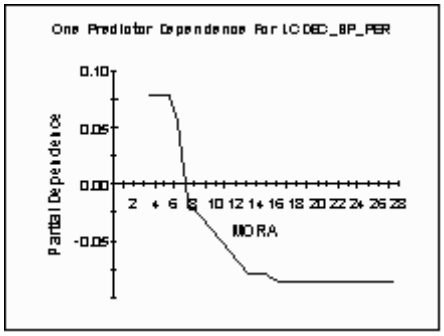
10.3.2.2.2 Antarctic

The top five predictors for the "Antarctic – least concern decreasing bird species (ANTLCD) secondary countries" model were: a) road sector energy consumption (% of total energy consumption); b) mortality rate, under-5 (per 1,000); c) other greenhouse gas emissions, HFC, PFC and SF6 (thousand metric tons of CO_2 equivalent); d) GDP (current US$); and e) total reserves (includes gold, current US$) (Appendix 2b). Partial dependence plots for the five most important predictors of the ANTLCD model are presented in figure 30. The relationships shown in the partial dependence plots indicate a negative correlation for road sector energy consumption (Fig. 20-a) and mortality rate (Fig 30-b) predictors. The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for other greenhouse gas emissions (Fig. 30-c), GDP (Fig. 30-d) and total reserves (Fig. 30-e) predictors. The effect on the model was higher in the highest values of these predictors. Germany, India, South Korea, Russian Federation, the U.S., Japan and China had the highest impact on the model.

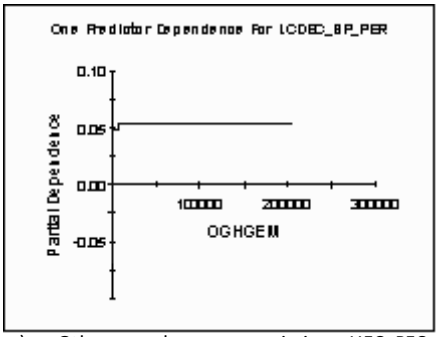
Figure 30: Partial dependence plots for the secondary countries of the ANTLCD model.



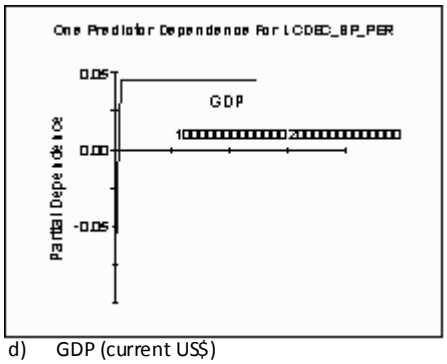
a) Road sector energy consumption (% of total energy consumption)



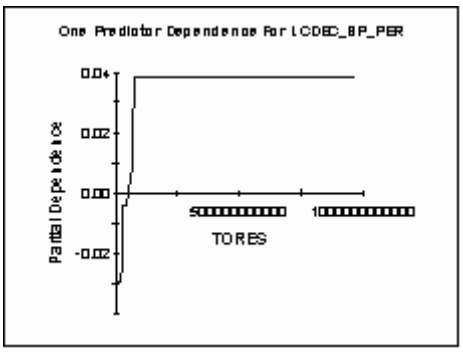
b) Mortality rate, under-5 (per 1,000)



c) Other greenhouse gas emissions, HFC, PFC and SF6 (thousand metric tons of CO_2 equivalent)



d) GDP (current US$)

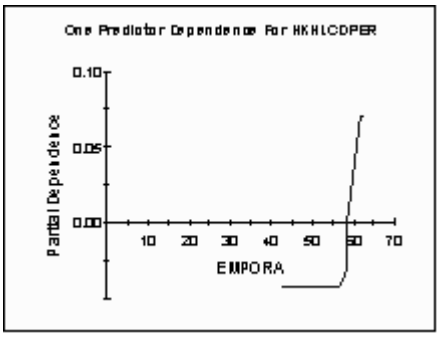


e) Total reserves (includes gold, current US$)

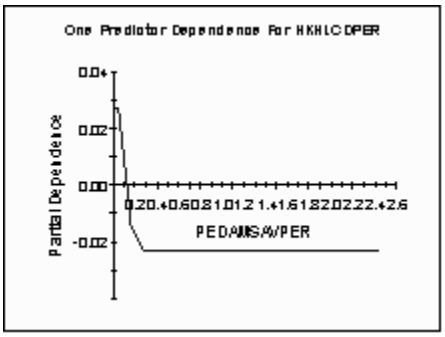
10.3.2.2.3 HKH

The top five predictors for the "Hindu Kush-Himalaya – least concern decreasing bird species (HKHLCD) secondary countries" model were: a) employment to population ratio, 15+, total (%); b) adjusted savings: particulate emission damage (%); c) gross capital formation (% of GDP); d) industry, value added (% of GDP); and e) inflation, GDP deflator (annual %) (Appendix 2b). Partial dependence plots for the five most important predictors of the HKHLCD model are presented in figure 31. The relationships shown in the partial dependence plots indicate a negative correlation for adjusted savings: particulate emission damage (Fig. 31-b), gross capital formation (Fig. 31-c), industry value added (Fig. 31-d) and inflation GDP deflator (Fig. 31-e). The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for the predictor employment to population ratio, 15+, total (Fig. 31-a). The effect on the model was higher in the highest values of these predictors. Switzerland, France, the U.S. and Italy had the highest impact on the model.

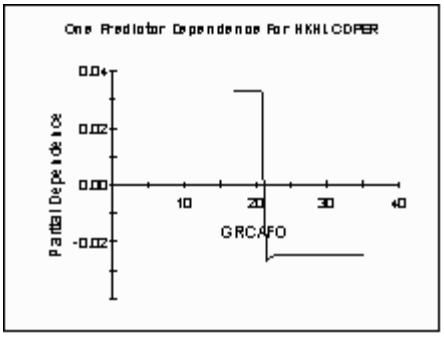
Figure 31: Partial dependence plots for the secondary countries of the HKHLCD model.



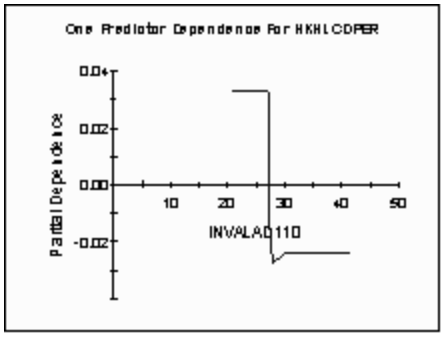
a) Employment to population ratio, 15+, total (%)



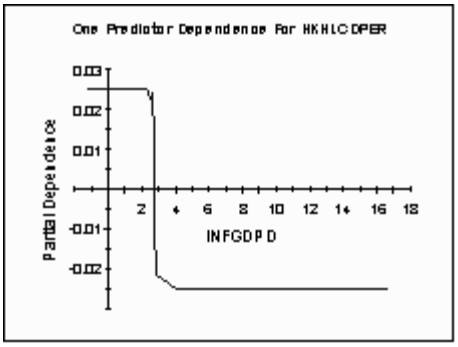
b) Adjusted savings: particulate emission damage (%)



c) Gross capital formation (% of GDP)



d) Industry, value added (% of GDP)

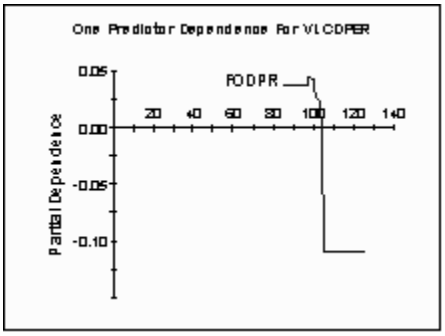


e) Inflation, GDP deflator (annual %)

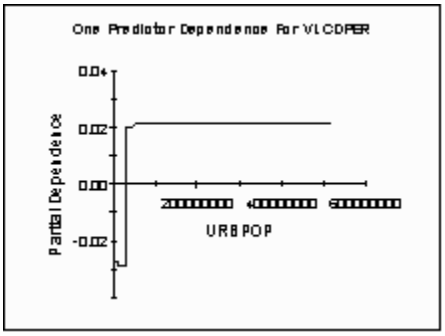
10.3.2.2.4 Three Poles

The top five predictors for the "Three Poles – least concern decreasing bird species (3PLCD) secondary countries" model were: a) food production index; b) urban population; c) GDP growth (annual %); d) forest area (% of land area); and e) population, total (Appendix 2b). Partial dependence plots for the five most important predictors of the 3PLCD model are presented in figure 32. The relationships shown in the partial dependence plots indicate a negative correlation for the predictor food production index (Fig. 32-a). The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for the predictor urban population (Fig. 32-b). The effect on the model was higher in the highest values of these predictors. Predictors that do not show a clear direction were: GDP growth (Fig. 32-c), forest area (Fig. 32-d) and total population (Fig. 32-e). China, India, the U.S., Brazil, the Russian Federation and Japan had the highest impact on the model.

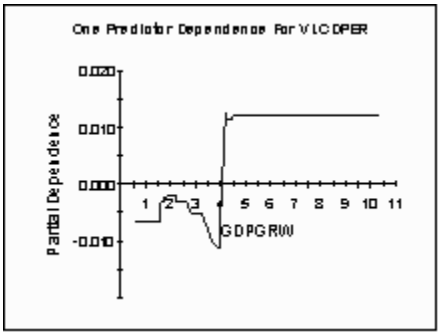
Figure 32: Partial dependence plots for the secondary countries of the 3PLCD model.



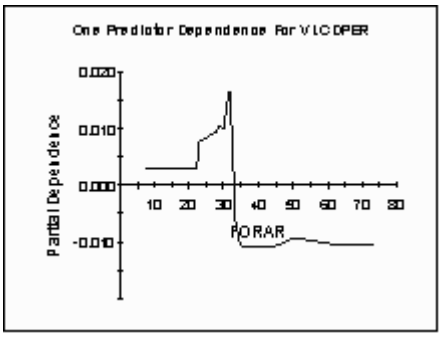
a) Food production index (1999-2001 = 100)



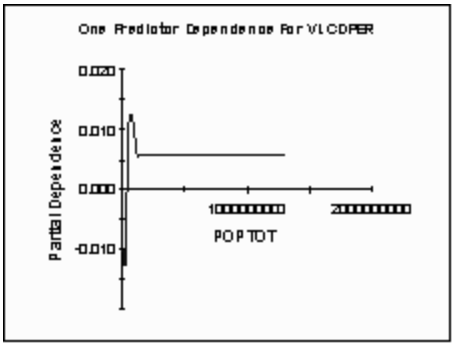
b) Urban population



c) GDP growth (anual)



d) Forest area (% of land area)



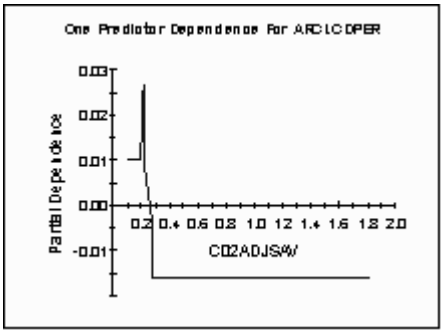
e) Population, total

10.3.2.3 Combined model

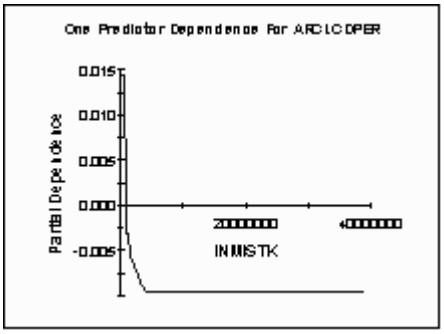
10.3.2.3.1 Arctic

The top five predictors for the "Arctic – least concern decreasing bird species (ARCLCD) combined (primary + secondary) countries" model were: a) adjusted savings: carbon dioxide damage (current US$); b) total international migrant stock; c) land area (km^2); d) GDP (current US$); and e) CO_2 emissions (metric tons per capita) (Appendix 2b). Partial dependence plots for the five most important predictors of the ARCLCD model are presented in figure 33. The relationships shown in the partial dependence plots indicate a negative correlation for total international migrant stock (Fig. 33-b), land area (Fig. 33-c), GDP (Fig. 33-d), and CO_2 emissions (Fig. 33-e). The predictor adjusted savings: carbon dioxide damage does not show a clear direction (Fig. 33-a). Sweden, Iceland and Greenland had the highest impact on the model.

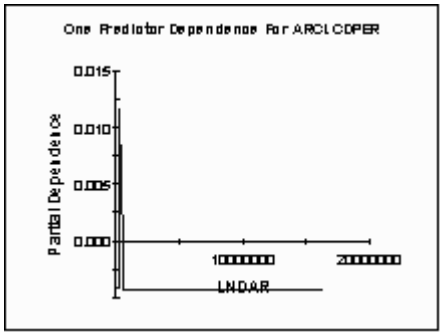
Figure 33: Partial dependence plots for the combined model (primary + secondary countries) of the ARCLCD model.



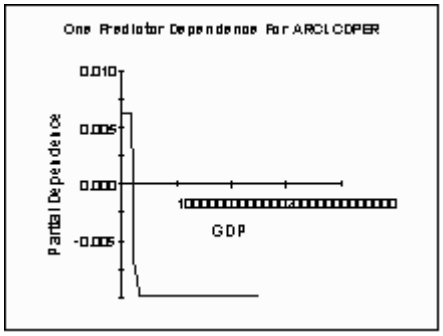
a) Adjusted savings: carbon dioxide damage (current US$)



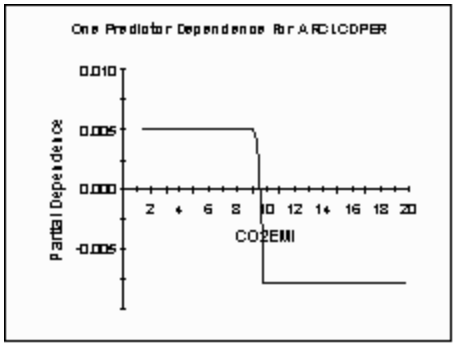
b) International migrant stock, total



c) Land area (km^2)



d) GDP (current US$)

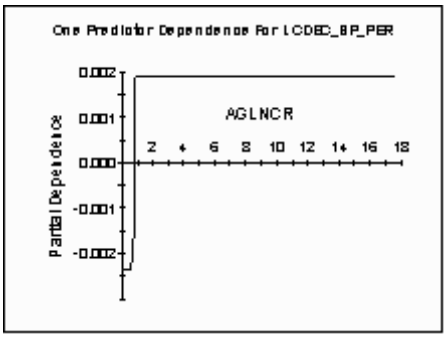


e) CO_2 emissions (metric tons per capita)

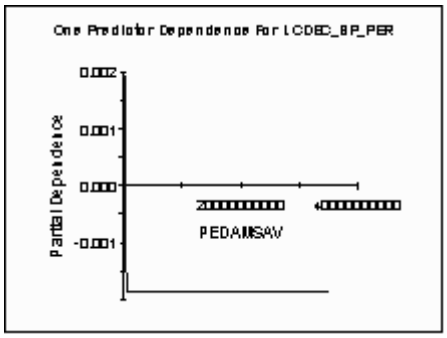
10.3.2.3.2 Antarctic

The top five predictors for the "Antarctic – least concern decreasing bird species (ANTLCD) combined (primary + secondary) countries" model (Appendix 2b) were: a) permanent cropland (% of land area); b) adjusted savings: particulate emission damage (current US$); c) birth rate, crude (per 1,000 people); d) CO_2 emissions from gaseous fuel consumption (% of total); and e) rural population (% of total population). Partial dependence plots for the five most important predictors of the ANTLCD model are presented in figure 34. The relationships shown in the partial dependence plots indicate a negative correlation for adjusted savings: particulate emission damage (Fig. 34-b), crude birth rate (Fig. 34-c) and CO_2 emissions from gaseous fuel consumption (Fig. 34-c) predictors. The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for permanent cropland (Fig. 34-a) and rural population (Fig. 34-e). The effect on the model was higher in the highest values of these predictors. China, Romania, South Africa, Poland, Finland, Ecuador, Ukraine, Bulgaria, Peru, Czech Republic, France, Spain and Australia had the highest impact on the model.

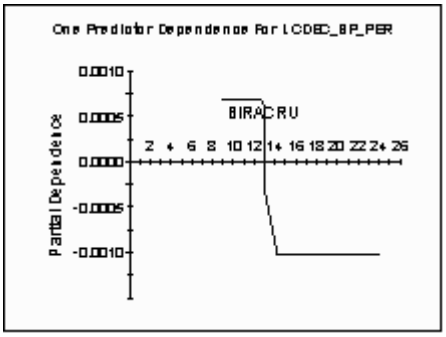
Figure 34: Partial dependence plots for the combined model (primary + secondary countries) of the ANTLCD model.



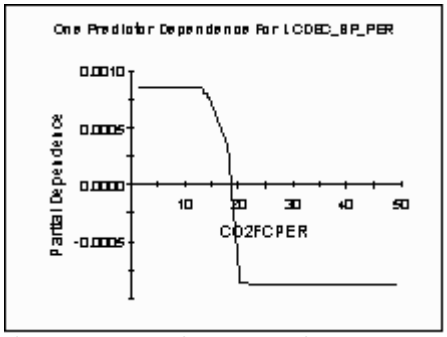
a) Permanent cropland (% of land area)



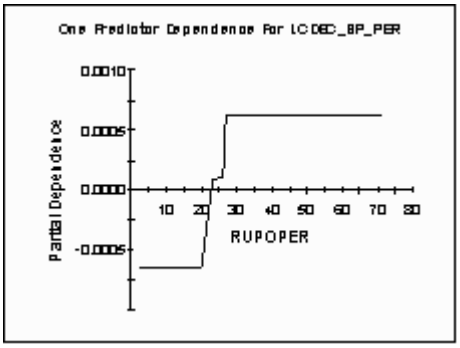
b) Adjusted savings: particulate emission damage



c) Birth rate, crude (per 1,000 people)



d) CO_2 emissions from gaseous fuel consumption (% of total)

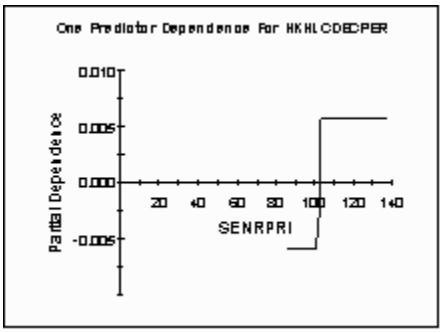


e) Rural population (% of total population)

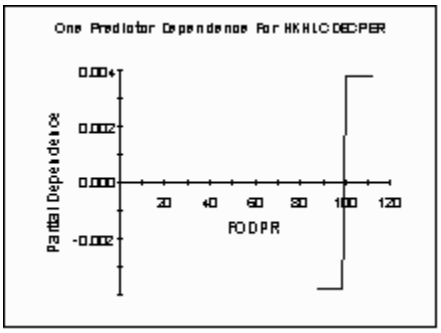
10.3.2.3.3 Hindu – Kush Himalaya (HKH)

The top five predictors for the "Hindu Kush Himalaya – least concern bird species (HKHLCD) combined (primary + secondary) countries" model were: a) school enrollment, primary (% gross); b) food production index; c) renewable internal freshwater resources, total (billion cubic meters); d) renewable internal freshwater resources per capita (cubic meters); and e) pump price for diesel fuel (US$ per liter) (Appendix 2b). Partial dependence plots for the five most important predictors of the HKHLCD are presented in figure 35. The relationships shown in the partial dependence plots indicate a negative correlation for pump price for diesel fuel predictor (Fig. 35-e). The effect on the model was higher in the lowest values of the predictor. On the contrary, a positive correlation was found for enrollment, primary (Fig. 35-a), food production index (Fig. 35-b), renewable internal freshwater resources (Fig. 35-c) renewable internal freshwater resources per capita (Fig. 35-d). The effect on the model was higher in the highest values of these predictors. The U.S., Australia, the Russian Federation, Myanmar and India had the highest impact on the model.

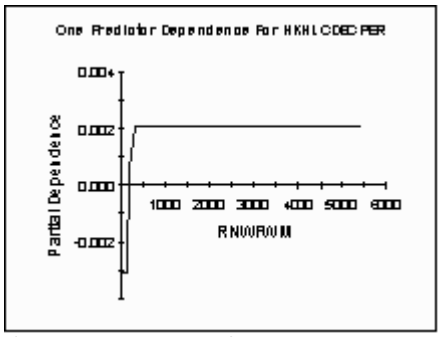
Figure 35: Partial dependence plots for the combined model (primary + secondary countries) of the HKHLCD model.



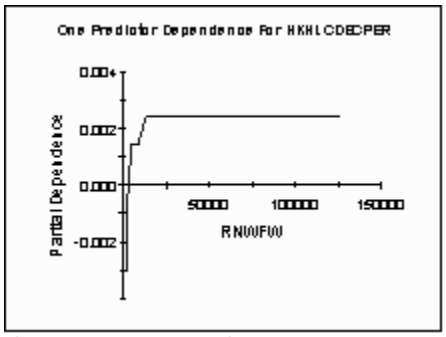
a) School enrollment, primary (% gross)



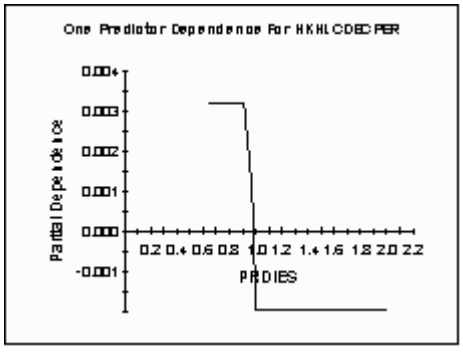
b) Food production index (1999-2001 = 100)



c) Renewable internal freshwater resources, total (billion cubic meters)



d) Renewable internal freshwater resources per capita (cubic meters)

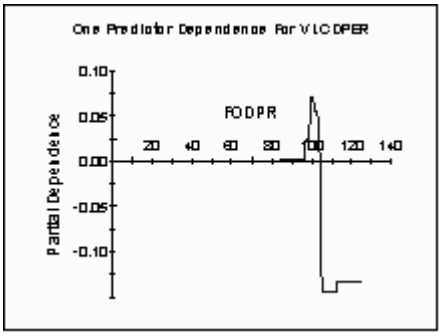


e) Pump price for diesel fuel (US$ per liter)

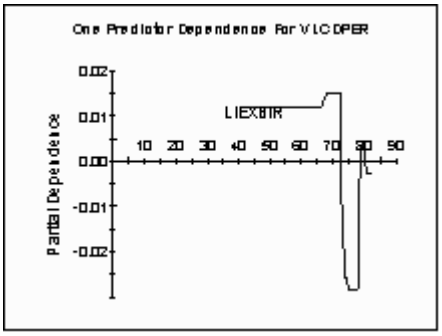
10.3.2.3.4 Three Poles

The top five predictors for the "Three Poles - least concern decreasing birds (3PLCD) – combined (primary + secondary) countries" model were: a) food production index; b) life expectancy at birth, total (years); c) inflation, GDP deflator (annual %); d) forest area (% of land area); and e) GDP growth (annual %) (Appendix 2b). Partial dependence plots for the five most important predictors of the 3PLCD model are presented in figure 36. The relationships shown in the partial dependence plots indicate a negative correlation for the predictor inflation GDP deflator (Fig. 36-c). The effect on the model was higher in the lowest values of the predictor. Predictors that do not show a clear direction were: life expectancy at birth, total (Fig. 36-b), inflation GDP deflator (Fig. 36-c), forest area (Fig. 36-d) and GDP growth (Fig. 36-e). China, Nepal, Poland, New Zealand, Canada had the highest impact on the model response.

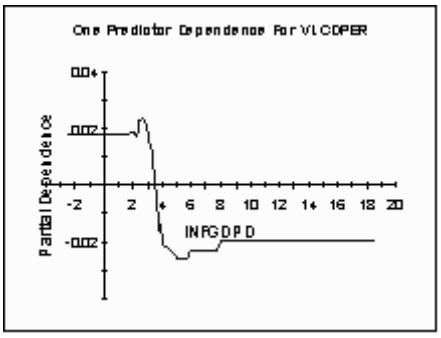
Figure 36: Partial dependence plots for the combined model (primary + secondary countries) of the 3PLCD model.



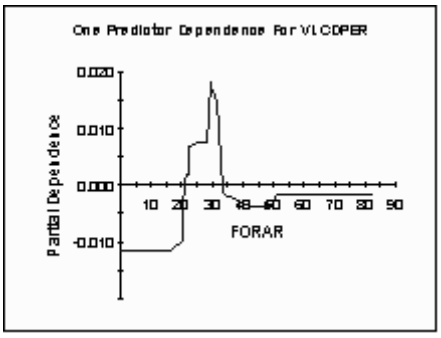
a) Food production index (1999-2001 = 100)



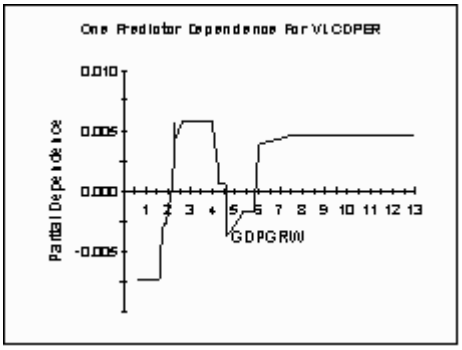
b) Life expectancy at birth, total (years)



c) Inflation, GDP deflator (annual %)



d) Forest area (% of land area)



e) GDP growth (annual %)

11. Discussion

This study was carried out in order to evaluate the effect of socioeconomic factors (The World Bank 2012a) on bird populations which are declining in the Three Poles regions. The results showed the expected and high contribution of the factors CO_2 emissions, GDP and GDP growth on declining bird populations. Here I will talk about data quality and present the main findings and discussion of results.

11.1 Data quality

The results obtained and described here are based on the best available data and processed by best-known techniques to handle them. However, data quality has to be discussed for predictors and response variables. The data provided by BirdLife and Nature Serve (2012) includes a high uncertainty regarding bird distribution. Moreover, spatial data used in GIS analyses bring along some difficulties such as different pixel sizes and extent of the covered area. Some maps are well defined and detailed, whereas some others are represented rather as simple features. One of the main uncertainties is the status of some of the bird species. There is a lack of data and research for many of these species (IUCN 2012).

The World Bank (2012a) data has many gaps. Therefore it was not possible to use all the predictors in the dataset that may have been important for the analysis. Due to gaps in the database from The World Bank Data (2012a) (Myanmar and Afghanistan for the HKH, and Greenland and Iceland for the Arctic), it was only possible to use 97 predictors (see Appendix 3). Nonetheless, the amount of predictors used for each pole was even less (33 for the Arctic, 94 for the Antarctic and 27 for the HKH). Data quality has the potential to affect model performance severely. Especially in cases where models do not show a clear link and are dependent on the best possible data available. Therefore, I want to advocate towards an increasing quality of spatial data and data procedures for collecting these.

11.2 Discussing the data, models and analysis

Due to gaps in the data from The World Bank (2012a), important predictors considered for this work, such as GDP per capita, could not be used to perform the analyses. The data used however, included several predictors related to economic activities and emissions, including GDP and GDP growth (see Appendix 3), and were sufficient to provide a good overview of the global economy. The species maps (BirdLife and Nature Serve 2012) provided a good sample of the bird biodiversity at the Three Poles. Togheter, these data is the best socioeconomic and environmental information available for birds of the Three Poles.

According to the gains charts (table 6, Appendix 4), model performance was good for the Three Poles models and secondary countries. Model performance was fair enough for primary countries and the combined (primary + secondary countries) model. For primary countries, the sample size was too small with only 8 records. In classic statistics such data would not be able to be analyzed and due to the degrees of freedom problem. Therefore it was necessary to run an additional classified analysis in Random Forest to assess the top five predictors. Random Forests has the capacity to analyze small datasets of this nature (https://www.salfordsystems.com/en/products/randomforests/overview).

Primary nations are the countries that are directly linked with the poles. Results from their analysis should be the strongest due to inference on causation, but they are weak in sample size. The secondary nations are not directly linked in space with the poles, but show correlations and as a group; they have a higher sample size which is most likely the reason for better model performance. The combined set is an approach to find and confirm general trends, and with statistical interactions. This set is a mix of data quality but has the highest sample size.

11.2.1 Countries contribution and models

Primary country models for the Arctic and Antarctic had only eight records, which was not enough to perform the analysis in Treenet®. A different analysis using Random Forests® was needed to identify the most important predictors for these models. A conglomerate of countries are driving the models, however some countries showed higher impact thoughout all models.

The contribution of the different countries was clear in most cases. The countries having the most impact on the models in this study are also the great emitters of CO_2 globally (Baumert et al. 2004). China for example is contributing very much to the "Three Poles, least concern decreasing (LCD) model". The U.S., Canada and UK showed a high contribution to the endangered birds (EN) model. A combination of different countries was contributing to the Arctic models. This may be related to the fact that global changes are affecting the Arctic more than any other region (Root et al. 2003, IPCC 2007, Parmesan 2007, Rosenzweig 2008, Walsh 2008, Serreze et al. 2010). Therefore, a global contribution without a specific trend is present in the Arctic models.
A higher amount of countries showed a contribution to the Antarctic models (e.g. Japan, Brazil, Peru, France, South Africa, Spain, Germany, India and South Korea). This may be related to the fact that many countries are affecting Antarctic ecosystems. The country that had an important contribution to all the Antarctic models was China. The HKH endangered (EN) birds and least concern decreasing birds (LCD) models showed that the countries with the highest contribution to the models were India and Myanmar. Japan showed also high contribution in several models, especially as a secondary country (e.g. the endangered response variable for all secondary countries models, as well as the least concern decreasing response variable for the Antarctic and Three Poles secondary countries models).

China as a primary country did not show an important contribution for the "Hindu Kush-Himalaya – endangered birds" (HKHEN) and the "Hindu Kush-Himalaya – least concern decreasing birds" (HKHLCD) models. This might be due to time, which the data in this study covers: 2000-2010. A more complete historical context might be needed to capture this complex process. Historically, China has been polluting and affecting its environment heavily. Recently, China started to exploit Tibetan resources in the HKH pole for example. On the other hand, China had an important contribution as secondary country to the Arctic and Antarctic pole and the combination of the Three Poles. Due to its new won economical power, issues in China are moreover affecting the whole world now. During the last decades or even centuries, China has polluted the environment. Currently China demands resources from other countries. China's main commercial partners are also Three Poles primary and secondary countries (Japan, South Korea, Germany and Australia) (CIA 2012).

The results of this work have global implications and are complex. While the detailed mechanisms are far from fully understood, the correlations shown here are very important to understand that resource use and GDP promotion stand in the way of bird population maintenance. Looking at the drivers of the bird extinction models here and on a large scale they support the hypothesis of this

study very well and the overall goal of this study to show socioeconomical effects on birds at the Three Poles. The perfect model that predicts biodiversity loss does not exist yet however (Holland et al. 2009).

Predictions from the Three Poles (3P) models showed the highest variation and usually it was not possible to define a clear positive or negative relationship. Regarding individual predictors, the general trend was a positive relationship for almost all important predictors (~"the bigger the predictors the more serious the bird endangerment"). The food production index showed a general positive relationship. It covers food crops that are considered edible and therefore is closely related to agriculture and land use change (habitat loss). This trend was present in the HKH models and Three Poles (3P) secondary countries.

Rural population shows a positive relationship in secondary countries and for the combined models. The higher the rural population the higher the effect on the model. Nonetheless, the global trend is a decrease of the rural population (The World Bank 2012) and population is moving to urban areas, where demand of resources increases with more negative consequences such as deforestation and higher GHG emissions. Many secondary countries and other emerging economies still have a high population in poor, rural areas and base their economies on agriculture and natural resource exploitation (CIA 2012, The World Bank 2012). The major negative effect on bird populations may not come directly from local people, but from the human footprint and deforestation due to economic growth (e.g. industrial plantations). Income and deforestation are closely related in emerging economies which are secondary countries, (Culas 2007) and consequences are also global, such as GHG emissions, that may reach the Three Poles affecting bird populations.

Agriculture land shows a negative relationship in the Three Poles secondary countries, the HKH combined models and the Three Poles primary countries model. This predictor also shows a positive relationship in the Three Poles primary and Arctic secondary countries model. This would suggest that an increase in the demand for commodities and the increase in deforestation to plant temporary crops, triggers a negative effect on the bird species at the Three Poles.

GDP shows a positive relationship for endangered birds (EN) in the Arctic and the Three Poles (3P) models. The higher the GDP, the higher the effect on the model. This may be related to the fact that Arctic economies are massively extracting natural resources. GDP also has a positive trend in the Antarctic secondary model for least concern decreasing (LCD) birds. In all cases, GDP and most of its proxies cause negative consequences for bird populations at the Three Poles. The impact of secondary countries is an increasing pressure on the Antarctic through tourism, extraction of resources and research.

School enrollment also shows a positive relationship for HKH models. The higher the level of education, the higher the effect on the model. School enrollment in countries such as India and Myanmar has increased, whereas in Nepal and Bangladesh no changes are visible (The World Bank 2012). One may associate higher education with more advanced ecological awareness. This is a false assumption in most cases because of higher schooling does not mean quality education, and especially in developing countries such as those in the third pole (Sabur and Ahmed 2010). However at a macroeconomic level, higher education also comes with the development of a country, which is directly linked to GDP growth and therefore a driver of biodiversity loss and

extinction. Traditionally, highly technical education means affluence and subsequent consumption, but does not have to be like that.

CO2 emission predictors do not show a clear relationship. However, other predictors are directly linked to increasing GHG emissions of global warming. (i.e. food production, agriculture, and education as an outcome of development). The IPCC (2007) suggests that 1/3 of climate change is driven by deforestation and agriculture issues. The top predictors show the impact on bird populations, and all of them are related to the increasing demand of resources that come from population growth, GDP growth and therefore an increase in CO2 emissions. The exact nature of this relationship in such data warrants more scrutiny. Likely, such data are coarse and some spatial interactions provide yet unmapped interactions leading to some of these findinga and which migh otherwise perceived as outliers.

11.3 Main findings

There are many factors involved in the process of biodiversity loss. This study confirms that there are socio-economic factors strongly associated to bird biodiversity loss at the Three Poles regions.

The results raise at least six points of interest:

- Open Access data, and when linked towards a unifying scheme, are essential for progressing towards new insights, revising human behavior and affecting long term culture and sustainability changes.
- As mentioned in the literature review, economic growth and other social factors are putting pressure on ecosystems at the Three Pole regions and contributing greatly to population decline of bird species.
- From the predictors available for this work (Appendix 3), GDP growth and food production are idenitified as the most important factors contributing to declining bird populations at the Three Poles.
- Economic growth is not compatible with sustainability (Martinez 2009) and anthropogenic impacts from primary and secondary countries are affecting bird populations at the Three Poles.
- The extinction process involves many factors and requires a comprehensive, interdisciplinary and non-linear analysis as started here.

The findings of this study also support previous research that proposes comprehensive changes in economy and use of resources (Bhattarai and Hamming 2001, Daly and Farley 2004, Culas 2007, Martinez 2009, Center for the Advancement of the Steady State Economy, Fuentes 2011, McLaughing 2011) and anthropogenic biodiversity loss (Bhattarai and Hamming 2001, Culas 2007, Czech 2008, Holland et al. 2009).

The results shown here are however among the first of this kind and with such data and methods. More work has to be conducted in understanding how economic growth and the related increasing demand of resources are bringing bird populations in the Three Poles regions to extinction and in more detail. Questions like: What are their extinction thresholds? Can such effects be foreseen and predicted before problems occur for a better management? How does such a management look like that avoids extinction and puts animals and mother Earth's rights first? The reasons and anthropogenic causes for the decline of bird populations are important to

predict and to calculate extinction rates (Drake and Griffen 2010) and to be pro-active and before problems occur. Birds are affected by several natural and anthropogenic causes; however in some cases it will not always be possible to identify the primary reason of changes in bird populations, nonetheless such changes are related to human activities (Fiedler 2009).

Birds are just one powerful dimension in the biodiversity argument. In order to protect bird species at the Three Poles and the fragile ecosystems in these areas we need to advocate for better policies and greenhouse gas emission reduction.

In a global system, we know that all is connected among ecosystems: species, processes and also human development (Chapin 1997, Young and Steffen 2009). Arguably, we need to protect the Three Poles in order to protect the Earth system as a whole. Climate change is global in its causes and consequences and is not only about temperature, or the weather. The whole picture of climate change is linked to human population, consumption and human activities (e.g. deforestation; land use change and the oceans). To achieve an effective conservation and protection of the Three Poles, scientific research findings, like those presented in this study, have to be fully taken into account by international governance structures to achieve.

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Appendix 1a: Settings for Treenet analyses – primary countries models

Settings	Arctic*		Antarctic*		Hindu Kush-Himalaya		Three Poles	
Response variable	**ARCEN**	**ARCLCD**	**ANTEN**	**ANTLCD**	**HKHEN**	**HKHLCD**	**3PEN**	**3PLCD**
Learn rate					0.07	0.07	0.3	0.01
Subsample fraction					0.7	0.8	0.85	0.85
Influence trimming factor					0.1	0.1	0.1	0.1
M-regression breakdown parameter					0.9	0.9	0.9	0.9
Number of trees to use					500	200	600	500
Maximum number of trees including restart continuations					10000	10000	10000	10000
Maximum nodes per tree					6	5	6	6
Minimum number of training observations in terminal nodes					6	6	6	6
Maximum number of most-optimal models to save summary results for					1	1	1	1
Optimal Logistic Model Selection Criterion					Cross entropy	Cross entropy	Cross entropy	Cross entropy
Regression Loss Criterion					Huber-M	Least squares	Least squares	Least squares
Testing					V=7	V=7	V=9	V=9

*Arctic and Antarctic primary countries models were not analyzed using Treenet (for details see seccion 9.2.2).

Appendix 1b: Settings for Treenet analyses – secondary countries models

Settings	Antarctic		Arctic		Hindu Kush-Himalaya		Three Poles	
Response variable	**ANTEN**	**ANTLCD**	**ARCEN**	**ARCLCD**	**ENHKH**	**LCHKH**	**3PEN**	**3PLCD**
Learn rate	0.1	0.07	0.03	0.09	0.07	0.07	0.01	0.01
Subsample fraction	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8
Influence trimming factor	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
M-regression breakdown parameter	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Number of trees to use	800	1000	500	500	500	200	200	200
Maximum number of trees including restart continuations	10000	10000	10000	10000	10000	10000	10000	10000
Maximum nodes per tree	5	6	6	6	6	5	6	6
Minimum number of training observations in terminal nodes	5	6	7	7	6	6	6	6
Maximum number of most-optimal models to save summary results for	1	1	1	1	1	1	1	1
Optimal Logistic Model Selection Criterion	Cross entropy	Cross entropy	Cross entropy	Cross entropy	Cross entropy	Cross entropy	Cross entropy	Cross entropy
Regression Loss Criterion	Huber-M	Least squares	Huber-M	Huber-M	Huber-M	Huber-M	Least squares	Least squares
Testing	Fr=0.2	Fr=0.2	V=11	v=6	V=10	V=8	V=7	V=7

Appendix 1c: Settings for Treenet analyses – combined models

Settings	Antarctic		Arctic		HKH		Three Poles	
Response variable	**ANTEN**	**ANTLCD**	**ARCEN**	**ARCEN**	**ENHKH**	**LCHKH**	**3PEN**	**3PLCD**
Learn rate	0.01	0.003	0.01	0.1	0.01	0.07	0.01	0.03
Subsample fraction	0.5	0.8	0.8	0.8	0.9	0.7	0.8	0.7
Influence trimming factor	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
M-regression breakdown parameter	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Number of trees to use	1000	400	2000	500	1800	200	200	200
Maximum number of trees including restart continuations	10000	10000	10000	10000	10000	10000	10000	10000
Maximum nodes per tree	6	6	5	6	6	5	6	6
Minimum number of training observations in terminal nodes	5	6	5	5	6	6	6	6
Maximum number of most-optimal models to save summary results for	1	1	1	1	1	1	1	1
Optimal Logistic Model Selection Criterion	Cross entropy	Cross entropy	Cross entropy	Cross entropy	Cross entropy	Cross entropy	Cross entropy	Cross entropy
Regression Loss Criterion	Least squares	Least squares	Least squares	Huber-M	Least squares	Least squares	Least squares	Huber-M
Testing	Fr=0.15	Fr=0.2	Fr=0.15	Fr=0.15	Fr=0.15	V=8	V=9	V=9

Appendix 2a: Top predictors for "endangered birds" (EN) models

Summary table showing the top predictors for EN models.

(+): positive, (–): negative, NC not clear, (x): not evaluated in Treenet (for details see seccion 9.2.2).

Predictor	Primary				Secondary				Combined				TOTAL
	ARCEN	ANTEN	HKHEN	3PEN	ARCEN	ANTEN	HKHEN	3PEN	ARCEN	ANTEN	HKHEN	3PEN	
Permanent cropland (% of land area)			+			–				NC			3
Agricultural land (% of land area)				+				–			–		3
Agricultural methane emissions (% of total)						+							1
Agriculture, value added (% of GDP)		x											1
Adjusted savings: carbon dioxide damage (current US$)									+				1
Adjusted savings: carbon dioxide damage (current US$)								NC	+				2
CO_2 emissions (metric tons per capita)												NC	1
CO_2 emissions from gaseous fuel consumption (% of total)						+				NC			2
CO2 emissions from liquid fuel consumption (% of total)							NC						1
Employment to population ratio, 15+, total (%)							NC						1
Food production index (1999-2001 = 100)		x		NC				+			+	NC	5
Forest area (km^2)				–									1
GDP (current US$)	x				+				+				3
GDP growth (annual %)				+				–				–	3

GEF benefits index for biodiversity (0 = no biodiversity potential to 100 = maximum)	x			+									2
Gross capital formation (% of GDP)							+						1
Imports of goods and services (% of GDP)						NC							1
International migrant stock, total					–				+				2
Industry, value added (% of GDP)							+						1
Life expectancy at birth, total (years)								+					1
Livestock production index (1999-2001 = 100)												NC	1
Land area (km^2)	x								+				2
Mortality rate, under-5 (per 1,000)			–										1
Motor vehicles (per 1,000 people)			+										1
Passenger cars (per 1,000 people)			–										1
Adjusted savings: particulate emission damage (current US$)		x								NC			2
Population in the largest city (% of urban population)	x									NC			2
Population growth (annual %)					–								1
Pump price for diesel fuel (US$ per liter)											–		1
Renewable internal freshwater resources, total (billion cubic meters)											+		1
Rural population	x												1
Rural population (% of total population)					+		+			NC		–	4

(+): positive, (–): negative, NC not clear, (x): not evaluated in Treenet (for details see seccion 9.2.2).

School enrollment, preprimary (% gross)		x											1
School enrollment, primary (% gross)			+								+		2
School enrollment, secondary (% gross)		x											1
Tax payments (number)						NC							1
Urban population (% of total)					–								1

(+): positive, (–): negative, NC not clear, (x): not evaluated in Treenet (for details see seccion 9.2.2).

Appendix 2b: Top predictors for "least concern decreasing" (LCD) models

Summary table showing the top predictors for LCD models:

(+): positive, (–): negative, NC not clear, (x): not evaluated in Treenet (for details see seccion 9.2.2).

Predictor	Primary				Secondary				Combined				TOTAL
	ARCLCD	ANTLCD	HKHLCD	3PLCD	ARCLCD	ANTLCD	HKHLCD	3PLCD	ARCLCD	ANTLCD	HKHLCD	3PLCD	
Permanent cropland (% of land area)										+			1
Agricultural land (% of land area)	x			–	+								3
Birth rate, crude (per 1,000 people)										–			1
Adjusted savings: carbon dioxide damage (current US$)									NC				1
Adjusted savings: carbon dioxide damage (current US$)	x	x											2
CO2 emissions (metric tons per capita)									–				1
CO2 emissions from gaseous fuel consumption (% of total)										–			1
CO2 emissions from solid fuel consumption (kt)			–										1
Death rate, crude (per 1,000 people)					NC								1
Employment to population ratio, 15+, total (%)							+						1
Food production index (1999-2001 = 100)				NC				–			+	NC	4
Forest area (% of land area)			+					NC				NC	3
GDP (current US$)	x					+			–				3
GDP growth (annual %)				NC				NC				NC	3

GEF benefits index for biodiversity (0 = no biodiversity potential to 100 = maximum)				NC									1
Gross capital formation (% of GDP)		x					–						2
Inflation, GDP deflator (annual %)							–					–	2
International migrant stock, total	x				+				–				3
Industry, value added (% of GDP)							–						1
Life expectancy at birth, total (years)					+							NC	2
Livestock production index (1999-2001 = 100)	x												1
Land area (km^2)									–				1
Mortality rate, under-5 (per 1,000)						–							1
Other greenhouse gas emissions, HFC, PFC and SF6 (thousand metric tons of CO2 equivalent)						+							1
Passenger cars (per 1,000 people)			–										1
Adjusted savings: particulate emission damage (current US$)										–			1
Adjusted savings: particulate emission damage (% of GNI)							–						1
Population in the largest city (% of urban population)		x											1
Population growth (annual %)				NC									1
Population, total					–			NC					2
Pump price for diesel fuel (US$ per liter)											–		1
Road sector energy consumption (% of total energy consumption)						–							1

(+): positive, (–): negative, NC not clear, (x): not evaluated in Treenet (for details see seccion 9.2.2).

Renewable internal freshwater resources per capita (cubic meters)		x									+		2
Renewable internal freshwater resources, total (billion cubic meters)											+		1
Rural population		x											1
Rural population (% of total population)										+			1
School enrollment, primary (% gross)			+								+		2
School enrollment, secondary (% gross)			+										1
Total reserves (includes gold, current US$)						+							1
Urban population								+					1

(+): positive, (–): negative, NC not clear, (x): not evaluated in Treenet (for details see seccion 9.2.2).

Appendix 3: A complete list of predictors

The list of the 98 predictors used in the analyses.

CODE	NAME	DESCRIPTION	SOURCE
AGLNCR	Permanent cropland (% of land area)	Permanent cropland is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber. This category includes land under flowering shrubs, fruit trees, nut trees, and vines, but excludes land under trees grown for wood or timber.	Food and Agriculture Organization, electronic files and web site.
AGLND	Agricultural land (% of land area)	Agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures. Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded. Land under permanent crops is land cultivated with crops that occupy the land for long periods and need not be replanted after each harvest, such as cocoa, coffee, and rubber. This category includes land under flowering shrubs, fruit trees, nut trees, and vines, but excludes land under trees grown for wood or timber. Permanent pasture is land used for five or more years for forage, including natural and cultivated crops.	Food and Agriculture Organization, electronic files and web site.
AGMEEM	Agricultural methane emissions (% of total)	Agricultural methane emissions are emissions from animals, animal waste, rice production, agricultural waste burning (nonenergy, on-site), and savannah burning.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).
AGNIEM	Agricultural nitrous oxide emissions (% of total)	Agricultural nitrous oxide emissions are emissions produced through fertilizer use (synthetic and animal manure), animal waste management, agricultural waste burning (nonenergy, on-site), and savannah burning.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).
AGVAAD	Agriculture, value added (% of GDP)	Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator.	World Bank national accounts data, and OECD National Accounts data files.
AGYLDCREL	Cereal yield (kg per hectare)	Cereal yield, measured as kilograms per hectare of harvested land, includes wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains. Production data on cereals relate to crops harvested for dry grain only. Cereal crops harvested for hay or harvested green for food, feed, or silage and those used for grazing are excluded. The FAO allocates production data to the calendar year in which the bulk of the harvest took place. Most of a crop harvested near the end of a year will be used in the following year.	Food and Agriculture Organization, electronic files and web site.
ALNUEN	Alternative and nuclear energy (% of total energy use)	Clean energy is noncarbohydrate energy that does not produce carbon dioxide when generated. It includes hydropower and nuclear, geothermal, and solar power, among others.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).

ARLAPER	Arable land (hectares per person)	Arable land (hectares per person) includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.	Food and Agriculture Organization, electronic files and web site.
ARLND	Arable land (% of land area)	Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.	Food and Agriculture Organization, electronic files and web site.
BIRACRU	Birth rate, crude (per 1,000 people)	Crude birth rate indicates the number of live births occurring during the year, per 1,000 population estimated at midyear. Subtracting the crude death rate from the crude birth rate provides the rate of natural increase, which is equal to the rate of population change in the absence of migration.	(1) United Nations Population Division. 2009. World Population Prospects: The 2008 Revision. New York, United Nations, Department of Economic and Social Affairs (advanced Excel tables), (2) United Nations Statistical Division. Population and Vital Statistics Report (various years), (3) Census reports and other statistical publications from national statistical offices, (4) Eurostat: Demographic Statistics, (5) Secretariat of the Pacific Community: Statistics and Demography Programme, and (6) U.S. Census Bureau: International Database.
C02ADJSAV	Adjusted savings: carbon dioxide damage (current US$)	Carbon dioxide damage is estimated to be $20 per ton of carbon (the unit damage in 1995 U.S. dollars) times the number of tons of carbon emitted.	World Bank staff estimates based on Samuel Fankhauser's "Valuing Climate Change: The Economics of the Greenhouse" (1995).
C02DAM	Adjusted savings: carbon dioxide damage (current US$)	Carbon dioxide damage is estimated to be $20 per ton of carbon (the unit damage in 1995 U.S. dollars) times the number of tons of carbon emitted.	World Bank staff estimates based on Samuel Fankhauser's "Valuing Climate Change: The Economics of the Greenhouse" (1995).
CO2EMI	CO_2 emissions (metric tons per capita)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
CO2FCONS	CO_2 emissions from gaseous fuel consumption (kt)	Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of natural gas as an energy source.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
CO2FCPER	CO_2 emissions from gaseous fuel consumption (% of total)	Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of natural gas as an energy source.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

CO2IND	CO_2 emissions from manufacturing industries and construction (million metric tons)	CO2 emissions from manufacturing industries and construction contains the emissions from combustion of fuels in industry. The IPCC Source/Sink Category 1 A 2 includes these emissions. However, in the 1996 IPCC Guidelines, the IPCC category also includes emissions from industry autoproducers that generate electricity and/or heat. The IEA data are not collected in a way that allows the energy consumption to be split by specific end-use and therefore, autoproducers are shown as a separate item (Unallocated Autoproducers). Manufacturing industries and construction also includes emissions from coke inputs into blast furnaces, which may be reported either in the transformation sector, the industry sector or the separate IPCC Source/Sink Category 2, Industrial Processes.	
CO2KGGDP	CO_2 emissions (kg per 2005 PPP $ of GDP)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
CO2KT	CO_2 emissions (kt)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
CO2LIQPER	CO_2 emissions from liquid fuel consumption (% of total)	Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of petroleum-derived fuels as an energy source.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
CO2LIQU	CO_2 emissions from liquid fuel consumption (kt)	Carbon dioxide emissions from liquid fuel consumption refer mainly to emissions from use of petroleum-derived fuels as an energy source.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
CO2OTHERS	CO_2 emissions from other sectors, excluding residential buildings and commercial and public services (million metric tons)	CO2 emissions from other sectors, less residential buildings and commercial and public services, contains the emissions from commercial/institutional activities, residential, agriculture/forestry, fishing and other emissions not specified elsewhere that are included in the IPCC Source/Sink Categories 1 A 4 and 1 A 5. In the 1996 IPCC Guidelines, the category also includes emissions from autoproducers in the commercial/residential/agricultural sectors that generate electricity and/or heat. The IEA data are not collected in a way that allows the energy consumption to be split by specific end-use and therefore, autoproducers are shown as a separate item (Unallocated Autoproducers).	
co2res	CO_2 emissions from residential buildings and commercial and public services (million metric tons)	CO_2 emissions from residential buildings and commercial and public services contains all emissions from fuel combustion in households. This corresponds to IPCC Source/Sink Category 1 A 4 b. Commercial and public services includes emissions from all activities of ISIC Divisions 41, 50-52, 55, 63-67, 70-75, 80, 85, 90-93 and 99.	IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp), International Energy Agency electronic files on CO2 Emissions from Fuel Combustion.
CO2SOLIDFC	CO_2 emissions from solid fuel consumption (kt)	Carbon dioxide emissions from solid fuel consumption refer mainly to emissions from use of coal as an energy source.	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.

CO2TRANSP	CO_2 emissions from transport (million metric tons)	CO_2 emissions from transport contains emissions from the combustion of fuel for all transport activity, regardless of the sector, except for international marine bunkers and international aviation. This includes domestic aviation, domestic navigation, road, rail and pipeline transport, and corresponds to IPCC Source/Sink Category 1 A 3. In addition, the IEA data are not collected in a way that allows the autoproducer consumption to be split by specific end-use and therefore, autoproducers are shown as a separate item (Unallocated Autoproducers).	
DERACRU	Death rate, crude (per 1,000 people)	Crude death rate indicates the number of deaths occurring during the year, per 1,000 population estimated at midyear. Subtracting the crude death rate from the crude birth rate provides the rate of natural increase, which is equal to the rate of population change in the absence of migration.	(1) United Nations Population Division. 2009. World Population Prospects: The 2008 Revision. New York, United Nations, Department of Economic and Social Affairs (advanced Excel tables), (2) United Nations Statistical Division. Population and Vital Statistics Report (various years), (3) Census reports and other statistical publications from national statistical offices, (4) Eurostat: Demographic Statistics, (5) Secretariat of the Pacific Community: Statistics and Demography Programme, and (6) U.S. Census Bureau: International Database.
DIESPC	Road sector diesel fuel consumption per capita (kt of oil equivalent)	Diesel is heavy oils used as a fuel for internal combustion in diesel engines.	International Road Federation, World Road Statistics and electronic files, except where noted, and International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).
ELPOCO	Electric power consumption (kWh per capita)	Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp), Energy Statistics and Balances of Non-OECD Countries and Energy Statistics of OECD Countries.
EMPORA	Employment to population ratio, 15+, total (%)	Employment to population ratio is the proportion of a country's population that is employed. Ages 15 and older are generally considered the working-age population.	International Labour Organization, Key Indicators of the Labour Market database.
ENIMP	Energy imports, net (% of energy use)	Net energy imports are estimated as energy use less production, both measured in oil equivalents. A negative value indicates that the country is a net exporter. Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp) and United Nations, Energy Statistics Yearbook.
ENPROD	Energy production (kt of oil equivalent)	Energy production refers to forms of primary energy--petroleum (crude oil, natural gas liquids, and oil from nonconventional sources), natural gas, solid fuels (coal, lignite, and other derived fuels), and combustible renewables and waste--and primary electricity, all converted into oil equivalents.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).
ENUSE	Energy use (kg of oil equivalent per capita)	Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).
ENUSKT	Energy use (kt of oil equivalent)	Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).

EXPORT	Exports of goods and services (% of GDP)	Exports of goods and services represent the value of all goods and other market services provided to the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments.	World Bank national accounts data, and OECD National Accounts data files.
FERATO	Fertility rate, total (births per woman)	Total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with current age-specific fertility rates.	(1) United Nations Population Division. 2009. World Population Prospects: The 2008 Revision. New York, United Nations, Department of Economic and Social Affairs (advanced Excel tables). Available at http://esa.un.org/unpd/wpp2008/index.htm. (2) Census reports and other statistical publications from national statistical offices, (3) Eurostat: Demographic Statistics, (4) Secretariat of the Pacific Community: Statistics and Demography Programme, (5) U.S. Census Bureau: International Database, and (6) household surveys conducted by national agencies, Macro International, and the U.S. Centers for Disease Control and Prevention.
FODINV	Foreign direct investment, net inflows (BoP, current US$)	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors. Data are in current U.S. dollars.	International Monetary Fund, Balance of Payments database, supplemented by data from the United Nations Conference on Trade and Development and official national sources.
FODPR	Food production index (1999-2001 = 100)	Food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value.	Food and Agriculture Organization, electronic files and web site.
FORAR	Forest area (% of land area)	Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens.	Food and Agriculture Organization, electronic files and web site.
FORKM	Forest area (km^2)	Forest area is land under natural or planted stands of trees of at least 5 meters in situ, whether productive or not, and excludes tree stands in agricultural production systems (for example, in fruit plantations and agroforestry systems) and trees in urban parks and gardens.	Food and Agriculture Organization, electronic files and web site.
FOSENC	Fossil fuel energy consumption (% of total)	Fossil fuel comprises coal, oil, petroleum, and natural gas products.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).
GASPC	Road sector gasoline fuel consumption per capita (kt of oil equivalent)	Gasoline is light hydrocarbon oil use in internal combustion engine such as motor vehicles, excluding aircraft.	International Road Federation, World Road Statistics and electronic files, except where noted, and International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).

GDP	GDP (current US$)	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars. Dollar figures for GDP are converted from domestic currencies using single year official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used.	World Bank national accounts data, and OECD National Accounts data files.
GDPGRW	GDP growth (annual %)	Annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2000 U.S. dollars. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.	World Bank national accounts data, and OECD National Accounts data files.
GDPPC	GDP per capita (current US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars.	World Bank national accounts data, and OECD National Accounts data files.
GEFBIO	GEF benefits index for biodiversity (0 = no biodiversity potential to 100 = maximum)	GEF benefits index for biodiversity is a composite index of relative biodiversity potential for each country based on the species represented in each country, their threat status, and the diversity of habitat types in each country. The index has been normalized so that values run from 0 (no biodiversity potential) to 100 (maximum biodiversity potential).	Kiran Dev Pandey, Piet Buys, Ken Chomitz, and David Wheeler's, "Biodiversity Conservation Indicators: New Tools for Priority Setting at the Global Environment Facility" (2006).
GNIPC	GNI per capita, PPP (current international $)	GNI per capita based on purchasing power parity (PPP). PPP GNI is gross national income (GNI) converted to international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GNI as a U.S. dollar has in the United States. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. Data are in current international dollars.	World Bank, International Comparison Program database.
GRCAFO	Gross capital formation (% of GDP)	Gross capital formation (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress." According to the 1993 SNA, net acquisitions of valuables are also considered capital formation.	World Bank national accounts data, and OECD National Accounts data files.
HEEXPC	Health expenditure per capita (current US$)	Total health expenditure is the sum of public and private health expenditures as a ratio of total population. It covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation. Data are in current	World Health Organization National Health Account database (www.who.int/nha/en) supplemented by country data.

		U.S. dollars.	
IMPORT	Imports of goods and services (% of GDP)	Imports of goods and services represent the value of all goods and other market services received from the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments.	World Bank national accounts data, and OECD National Accounts data files.
INFCOPR	Inflation, consumer prices (annual %)	Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. The Laspeyres formula is generally used.	International Monetary Fund, International Financial Statistics and data files.
INFGDPD	Inflation, GDP deflator (annual %)	Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.	World Bank national accounts data, and OECD National Accounts data files.
INMISTK	International migrant stock, total	International migrant stock is the number of people born in a country other than that in which they live. It also includes refugees. The data used to estimate the international migrant stock at a particular time are obtained mainly from population censuses. The estimates are derived from the data on foreign-born population--people who have residence in one country but were born in another country. When data on the foreign-born population are not available, data on foreign population--that is, people who are citizens of a country other than the country in which they reside--are used as estimates. After the breakup of the Soviet Union in 1991 people living in one of the newly independent countries who were born in another were classified as international migrants. Estimates of migrant stock in the newly independent states from 1990 on are based on the 1989 census of the Soviet Union. For countries with information on the international migrant stock for at least two points in time, interpolation or extrapolation was used to estimate the international migrant stock on July 1 of the reference years. For countries with only one observation, estimates for the reference years were derived using rates of change in the migrant stock in the years preceding or following the single observation available. A model was used to estimate migrants for countries that had no data.	United Nations Population Division, Trends in Total Migrant Stock: 2008 Revision.
INVALAD	Industry, value added (% of GDP)	Industry corresponds to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator.	World Bank national accounts data, and OECD National Accounts data files.

IWATSO	Improved water source, rural (% of rural population with access)	Access to an improved water source refers to the percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 liters a person a day from a source within one kilometer of the dwelling.	World Health Organization and United Nations Children's Fund, Joint Measurement Programme (JMP) (http://www.wssinfo.org/).
LAFOTO	Labor force, total	Total labor force comprises people ages 15 and older who meet the International Labour Organization definition of the economically active population: all people who supply labor for the production of goods and services during a specified period. It includes both the employed and the unemployed. While national practices vary in the treatment of such groups as the armed forces and seasonal or part-time workers, in general the labor force includes the armed forces, the unemployed, and first-time job-seekers, but excludes homemakers and other unpaid caregivers and workers in the informal sector.	International Labour Organization, using World Bank population estimates.
LAPART	Labor participation rate, total (% of total population ages 15+)	Labor force participation rate is the proportion of the population ages 15 and older that is economically active: all people who supply labor for the production of goods and services during a specified period.	International Labour Organization, Key Indicators of the Labour Market database.
LIEXBIR	Life expectancy at birth, total (years)	Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.	Derived from male and female life expectancy at birth. Male and female life expectancy source: (1) United Nations Population Division. 2009. World Population Prospects: The 2008 Revision. New York, United Nations, Department of Economic and Social Affairs (advanced Excel tables), (2) Census reports and other statistical publications from national statistical offices, (3) Eurostat: Demographic Statistics, (4) Secretariat of the Pacific Community: Statistics and Demography Programme, and (5) U.S. Census Bureau: International Database.
LIVPRO	Livestock production index (1999-2001 = 100)	Livestock production index includes meat and milk from all sources, dairy products such as cheese, and eggs, honey, raw silk, wool, and hides and skins.	Food and Agriculture Organization, electronic files and web site.
LNDAR	Land area (km^2)	Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.	Food and Agriculture Organization, electronic files and web site.
LPRFE	Labor participation rate, female (% of female population ages 15+)	Labor force participation rate is the proportion of the population ages 15 and older that is economically active: all people who supply labor for the production of goods and services during a specified period.	International Labour Organization, Key Indicators of the Labour Market database.
LPRMA	Labor participation rate, male (% of male population ages 15+)	Labor force participation rate is the proportion of the population ages 15 and older that is economically active: all people who supply labor for the production of goods and services during a specified period.	International Labour Organization, Key Indicators of the Labour Market database.
MERTRD	Merchandise trade (% of GDP)	Merchandise trade as a share of GDP is the sum of merchandise exports and imports divided by the value of GDP, all in current U.S. dollars.	World Trade Organization, and World Bank GDP estimates.
METEM	Methane emissions (kt of CO_2 equivalent)	Methane emissions are those stemming from human activities such as agriculture and from industrial methane production.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).

MILEXP	Military expenditure (% of GDP)	Military expenditures data from SIPRI are derived from the NATO definition, which includes all current and capital expenditures on the armed forces, including peacekeeping forces; defense ministries and other government agencies engaged in defense projects; paramilitary forces, if these are judged to be trained and equipped for military operations; and military space activities. Such expenditures include military and civil personnel, including retirement pensions of military personnel and social services for personnel; operation and maintenance; procurement; military research and development; and military aid (in the military expenditures of the donor country). Excluded are civil defense and current expenditures for previous military activities, such as for veterans' benefits, demobilization, conversion, and destruction of weapons. This definition cannot be applied for all countries, however, since that would require much more detailed information than is available about what is included in military budgets and off-budget military expenditure items. (For example, military budgets might or might not cover civil defense, reserves and auxiliary forces, police and paramilitary forces, dual-purpose forces such as military and civilian police, military grants in kind, pensions for military personnel, and social security contributions paid by one part of government to another.)	Stockholm International Peace Research Institute (SIPRI), Yearbook: Armaments, Disarmament and International Security.
MORA5U	Mortality rate, under-5 (per 1,000)	Under-five mortality rate is the probability per 1,000 that a newborn baby will die before reaching age five, if subject to current age-specific mortality rates.	Level & Trends in Child Mortality. Report 2010. Estimates Developed by the UN Inter-agency Group for Child Mortality Estimation (UNICEF, WHO, World Bank, UN DESA, UNPD).
MOTVEH	Motor vehicles (per 1,000 people)	Motor vehicles include cars, buses, and freight vehicles but do not include two-wheelers. Population refers to midyear population in the year for which data are available.	International Road Federation, World Road Statistics and data files.
NATRESDEPPER	Adjusted savings: natural resources depletion (% of GNI)	Natural resource depletion is the sum of net forest depletion, energy depletion, and mineral depletion. Net forest depletion is unit resource rents times the excess of roundwood harvest over natural growth. Energy depletion is the ratio of the value of the stock of energy resources to the remaining reserve lifetime (capped at 25 years). It covers coal, crude oil, and natural gas. Mineral depletion is the ratio of the value of the stock of mineral resources to the remaining reserve lifetime (capped at 25 years). It covers tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.	World Bank staff estimates based on sources and methods in World Bank's "The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium" (2011).
NETMIG	Net migration	Net migration is the net total of migrants during the period, that is, the total number of immigrants less the annual number of emigrants, including both citizens and noncitizens. Data are five-year estimates. To derive estimates of net migration, the United Nations Population Division takes into account the past migration history of a country or area, the migration policy of a country, and the influx of refugees in recent periods. The data to calculate these official estimates come from a variety of sources, including border statistics, administrative records, surveys, and censuses. When no official estimates can be made because of insufficient data, net migration is derived through the balance equation, which is the difference between overall population growth and the natural increase during the 1990-2000 intercensal period.	United Nations Population Division, World Population Prospects 2008.
OGHGEM	Other greenhouse gas emissions, HFC, PFC and SF6 (thousand metric tons of CO_2 equivalent)	Other greenhouse gas emissions are by-product emissions of hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).

PASCAR	Passenger cars (per 1,000 people)	Passenger cars refer to road motor vehicles, other than two-wheelers, intended for the carriage of passengers and designed to seat no more than nine people (including the driver).	International Road Federation, World Road Statistics and data files.
PEDAMSAV	Adjusted savings: particulate emission damage (current US$)	Particulate emissions damage is calculated as the willingness to pay to avoid mortality attributable to particulate emissions.	Kiran D. Pandey and others' "The Human Costs of Air Pollution: New Estimates for Developing Countries" (working paper).
PEDAMSAVPER	Adjusted savings: particulate emission damage (% of GNI)	Particulate emissions damage is calculated as the willingness to pay to avoid mortality attributable to particulate emissions.	Kiran D. Pandey and others' "The Human Costs of Air Pollution: New Estimates for Developing Countries" (working paper).
PLGCIT	Population in the largest city (% of urban population)	Population in largest city is the percentage of a country's urban population living in that country's largest metropolitan area.	United Nations, World Urbanization Prospects.
PM10_	PM10, country level (micrograms per cubic meter)	Particulate matter concentrations refer to fine suspended particulates less than 10 microns in diameter (PM10) that are capable of penetrating deep into the respiratory tract and causing significant health damage. Data for countries and aggregates for regions and income groups are urban-population weighted PM10 levels in residential areas of cities with more than 100,000 residents. The estimates represent the average annual exposure level of the average urban resident to outdoor particulate matter. The state of a country's technology and pollution controls is an important determinant of particulate matter concentrations.	Kiren Dev Pandey, David Wheeler, Bart Ostro, Uwe Deichmann, Kirk Hamilton, and Katherine Bolt. "Ambient Particulate Matter Concentrations in Residential and Pollution Hotspot Areas of World Cities: New Estimates Based on the Global Model of Ambient Particulates (GMAPS)," World Bank, Development Research Group and Environment Department (2006).
POP014_	Population ages 0-14 (% of total)	Population between the ages 0 to 14 as a percentage of the total population. Population is based on the de facto definition of population.	World Bank staff estimates from various sources including census reports, the United Nations Population Division's World Population Prospects, national statistical offices, household surveys conducted by national agencies, and Macro International.
POP1564_	Population ages 15-64 (% of total)	Population ages 15 to 64 is the percentage of the total population that is in the age group 15 to 64. Population is based on the de facto definition of population.	World Bank staff estimates from various sources including census reports, the United Nations Population Division's World Population Prospects, national statistical offices, household surveys conducted by national agencies, and Macro International.
POP65_	Population ages 65 and above (% of total)	Population ages 65 and above as a percentage of the total population. Population is based on the de facto definition of population.	World Bank staff estimates from various sources including census reports, the United Nations Population Division's World Population Prospects, national statistical offices, household surveys conducted by national agencies, and Macro International.
POPGRW	Population growth (annual %)	Annual population growth rate for year t is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage . Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of the country of origin.	Derived from total population. Population source: (1) United Nations Population Division. 2009. World Population Prospects: The 2008 Revision. New York, United Nations, Department of Economic and Social Affairs (advanced Excel tables). Available at http://esa.un.org/unpd/wpp2008/index.htm. (2) Census reports and other statistical publications from national statistical offices, (3) Eurostat: Demographic Statistics, (4) Secretariat of the Pacific Community: Statistics and Demography Programme, (5) U.S. Census Bureau: International Database, and (6) World bank estimates based on the data from the sources above, household surveys conducted by national agencies, Macro International, the U.S. Centers for Disease Control and Prevention, and refugees

			statistics from the United Nations High Commissioner for Refugees.
POPTOT	Population, total	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. The values shown are midyear estimates.	(1) United Nations Population Division. 2009. World Population Prospects: The 2008 Revision. New York, United Nations, Department of Economic and Social Affairs (advanced Excel tables). Available at http://esa.un.org/unpd/wpp2008/index.htm. (2) Census reports and other statistical publications from national statistical offices, (3) Eurostat: Demographic Statistics, (4) Secretariat of the Pacific Community: Statistics and Demography Programme, (5) U.S. Census Bureau: International Database, and (6) World bank estimates based on the data from the sources above, household surveys conducted by national agencies, Macro International, the U.S. Centers for Disease Control and Prevention, and refugees statistics from the United Nations High Commissioner for Refugees.
PRDIES	Pump price for diesel fuel (US$ per liter)	Fuel prices refer to the pump prices of the most widely sold grade of diesel fuel. Prices have been converted from the local currency to U.S. dollars.	German Agency for Technical Cooperation (GTZ).
PRGAS	Pump price for gasoline (US$ per liter)	Fuel prices refer to the pump prices of the most widely sold grade of gasoline. Prices have been converted from the local currency to U.S. dollars.	German Agency for Technical Cooperation (GTZ).
RDENCOM	Road sector energy consumption (% of total energy consumption)	Road sector energy consumption is the total energy used in the road sector including petroleum products, natural gas, electricity, and combustible renewable and waste. Total energy consumption is the total country energy consumption.	International Road Federation, World Road Statistics and electronic files, except where noted, and International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).
REFORI	Refugee population by country or territory of origin	Refugees are people who are recognized as refugees under the 1951 Convention Relating to the Status of Refugees or its 1967 Protocol, the 1969 Organization of African Unity Convention Governing the Specific Aspects of Refugee Problems in Africa, people recognized as refugees in accordance with the UNHCR statute, people granted refugee-like humanitarian status, and people provided temporary protection. Asylum seekers--people who have applied for asylum or refugee status and who have not yet received a decision or who are registered as asylum seekers--are excluded. Palestinian refugees are people (and their descendants) whose residence was Palestine between June 1946 and May 1948 and who lost their homes and means of livelihood as a result of the 1948 Arab-Israeli conflict. Country of origin generally refers to the nationality or country of citizenship of a claimant.	United Nations High Commissioner for Refugees (UNHCR), Statistical Yearbook and data files, complemented by statistics on Palestinian refugees under the mandate of the UNRWA as published on its website. Data from UNHCR are available online at: www.unhcr.org/statistics/populationdatabase.
RENWAS	Combustible renewables and waste (% of total energy)	Combustible renewables and waste comprise solid biomass, liquid biomass, biogas, industrial waste, and municipal waste, measured as a percentage of total energy use.	International Energy Agency (IEA Statistics © OECD/IEA, http://www.iea.org/stats/index.asp).
RNWFW	Renewable internal freshwater resources per capita (cubic meters)	Renewable internal freshwater resources flows refer to internal renewable resources (internal river flows and groundwater from rainfall) in the country. Renewable internal freshwater resources per capita are calculated using The World Bank's population estimates.	Food and Agriculture Organization, AQUASTAT data.

RNWFWM	Renewable internal freshwater resources, total (billion cubic meters)	Renewable internal freshwater resources flows refer to internal renewable resources (internal river flows and groundwater from rainfall) in the country.	Food and Agriculture Organization, AQUASTAT data.
RUPOPER	Rural population (% of total population)	Rural population refers to people living in rural areas as defined by national statistical offices. It is calculated as the difference between total population and urban population.	World Bank Staff estimates based on United Nations, World Urbanization Prospects.
RURPOP	Rural population	Rural population refers to people living in rural areas as defined by national statistical offices. It is calculated as the difference between total population and urban population.	The data on urban population shares used to estimate rural population come from the United Nations, World Urbanization Prospects. Total population figures are World Bank estimates.
SENRPRE	School enrollment, preprimary (% gross)	Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Preprimary education refers to the initial stage of organized instruction, designed primarily to introduce very young children to a school-type environment.	United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
SENRPRI	School enrollment, primary (% gross)	Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of such subjects as history, geography, natural science, social science, art, and music.	United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
SENRSEC	School enrollment, secondary (% gross)	Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers.	United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
SEVALAD	Services, etc., value added (% of GDP)	Services correspond to ISIC divisions 50-99 and they include value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services. Also included are imputed bank service charges, import duties, and any statistical discrepancies noted by national compilers as well as discrepancies arising from rescaling. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The industrial origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3. Note: For VAB countries, gross value added at factor cost is used as the denominator.	World Bank national accounts data, and OECD National Accounts data files.
TAXPAY	Tax payments (number)	Tax payments by businesses are the total number of taxes paid by businesses, including electronic filing. The tax is counted as paid once a year even if payments are more frequent.	World Bank, Doing Business project (http://www.doingbusiness.org/).
TORES	Total reserves (includes gold, current US$)	Total reserves comprise holdings of monetary gold, special drawing rights, reserves of IMF members held by the IMF, and holdings of foreign exchange under the control of monetary authorities. The gold component of these reserves is valued at year-end (December 31) London prices. Data are in current U.S. dollars.	International Monetary Fund, International Financial Statistics and data files.

TOTTAX	Total tax rate (% of commercial profits)	Total tax rate measures the amount of taxes and mandatory contributions payable by businesses after accounting for allowable deductions and exemptions as a share of commercial profits. Taxes withheld (such as personal income tax) or collected and remitted to tax authorities (such as value added taxes, sales taxes or goods and service taxes) are excluded.	World Bank, Doing Business project (http://www.doingbusiness.org/).
UNEMTO	Unemployment, total (% of total labor force)	Unemployment refers to the share of the labor force that is without work but available for and seeking employment. Definitions of labor force and unemployment differ by country.	International Labour Organization, Key Indicators of the Labour Market database.
URBPOP	Urban population	Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects.	World Bank Staff estimates based on United Nations, World Urbanization Prospects.
URPOPR	Urban population (% of total)	Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects.	United Nations, World Urbanization Prospects.

Appendix 4: Response curves and gains charts

A4.1 Endangered birds models

A4.1.1 Model primary countries

A4.1.1.1 EN - Arctic model

No information available (for details see seccion 9.2.2)

A4.1.1.2 EN - Antarctic model

No information available (for details see seccion 9.2.2)

A4.1.1.3 EN - HKH model

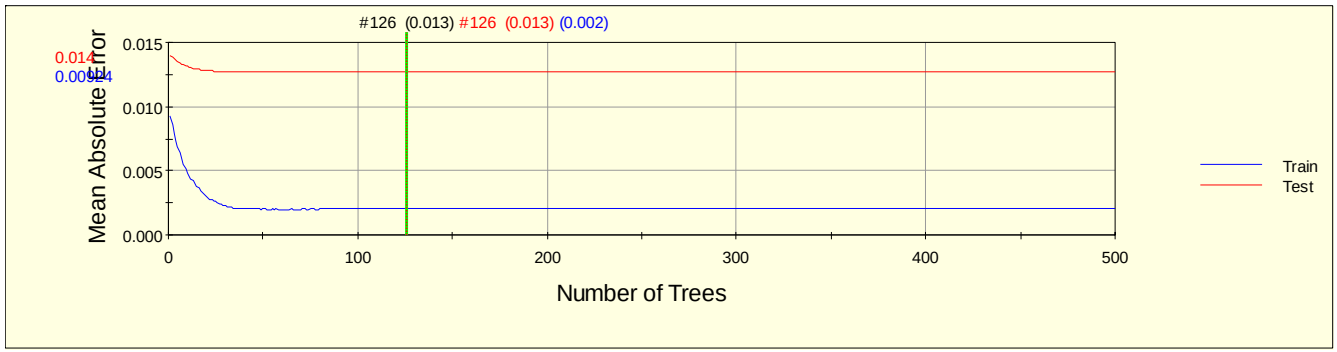

Figure 37: Response curve for the model of HKHEN primary countries.

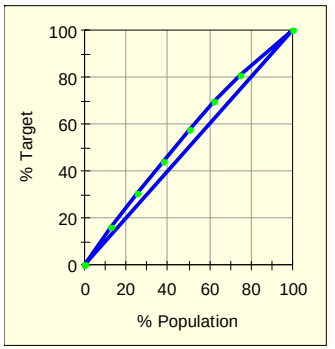

Figure 38: Gains chart for the model of HKHEN primary countries.

A4.1.1.4 EN - Three Poles model

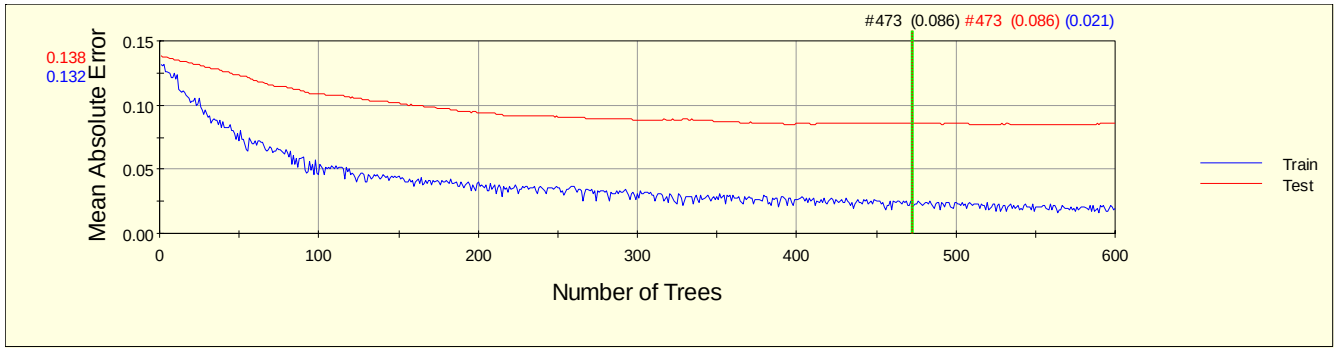

Figure 40: Response curve for the model of 3PEN primary countries.

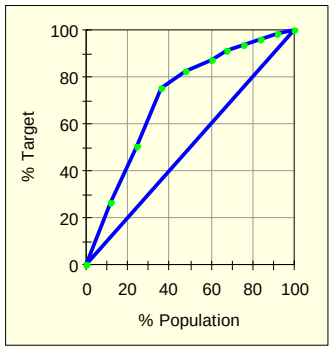

Figure 39: Gains chart for the model of 3PEN primary countries.

A4.1.2 Model secondary countries

A4.1.2.1 Arctic

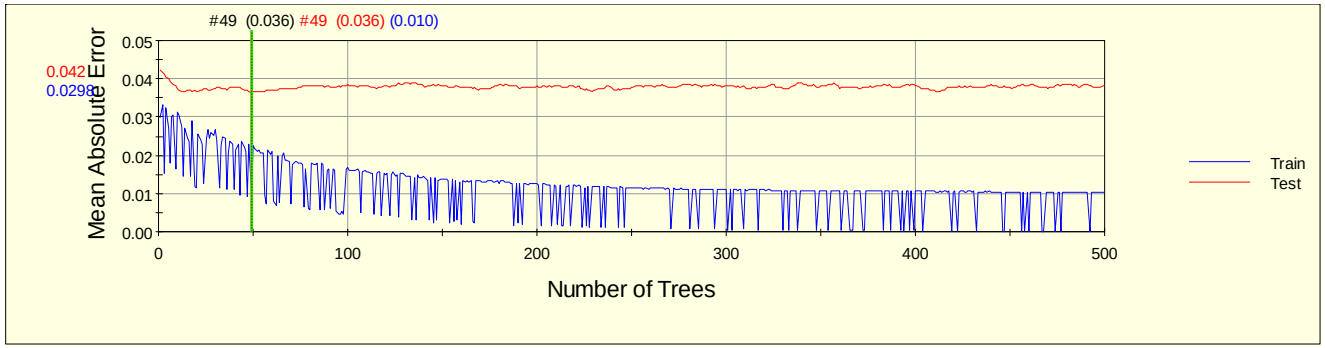

Figure 41: Response curve for the model of ARCEN secondary countries.

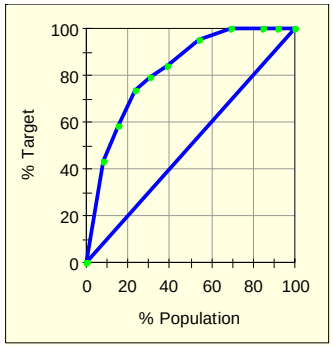

Figure 42: Gains chart for the model of ARCEN secondary countries.

A4.1.2.2 Antarctic

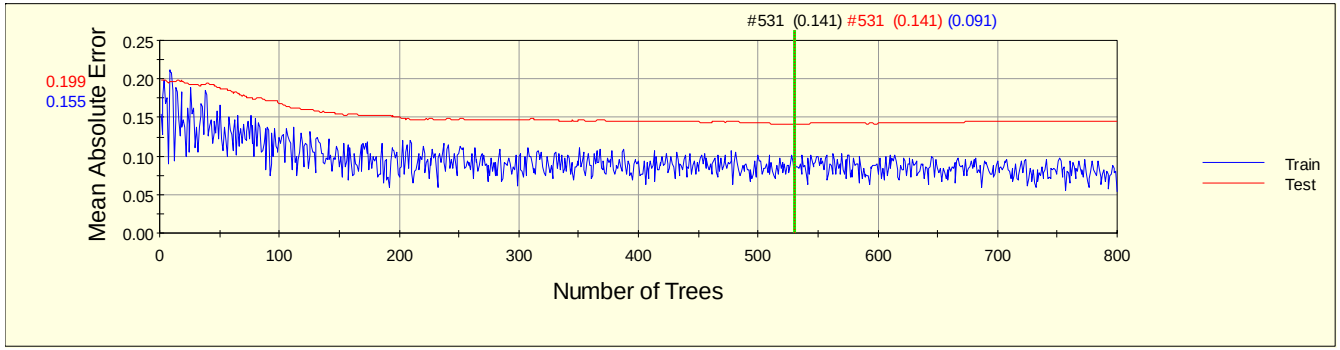

Figure 44: Response curve for the model of ANTEN secondary countries.

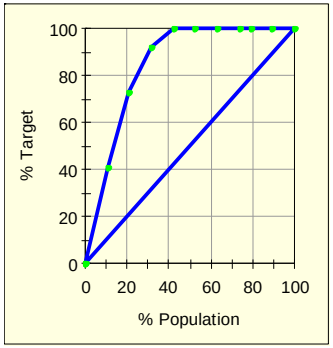

Figure 43: Gains chart for the model of ANTEN secondary countries.

A4.1.2.3 HKH

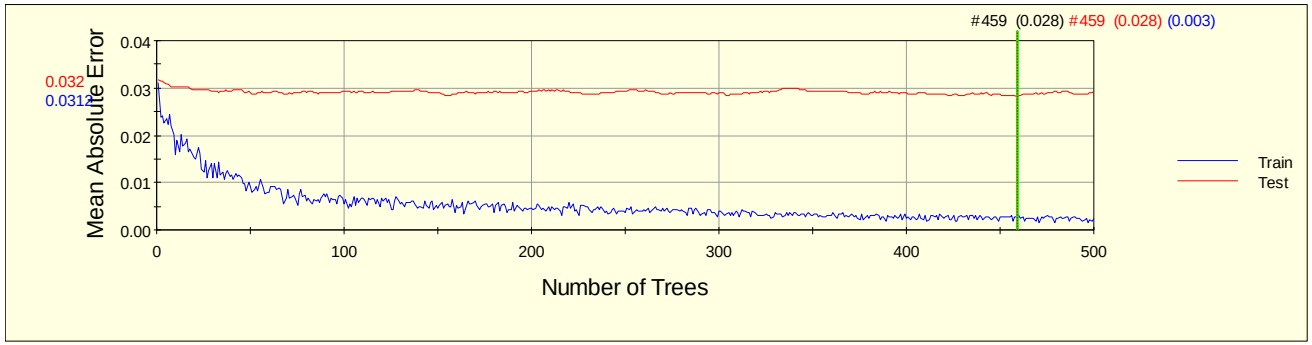

Figure 45: Response curve for the model of HKHEN secondary countries.

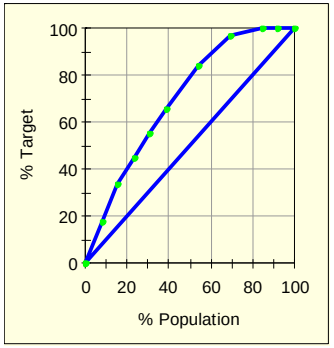

Figure 46: Gains chart for the model of HKHEN secondary countries.

A4.1.2.4 Three Poles

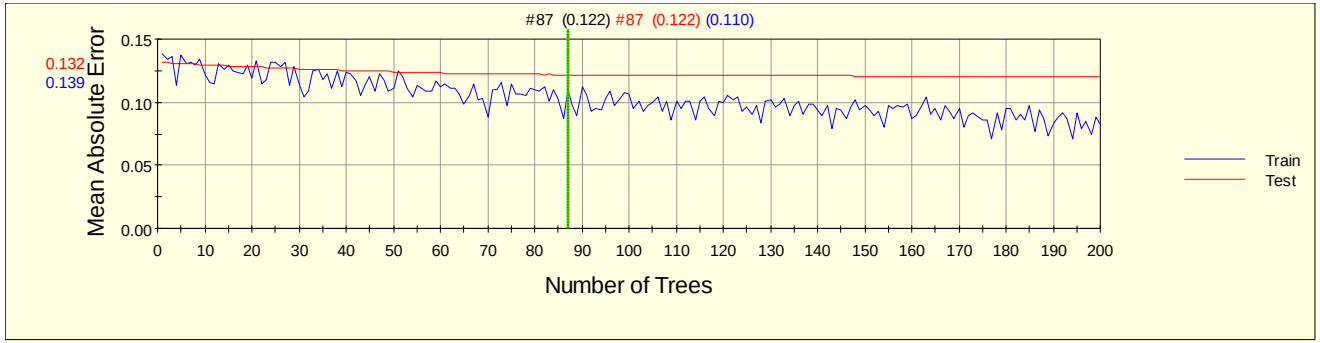

Figure 48: Response curve for the model of 3PEN secondary countries.

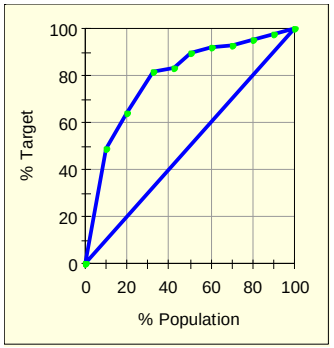

Figure 47: Gains chart for the model of HKHEN secondary countries.

A.4.1.3 Model combined

A.4.1.3.1 Arctic

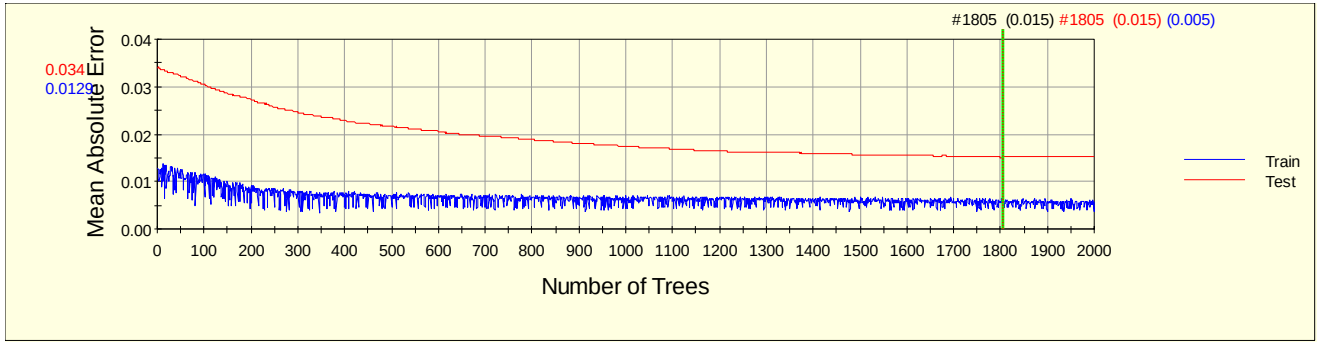

Figure 50: Response curve for the model of ARCEN combined (primary + secondary countries).

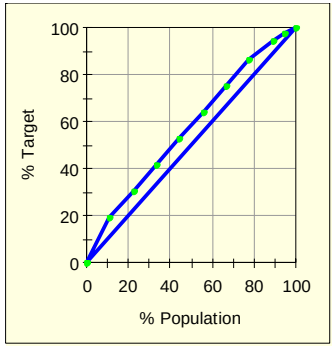

Figure 49: Gains chart for the model of ARCEN combined (primary +

A.4.1.3.2 Antarctic

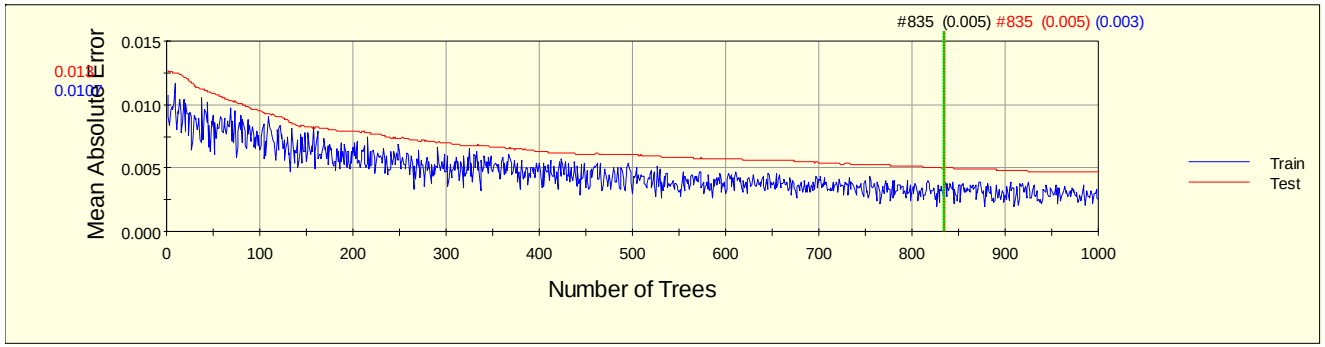

Figure 52: Response curve for the model of ANTEN combined (primary + secondary countries).

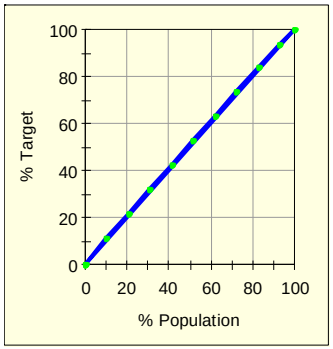

Figure 51: Gains chart for the model of ANTEN combined (primary +

A.4.1.3.3 HKH

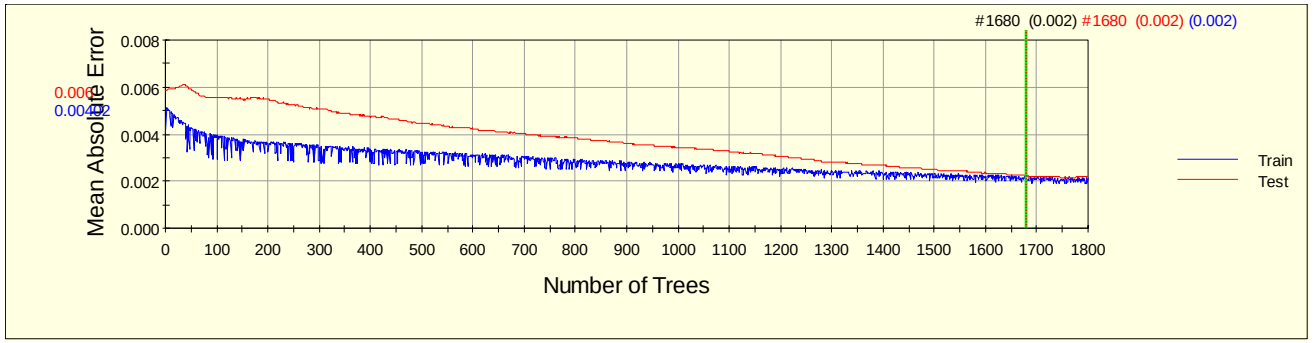

Figure 53: Response curve for the model of HKHEN combined (primary + secondary countries).

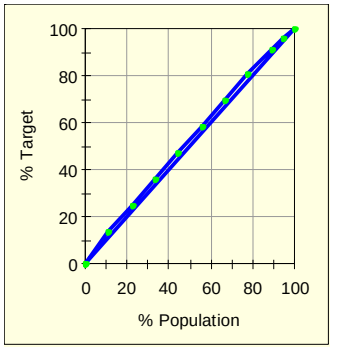

Figure 54: Gains chart for the model of HKHEN combined (primary + secondary countries).

A.4.1.3.4 Three Poles

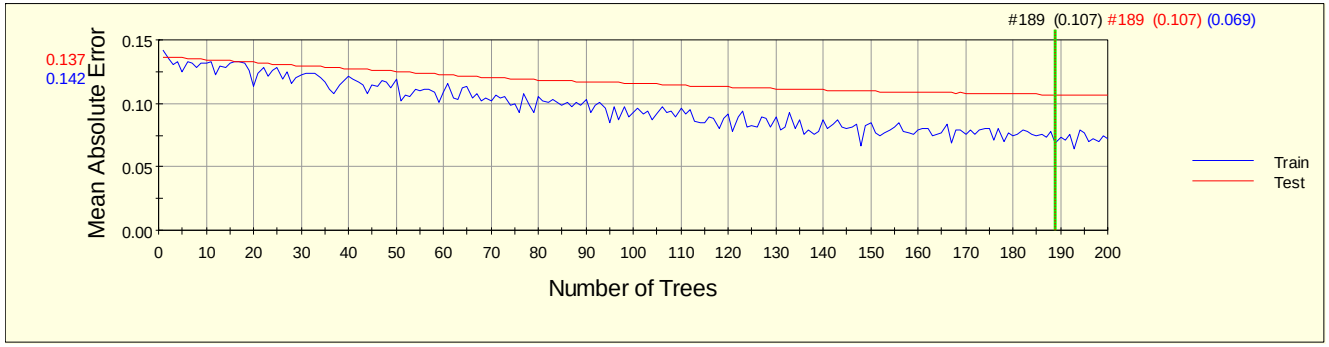

Figure 56: Response curve for the model of 3PEN combined (primary + secondary countries).

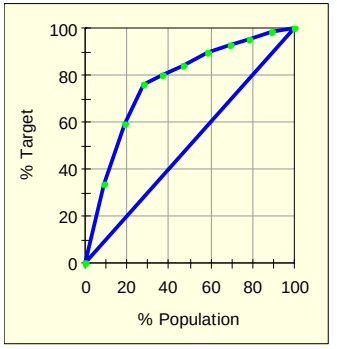

Figure 55: Gains chart for the model of 3PEN combined (primary + secondary countries).

A4.2 Least Concern Decreasing models

A4.2.1 Model primary countries

A4.2.1.1 Arctic

No data available (for details see seccion 9.2.2)

A4.2.1.2 Antarctic

No data available (for details see seccion 9.2.2)

A4.2.1.3 HKH

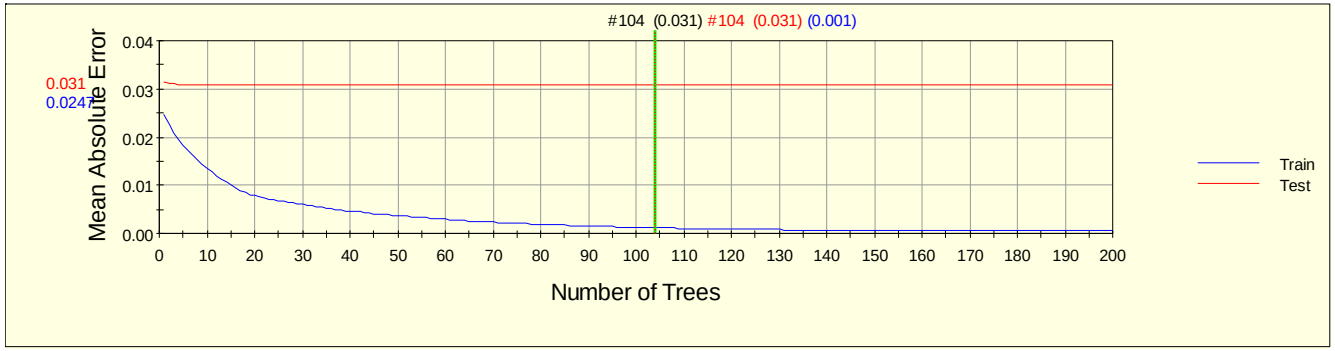

Figure 58: Response curve for the model of HKHLCD primary countries.

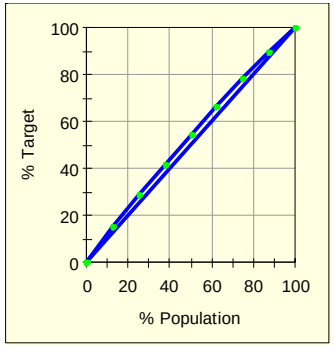

Figure 57: Gains chart for the model of HKHLCD primary countries.

A4.2.1.4 Three Poles

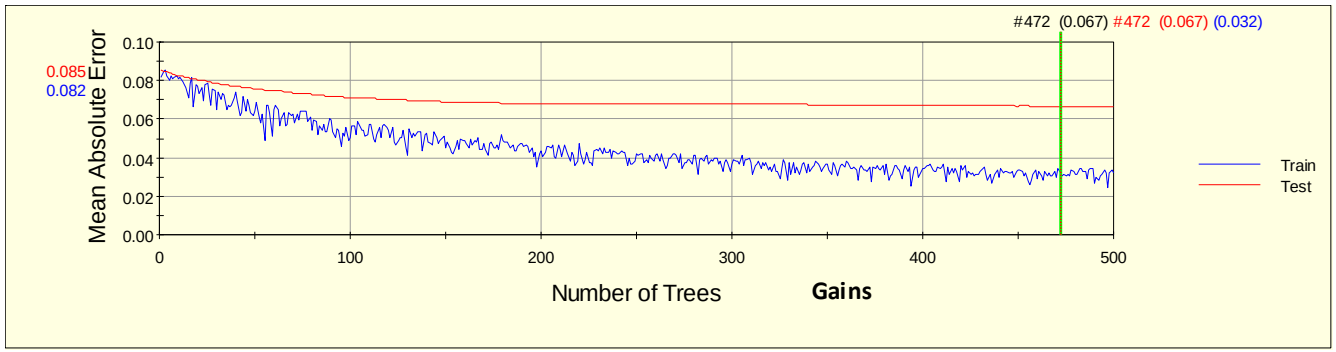

Figure 59: Response curve for the model of 3PLCD primary countries.

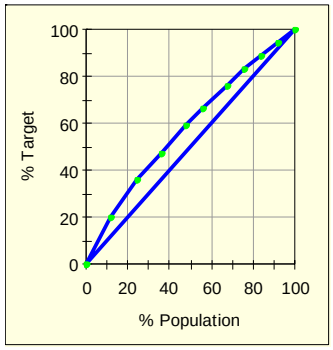

Figure 60: Gains chart for the model of 3PLCD primary countries.

A4.2.2 Model secondary countries

A4.2.2.1 Arctic

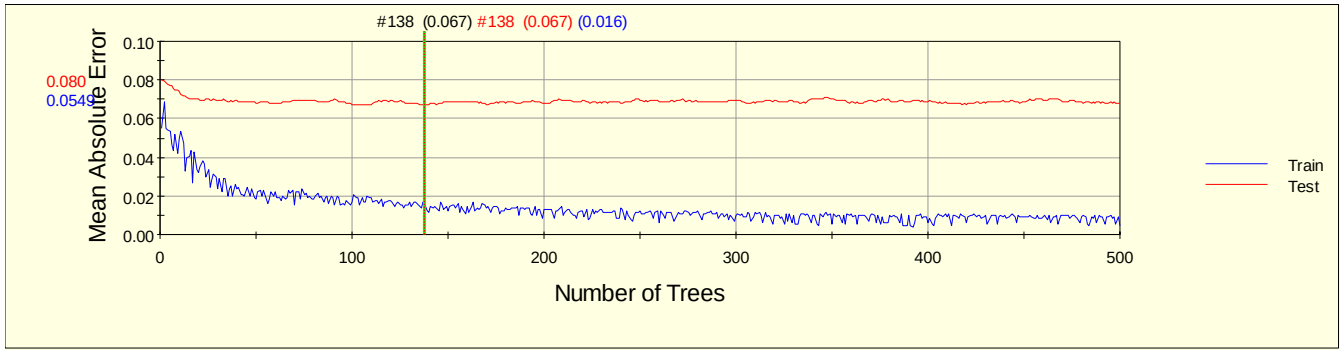

Figure 61: Response curve for the model of ARCLCD secondary

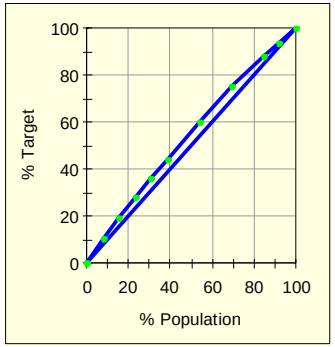

Figure 62: Gains chart for the model of ARCLCD secondary countries.

A4.2.2.2 Antarctic

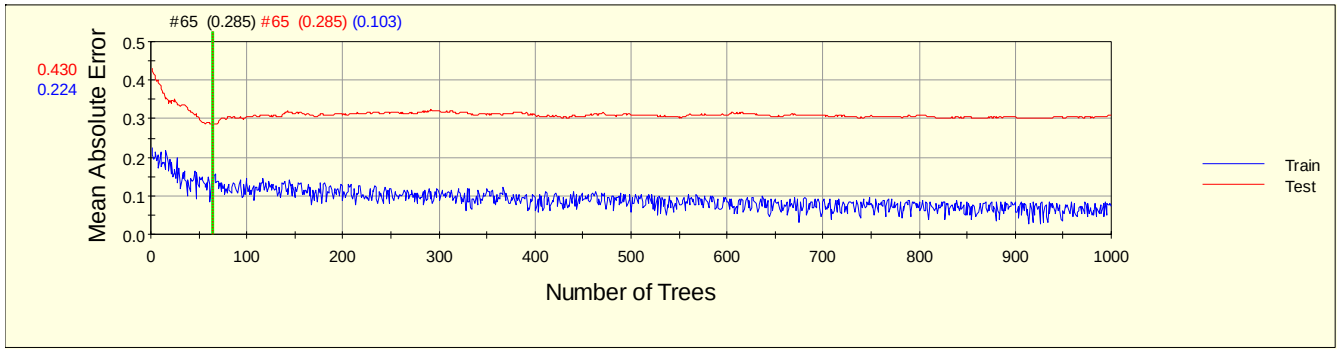

Figure 63: Response curve for the model of ANTLCD secondary

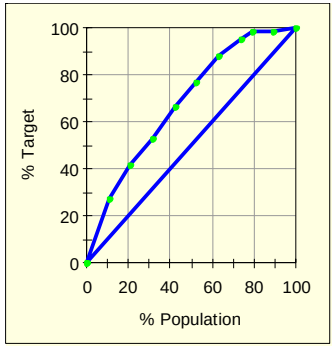

Figure 64: Gains chart for the model of ANTLCD secondary countries.

A4.2.2.3 HKH

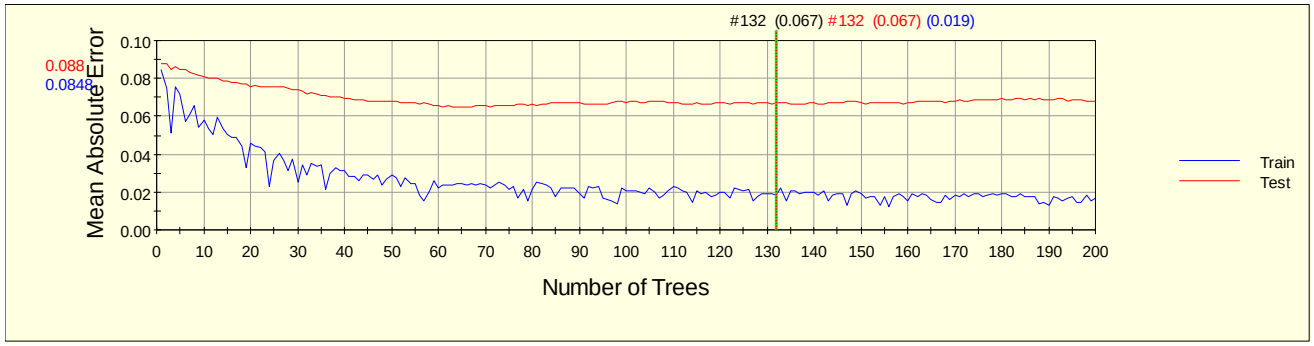

Figure 65: Response curve for the model of HKHLCD secondary countries.

Figure 66: Gains chart for the model of HKHLCD secondary countries.

A4.2.2.4 Three Poles

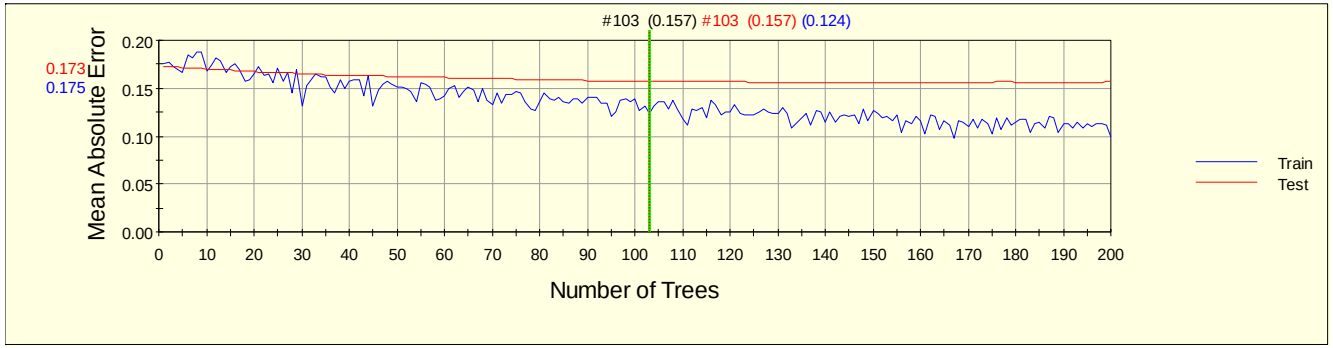

Figure 67: Response curve for the model of 3PLCD secondary countries.

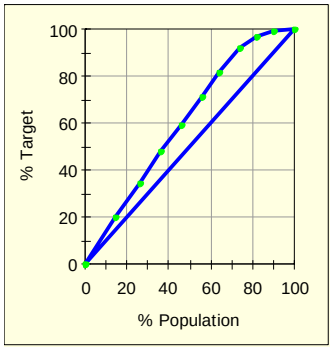

Figure 68: Gains chart for the model of 3PLCD secondary countries.

A4.2.3 Model combined

A4.2.3.1 Arctic

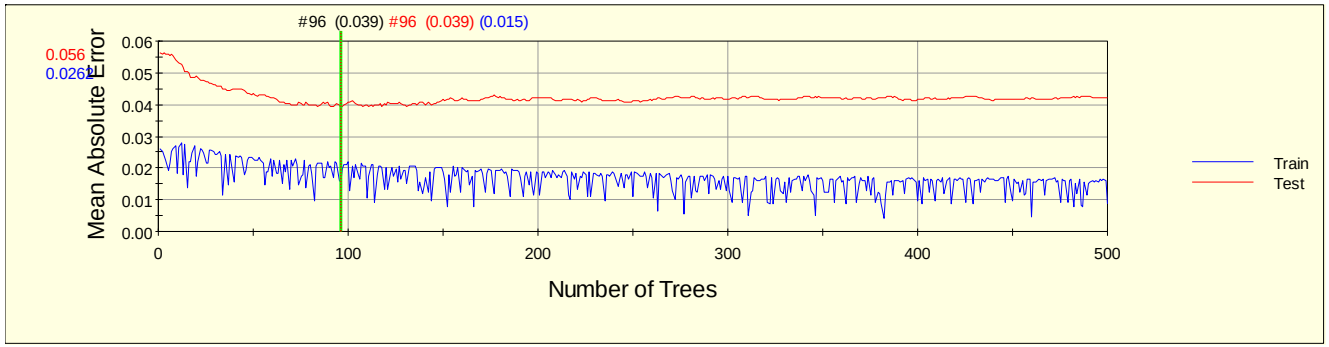

Figure 69: Response curve for the model of ARCLCD combined (primary + secondary countries).

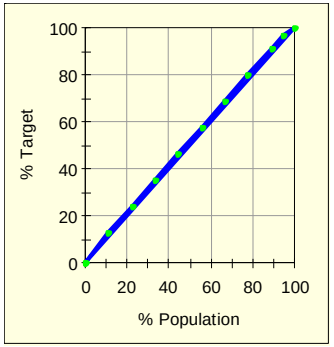

Figure 70: Gains chart for the model of ARCLCD combined (primary + secondary countries).

A4.2.3.2 Antarctic

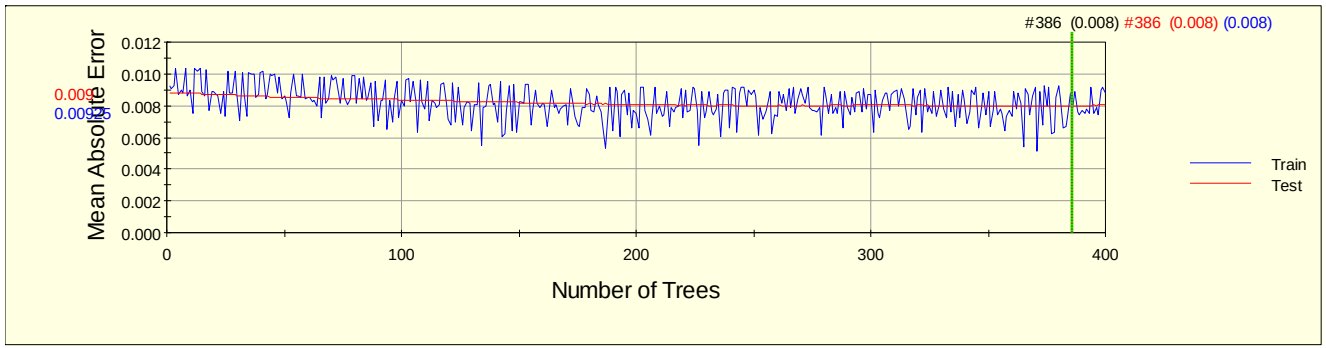

Figure 71: Response curve for the model of ANTLCD combined (primary + secondary countries).

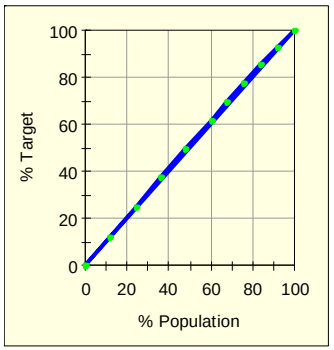

Figure 72: Gains chart for the model of ANTLCD combined (primary + secondary countries).

A4.2.3.3 HKH

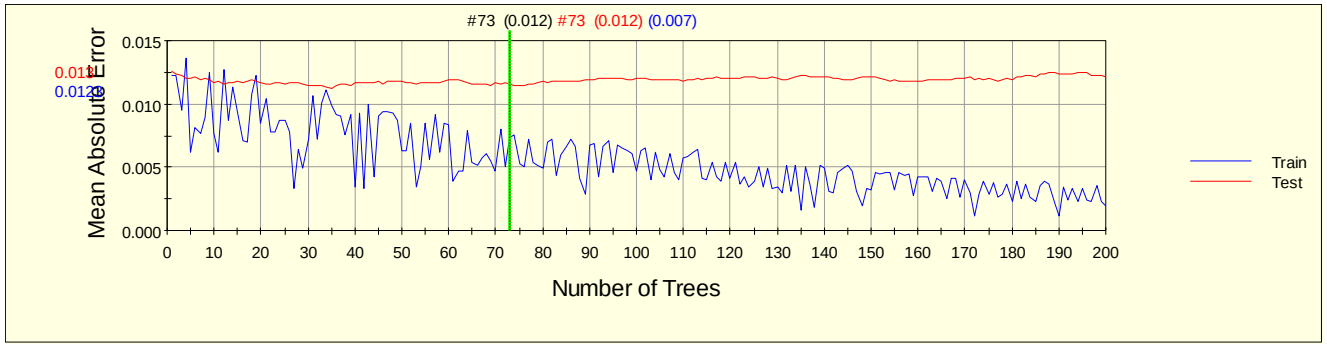

Figure 73: Response curve for the model of HKHLCD combined (primary + secondary countries).

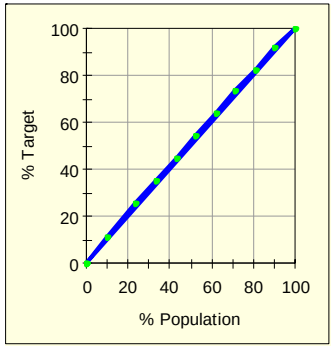

Figure 74: Gains chart for the model of HKHLCD combined (primary + secondary countries).

A4.2.3.4 Three Poles

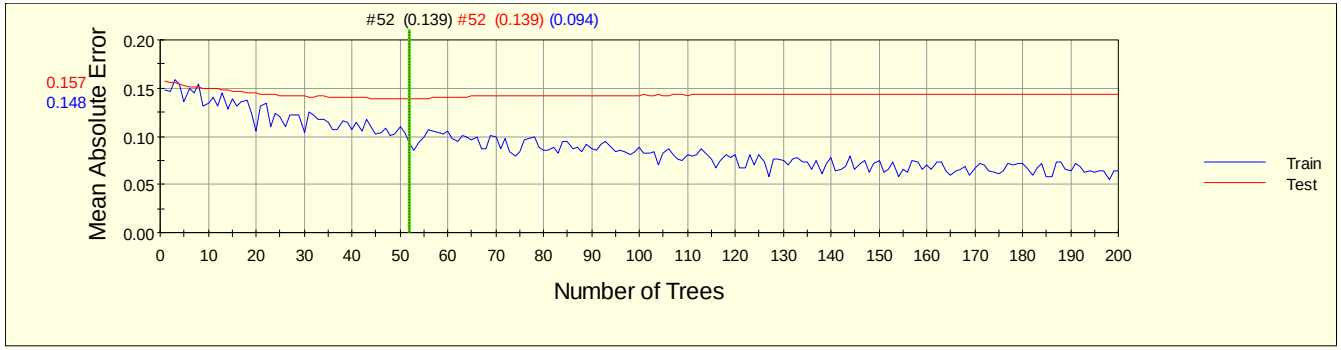

Figure 75: Response curve for the model of 3PLCD combined (primary + secondary countries).

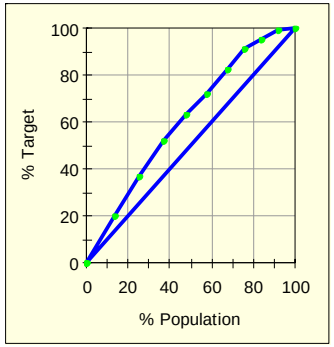

Figure 76: Gains chart for the model of 3PLCD combined (primary + secondary countries).

Appendix 5: Metadata (abstract)

Here I present an abstract of the metadata. For the complete version of metadata, please see the XML file version online.

These data are part of a M.Sc. thesis by the author Cynthia Resendiz with the Master of International Nature Conservation (MINC) program from Georg-August University (Germany) and Lincoln University (New Zealand). This dataset represents a unique compiled data set for the Three Poles regions (Arctic, Antarctic and Hindu Kush-Himalaya). It consists of 24 datasets, classified by country and by pole. The raw data was taken from the World Development Indicators from The World Bank (2012), the IUCN Red List of Theratened Species version 2012.2. (IUCN 2012) and bird distribution maps provided by BirdLife (BirdLife and Nature Serve 2012). The maps were processed in ArcGIS 10.1 to link species and countires. Each dataset contains the total of birds divided into endangerement categories (critically endangered, endangered, vulnerable and near threatened) and birds in the least concern category with populations that are decreasing. Each dataset contain a selection of socioeconomic indicators, averaged for the period of time 2000-2011 and presented by country.

Data are available for download and in three categories:
1) The data on socioeconomic variables provided by The World Bank.
2) The data on the IUCN categories.
3) The bird distribution maps of the Three Poles

See a detailed listing of data in the M.Sc. by the author.

This dataset is used for a M.Sc. thesis by the author, and freely available upon request. For questions and details we suggest contacting the authors.