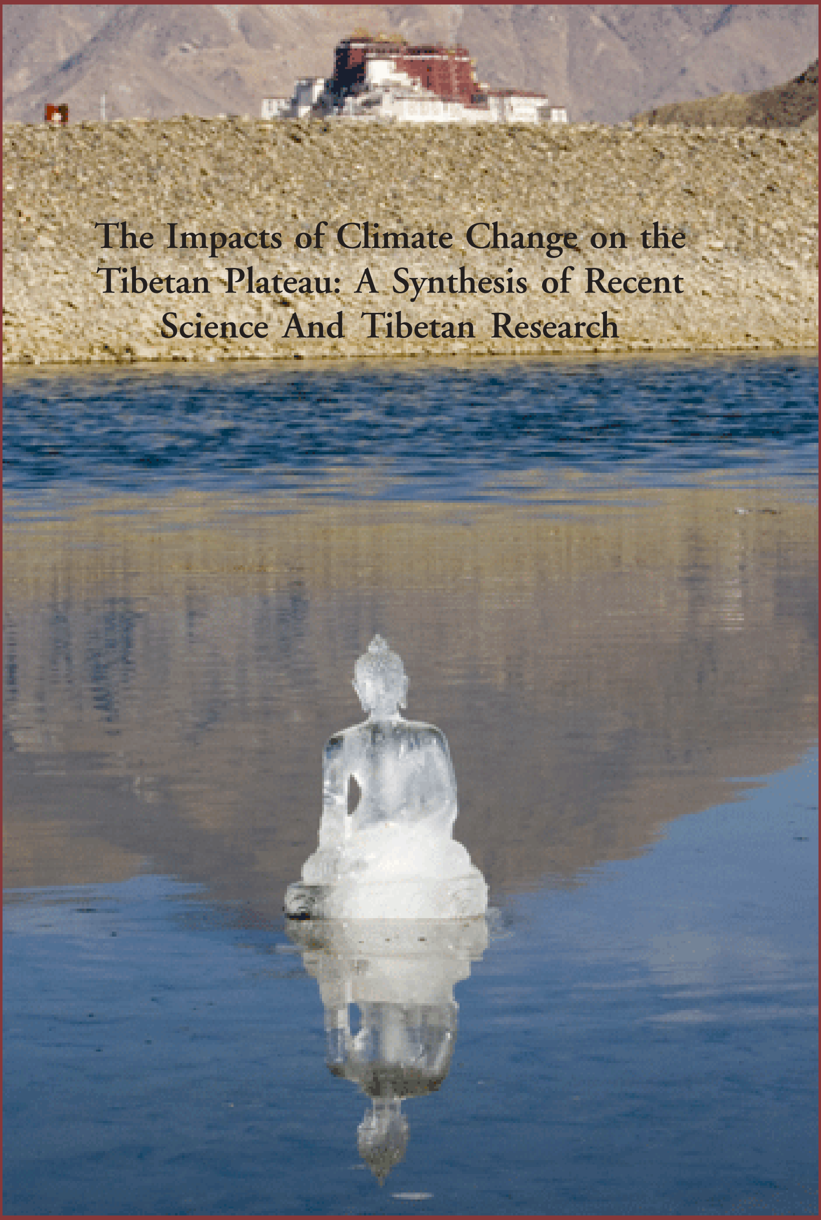
The Impacts of Climate Change on the Tibetan Plateau: A Synthesis of Recent Science And Tibetan Research



Environment and Development Desk
Department of Information and International Relations (DIIR)
Central Tibetan Administration
Dharamshala - 176215
H.P. INDIA

The Impacts of Climate Change on the Tibetan Plateau: A Synthesis of Recent Science And Tibetan Research

Environment and Development Desk
Department of Information and International Relations (DIIR)
Central Tibetan Administration
Dharamshala - 176215
H.P. INDIA
Tel: +91-1892-222457, 222510, 224662
Fax: +91 - 1892-224957
E-mail: edd@gov.tibet.net
Website: www.tibet.net

Number of copies: 1000

ISBN : 978-81-86627-92-1

Published by:
Environment and Development Desk
Department of Information and International Relations (DIIR)
Central Tibetan Administration
Dharamshala - 176215
H.P. INDIA
Tel: +91-1892-222457, 222510, 224662
Fax: +91 - 1892-224957
E-mail: edd@gov.tibet.net
Website: www.tibet.net

Printed at: Vee Enn Print-O-Pac
New Delhi # 011-66605040

Cover Image by Tibetan Artist Gade, part of his Ice Buddha series of photographs of his art installation of Shakyamuni Buddha carved out of ice, melting into the Kyichu below the Potala Palace. Downloaded from www.asianart.com

CONTENTS

Executive summary i

Introduction 1

The Significance of the Tibetan Plateau 1
Glaciers and Rivers 2
Permafrost Soils as Carbon Sinks..4
Alpine Grasslands and Meadows..5
Wetlands as Carbon Sequesters..6
Influence on Asian Monsoon Pattern..................................9
Climate Feedback from the Prevailing Tibetan Plateau.........10
Retreating Glaciers and Permafrost Thawing...10
GHGs Emission from Shrinking Lakes and Wetlands............................12
Loss of Carbon Sinks from Degraded Grasslands..................................12

Impacts on the Tibetan Plateau 12
Rise in Temperature.. 13
Glacial Retreat...15
Permafrost Degradation... 20
Contraction of Lakes and Wetlands................................. 22
Contraction of Tso Ngonpo (Ch: Qinghai Hu)................ 23
Decrease in the Rivers run-off..24
Impacts on Plant and Animal Species...............................26
Degradation and Desertification of Grasslands: Exclusion of Pastoral Nomads.. 27
Does Exclusion of Grazing Improve the Grasssland?..........29
Food Security and Human adaptations.............................30
Positive Impacts...32

Human Causes 33
The onset of Permafrost Degradation: Highway Construction... 33
Grassland Degradation: Intensive Farming........................34
China's Global Climate Footprint....................................36
Resource Extraction and Mining.....................................38

Recommendations 41

Conclusion 44

EXECUTIVE SUMMARY

This report is the first by Tibetan scientists and social scientists to comprehensively survey the full range of scientific findings on all aspects of climate change on the Tibetan Plateau.

This synthesis report summarises over 150 recent research reports published in scientific journals, by Chinese and international scientists, all fully referenced.

Tibet is in trouble, as climate change is now happening faster than in many areas, with multiple impacts on human livelihoods, rangeland degradation, desertification, loss of glaciers and more, all detailed here. Trouble in Tibet means trouble downstream and downwind from Tibet, across Asia, where Tibetan rivers flow and Tibetan climate generates and regulates monsoon rains over Asia.

The Intergovernmental Panel on Climate Change rightly treats Tibet separately, since the plateau is close to two per cent of the land surface of our planet; and is a huge island in the sky, between four and eight kilometres above sea level, exerting a profound impact on Asia, even on the north Pacific. So the science says.

These are good reasons for Tibet, until now a net sequester of carbon, to attract worldwide attention. Though cold, Tibet also heats quickly in spring and summer, diverting the jet stream, establishing an intense low that draws monsoon clouds deep inland, into the heart of Eurasia. The Tibetan climate is alpine and desiccating, yet in places also humid and even subtropical where the Indian monsoon penetrates the mighty Himalayas. For all these reasons, the glaciers, snow peaks, innumerable rivers, lakes, forests and wetlands of Tibet have long provided major environmental services to Asia, from Pakistan to Vietnam to northern China. Tibetans did almost nothing to diminish those environmental services. There was almost no Tibetan industrialisation, damming of rivers, draining of wetlands, fishing, or hunting of wildlife. Tibet remained unfenced; its grasslands intact, its cold climate able to hold enormous amounts of organic carbon in the soil. The human population used land extensively and lightly, a mobile culture with its domestic herds and a deep knowledge of how to sustain the grasslands with a light touch, by moving on to allow the hardy grasses and sedges of the alpine meadows to regrow.

In recent years every one of these services has been damaged, so much so that Tibet is fast moving from being a net sequester of carbon to becoming a net emitter. In part this is due to the climate change that affects the whole planet, though the data available suggests it is happening faster in Tibet. Much of the damage is due to direct human interventions in Tibet, which now concentrate population in towns and cities, transport hubs and corridors, even concentrating nomads in settlements, their remaining animals fenced in, unable to move far. Millions of non-Tibetan settlers have moved in, supported by an energy-intensive importation of modern luxuries and basics which Tibetans had little use for. Huge areas of forest were cut for export to China; dozens of destructive, unregulated artisanal gold mines scarred the Tibetan earth and rivers, and now large scale industrial mining of copper, gold, chromite, oil and gas extract Tibetan resources for Chinese industry. The damming of Tibetan rivers, commercial fishing of Tibetan lakes, draining of wetlands, introduction of invasive alien species all compromise Tibet's ability to remain a carbon sink.

In addition to these localised impacts, global climate change is fast melting the most glaciated region on earth. In the short term this means greater river flows, floods, landslides and glacial lake outbursts. In the longer term -now measured in only a few coming decades- it will mean the loss of the glaciers, and with them the loss of year-round regulated flow through to the lowlands of Asia.

The permafrost frozen soils of much of the Tibetan Plateau used to hold water as ice in winter, thawing in spring to release water for wetland and pasture plants, and for freshly sown crops. Now that the temperatures are fast rising across Tibet, wetlands are drying, their stored carbon becoming methane vented to the sky. Carbon sinks become sources of atmospheric carbon. The permafrost area steadily shrinks. As ice in the subsoil active layer thaws into water it now drains away before plant roots can reach down to it. The result is desiccation and desertification, both now advancing rapidly.

On the rangelands decades of compulsory overstocking in the 1960s and 1970s set off a process of degradation which turns the carbon-rich living turf black, exposed to the gales and blizzards which are becoming more extreme, according to the latest science. Rangeland degradation is now so widespread that the plants, usually able to store most of their biomass and their carbon below ground, below the teeth of the grazers, away from the biting winds, now die. Quickly the high alpine meadows turn black, the soil is whipped away by gales, and all that is left is bare earth, with little likelihood of recolonisation by life for centuries. So extensive is the degradation of the rangeland that nomads are now compelled to leave their lands and herds, in the name of "ecological migration" and watershed conservation. The nomads could be integral to the rehabilitation of degraded rangelands, but instead they are excluded, a classic tragedy of the commons even though nomads always cared for commonly held land.

These are among the impacts of climate change documented in this report. Readers interested to check the evidence for this long list of detriment and decline will discover, in the endnotes, that there has been a huge research effort, largely by Chinese scientists, much of it published in specialist journals hard to obtain. While their findings sometimes differ, the picture that emerges is of a Tibetan Plateau now prone to heating, drying and more extreme weather, which in turn compromises the monsoons of both India and China.

Since Tibetans did so little to cause global climate change, but are now at the forefront of its impacts, we pray the world's governments, at Copenhagen and beyond, can act in the interests of the whole planet and not just their own short term interests.

We are distressed that, as Tibetans, we can no longer guarantee our Asian neighbours the environmental services we all used to take for granted. We pray wisdom may prevail and that all emitting countries, whether new or old emitters, will contribute to effective solutions. And we especially look forward to global assistance in financing the remediation of the Tibetan Plateau, so we can once more provide pure water and a monsoon engine that is no longer faltering and compromised.

Introduction

Climate change and its impact has been the most debated issue these days, simply due to its global and local impacts. In its worst scenario, it could wipe out several countries from the world map and threaten the very existence of human species. The scientist and climatologist have long forecasted this warming event and its impact, but it hardly mattered to most of the decision makers leading to poor environmental governance. Over the past few years, we have witnessed the consequences of our/their negligence in various forms: droughts, flooding, thinning of Antarctic ice caps, etc. Implementation of sustainable development, selection of energy efficient and environmentally sound technologies, clean coal technology, harnessing renewable energy, resource conservation, implementing cleaner production and clean development mechanism looks promising on papers and in pilot demonstrations. But in the race of urbanization, these options are pushed aside while the mainstream does exactly the opposite.

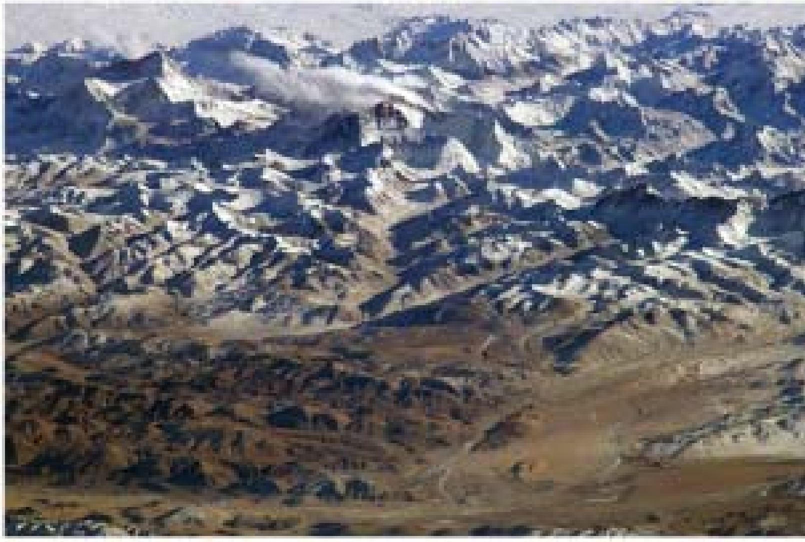
The unprecedented changes in global climate due to anthropogenic factors have seen affecting the polar ice caps but we are yet to witness the (human-caused) impacts of climate feedback and its carbon flux. Financially the climate-related natural disasters made 2008 one of the most devastating years on record as costs associated with weather-related catastrophes are put at about 200 billion US dollars in 2008. This amount is double as compared to the losses incurred in 2007.

Just as the two poles are heating up at an alarming rate, Tibet (*The Third Pole*) too is under its grip. Its plateau has been heating faster than previously anticipated, resulting in glacial meltdown, permafrost degradation, desertification of grasslands, changes in river hydrology, drying up of wetlands. These changes to the nature of Tibet, not only affect the food security but also disturbs the whole carbon balance over the plateau, affecting the neighboring countries.

In the following chapters we will present our arguments and concerns in parallel with research findings and observations made by scientist and researchers from all over the world.

The Significance of the Tibetan Plateau

As referred to 'The Third Pole'[1] and 'The Water Tower of Asia'[2], these recent names bestowed on Tibet are self explanatory in valuing its snow capped mountains and its river sources. The Tibetan


Himalaya Range

Plateau contains more than 46,000 glaciers covering an area of 105,000 sq. km, the most glaciated region on earth. [3] It is guarded to the south by the mighty Himalayas, to the north by Kunlun, to its west by Hindu Kush and Pamir ranges. Since time immemorial, the plateau holds the Hindu Kush Himalayan Ice Sheet, considered as the largest ice mass outside the poles[4] and is melting away. The scientists have so far identified 34 such glacial lakes on the northern slopes of the Himalayas. Runoff from these region's mountains feeds the largest rivers across Southeast Asia, including the Yangtze, Yellow, Mekong, Brahmaputra, Sutlej and Indus rivers.[5]

Glaciers and Rivers

These snow peaks and glaciers enable Tibet to be the source of four major rivers that meets much of Asia's water demand, for instance as much as 70% of the summer flow in the Ganges and 50-60% of the flow in other major rivers[6] and the Drichu (*Yangtze River*) river basin accounts for 40% of China's freshwater resources, more than 70% of China's rice production, 50% of its grain production, more than 70% of fishery production, and 40% of the China's GDP.[7] The Plateau provides Asia's fresh water resource from the deserts of Pakistan and India to the rice paddies of southern Vietnam, from the great Tonlesap lake of Cambodia to the North China plain.[8]

Yarlung Tsangpo or more famously known as the 'Brahmaputra

River' with an average discharge of 20,000 m^3/s originates from the glaciers of Mt. Kailash range in Tibet. This mighty river drains an area of 651,335 km^2 connecting Tibet (50.5%), India (33.6%), Bangladesh (8.1%) and Bhutan (7.8%).[9,10] Close to 47% of the world population thrives on the watershed originating from the Tibetan Plateau. With the major Asian rivers originating from its plateau, the total river basin area (as of 2003 data) is estimated above 5,477,700 km^2. That is 3% of the land surface of our planet. Beyond the populations residing in the watersheds of these rivers are the additional hundreds of millions or billions who depend on monsoon rains drawn inland by the Tibetan Plateau.[11]

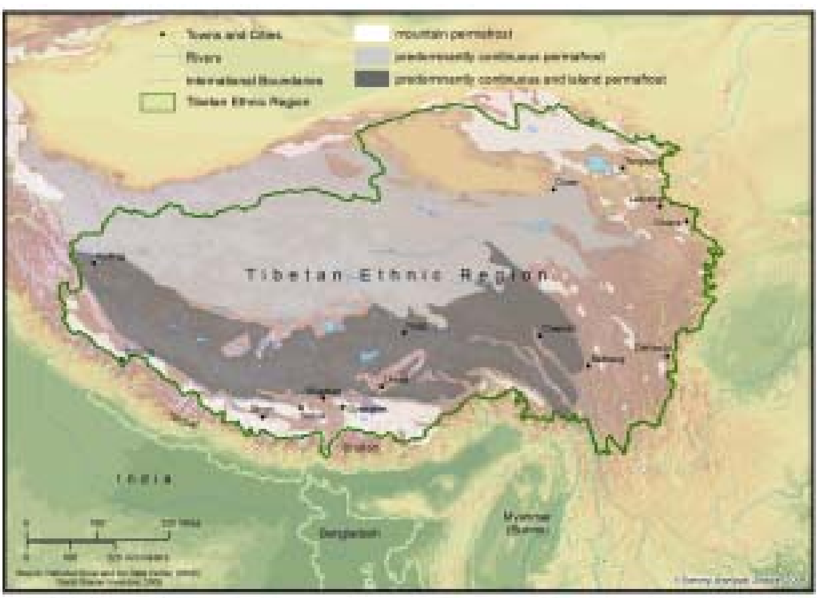
Zachu (Mekong); Image courtesy: Saigon Charlie

According to World Wildlife Fund for Nature (WWF), the Tibetan Plateau Steppe—one of the largest land-based wilderness areas left in the world—has the most pristine mountain grassland in Eurasia. Known as the "Roof of the World", this ecoregion has an average elevation of 4,500 metres (15,000 feet). From here several major rivers (including the Yangtze, Mekong and Indus) begin their long journeys to the sea. Due to its size and its position near the tropics, the Tibetan Plateau is one of the most ecologically diverse alpine communities on Earth.[12]

Permafrost Soils as Carbon Sink

About one third (23–48%) of the world's soil Carbon (*herein referred to as C*) is stored in the permafrost region.[13,14] Its degradation would lead to a huge amount of carbon entering the atmosphere, intensifying global warming. Unlike the ones that are widespread in the Arctic and boreal regions of Northern Hemisphere, the *permafrost* prevailing on the Tibetan Plateau (1.3-1.6 million km^2) are alpine permafrost due to its high altitudes.[15,16,17] Tibetan permafrost is warm permafrost, rich in ground ice, among the most sensitive to climate change and particularly vulnerable to warming temperature. The presence or absence of permafrost entails major variations in the soil's physical structure and the nutritional status of the soil.

Under the influence of warming climate over the Tibetan Plateau, the carbon release from its permafrost soil will take place due to the increased microbial decomposition of organic matter (*when the temperature rises above 0°C*).[18] Wang *et al* (2008)[19] indicated in their study that, there exist a significant statistical correla-



Tibetan Plateau Permafrost (Image courtesy: T. Wangyal Shawa)

Permafrost: *The subsurface earth materials remaining below 0°C for two or more years* tion between the thickness of the permafrost *active layer* and the vegetative cover in the Alpine landscapes of the Tibetan Plateau. The thawing of permafrost or increase in the active layer corresponds to the decrease in the vegetative cover. They estimated that the alpine permafrost on Tibetan Plateau stores about 12,300 million tons of C or 37% of the total grassland Soil Organic Carbon (*SOC*). A separate study conducted at the source region of the Machu (*Yellow River*) indicated that significant amount of methane are trapped in the permafrost layer of that region.[20]

The degradation of permafrost, besides disturbing the carbon balance over the plateau, will also lead to series of irreversible, yet gradual changes; it would result in the lowering of water table, loss of soil moisture content, drying of swamps, extinction of native plant species and desertification, it would also put the modern constructions at risk .[21,22,23,24]

Alpine Grasslands and Meadows

Tibet's rangeland, from the Northern Plateau of upper Tibet to the extreme eastern edge of the plateau, with an average altitude of 4500 meters, covers approximately 70% of the total area of Tibet. The types of rangeland vary from alpine meadows and mountain scrub to mountain sparse wood and mountain desert, which helps sustain domestic herds and nurture a wide variety of wildlife species.[25]

The Alpine grasslands (*alpine cold steppe and alpine cold meadows*) being the most dominant ecosystem on the Tibetan Plateau occupies over 60% of the total area and stores a large amount of organic carbon. The total SOC storage (*sampled from the top 1 meter soil*) in the alpine grasslands of Tibetan Plateau was estimated about 7.4 Pg C or 7400 million tons of C. The top soil in the alpine grasslands are enriched with Light Fraction Organic Carbon (LFOC) and the changes in the vegetative cover (*due to grassland degradation*) could easily loose a significant amount of LFOC. For instance, when the alpine meadow was severely degraded, the LFOC decreased by 92 percent. This easily released LFOC accounts for 34–54% of the total organic carbon (*TOC*).[26] Jin, H. J *et al* (2000) [27] in their permafrost study of the Tibetan Plateau indicated that during the

Active layer: *The top layer of permafrost soil that thaws during the summer and freezes during winter. The temperature in the lower levels of the soil will remain more stable than that at the surface, where the influence of the ambient temperature is greatest. This means that, over many years, the influence of cooling in winter and heating in summer will decrease as depth increases*

Tsekyok Grasslands; image courtesy: Losang

thaw season, the alpine meadows appear to absorb CO_2 at the rate of (1840–3050) $mg/m^2/day$.

The alpine (*cold swamp meadow*) soils of the Tibetan Plateau have approximately the same TOC content (14.4 kg/m^2 for the 0–0.30 m soil layer) as wetland soils in Arctic regions, but its TOC content is far higher than that of a tropical savannah.[28,29] With respect to the total carbon storage in the biomass of the Tibetan Plateau, it was estimated to be 1.87 Pg equivalent to 1870 million tons of C accounting to over 56% of the total biomass of grasslands of China.[30]

Wetlands as Carbon Sequesters

Wetlands throughout the world play a pivotal role in recharging the aquifers in the arid and semi-arid regions of the world. Wetlands in the Tibetan Plateau play a major role in regulating the flow of rivers and also are the major carbon stores. They act like sponge, absorbing water during the summer when the water is in excess and releasing it in the winter when the runoff is short. The recent warming of climate has resulted in much contraction of wetlands on the Tibetan Plateau. According to China Daily news report,[31] the contractions in the wetlands due to climate change have led to reduced flows of the Yangtze and Yellow rivers.

According to Chinese Scientists Jin, H. J. *et al* (1999 & 2000),[32,33] the fresh water wetlands on Tibetan Plateau cover

Lhalu wetland; image courtesy: Emily Yeh

approximately 1,33,000 km^2, in contrast to more recent statistics of 48,070 km^2 from Ding, W. X *et al* (2004 & 2007).[34,35] With their wealth of stored carbon, these wetlands provide a potential sink for the atmospheric carbon.[36]

If not managed properly they could become a source of greenhouse gases (GHGs). In one recent study conducted by *Zhang Fawei, Liu Anhua, Li Yingnian, Zhao Liang, Wang Qinxue and Du Mingyuan*, it was observed that the role of wetland as a carbon sink or source was closely related with the water table and the amount of precipitation.[37] According to it, the alpine wetlands of Haibei (*Northeast of the Tibetan Plateau*) absorbed about 316 g CO_2/m^2 during the growing season and emitted 546 g CO_2/m^2 in the non growing season. The wetlands of Lhalu (*situated to the northwest of Lhasa*), with its total area of 6.2 km^2 could absorb 78,800 tons of C and produces 57,300 tons of oxygen annually.[38]

The SOC storage in the Tibetan Plateau represents 2.5% of the global pool, although Tibet is only 1-7% of the earth's land surface 8% is stored in cold wetlands. This remarkably high organic carbon concentration in the cold wetland is due to the low rate of organic matter decomposition. Statistics of the natural wetland area (*excluding lake and floodplain*) by geographic regions in China revealed that the Tibetan Highland holds over 51% of total natural wetlands (*dominated by Salt Marsh, Peatland and Freshwater*

Marsh).[39] According to the calculations of Jin, H. J. *et al* (1999),[40] the annual CH_4 (*methane)* emissions from freshwater wetlands on the Tibetan Plateau were estimated between 0.75 to 1.05 Tg (1 Tg = 1 million ton) whereas, Ding, W. X. *et al* (2007 & 2004) [41,42] estimated the total emission to 0.56 Tg (0.56 million tons) from Salt Marsh, Peatland and Freshwater Marsh.

Wetlands may affect the atmospheric carbon cycle in four different ways.[43]

- i Wetlands may release carbon if the water levels are lowered or due to anthropogenic activities or poor land management. Warming climate will result in the melting of permafrost soils and subsequently emit methane hydrates entrapped by these wetlands.
- ii Many wetlands may continue to sequester/ absorb carbon from the atmosphere through photosynthesis and subsequent carbon accumulation in the soil.
- iii Wetlands tend to trap carbon-rich sediments from watershed sources, but may also release dissolved carbon through water flow into adjacent ecosystems. Such horizontal transport pathways may affect both sequestration and emission rates of carbon.
- iv Climate change may also affect the role of wetlands as a source and sink of GHGs.

As a result of increased temperature, the permafrost melts and ultimately leads to reduced carbon storage and sequestration by the wetlands. However, it was stated that[44,45] low summer temperatures (below 20°C) on the Tibetan Plateau lowered the CH_4 production and its emissions.

Influence on Asian Monsoon Pattern

The Tibetan Plateau plays an important role in generating regulating the Asian monsoon. In summer, the vast lands of Tibet and south Asia become hotter than the Indian Ocean, leading to a pressure gradient and the flow of air and moisture from the sea. The Tibetan Plateau begins this process in spring: as the land surface absorbs more sunlight than the atmosphere, the plateau creates a vast area of surface warmer than the air at that elevation, thereby

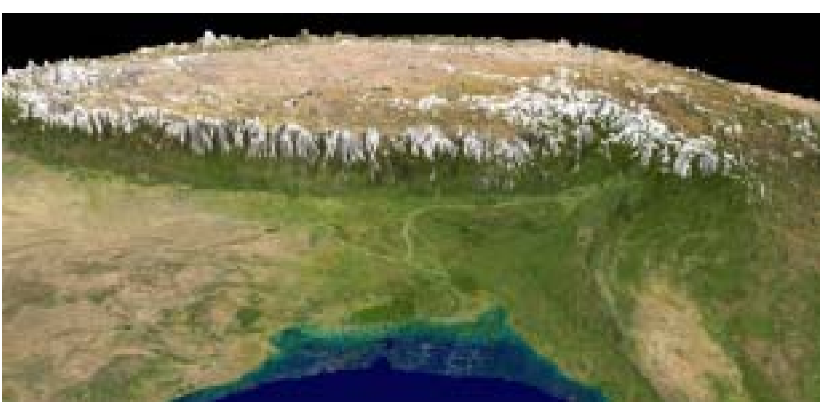
CH_4 (Methane): 21 times more Global Warming Potential (GWP) than Carbon dioxide

increasing the land–ocean pressure gradient and intensifying the monsoon.[46]

According to studies by Cheng and Wu (2007)[47] and Lin *et al* (2004)[48] the ground freezing and thawing of the Plateau have a significant influence on the atmospheric circulation. The rise in the soil moisture content (*due to subsoil active layer thawing*) increases the level of heat exchange between the atmosphere and ground surface. Heat and moisture variations produced by these processes play an important role in the climate of East Asia. For instance, the onset of summer precipitation in Southern China and in the (*middle and lower*) basin of the Drichu (*Yangtze River*) are influenced by the spring thaw timing over the Tibetan Plateau. According to Ding *et al* (2009)[49] there exists a significant relation between the spring snow depth over the Tibetan Plateau and the amount of summer precipitation on the middle and lower basins of Yangtze River.

The plateau's seasonal heating during summer and spring plays a principal role in determining the large-scale Asian weather circulation in summer. Heating over the Tibetan Plateau tends to generate a surface cyclonic circulation and upper-atmosphere anti-cyclonic circulation which results in the appearance of a large air motion in the eastern side of the plateau. Hence the summer monsoon of East China is attributed to the heating up of the Tibetan Plateau.[50]

It is found that the snow depth anomaly, especially in winter, is one of the factors influencing precipitation in China; however, it is perhaps not the only one. Nevertheless, it is proved that the winter snow anomaly over the Tibetan Plateau is relatively more



Upliftment of the Tibetan Plateau; image courtesy: NASA important than that in spring for the regional precipitation in China.

The increase of both snow cover and snow depth can delay the onset and weaken the intensity of the summer monsoon obviously, resulting in a decrease in precipitation in southern China and an increase in the Yangtze and Huaihe River basins.[51]

Climate Feedback from the Prevailing Tibetan Plateau

The interconnectivity of the climate system is truly amazing, yet sad. Recent studies have demonstrated how the emission of GHGs in one part of the world enhances the glacial retreat and permafrost melting in another part. As mentioned in the previous section, its glaciers, snow capped mountains, permafrost soils and its alpine wetlands hold a large reserve of carbon. These carbon pools are now beginning to disintegrate with the current trend of warming over the plateau, resulting in further emissions of GHGs. At present, the plateau is undergoing a multi-faceted environmental degradation; the melting of glaciers, non-sequential thawing of permafrost, drying up of wetlands and head region of river, and the failure to assimilate atmospheric carbon due to the vast desertification of grasslands. This would further enhance the warming process and will have an adverse effect on the plateau and its neighboring countries.

With the wealth of carbon (*main component of GHGs*) trapped/stored in its natural landscapes, the Tibetan Plateau becomes one of the most significant land features on the earth.

Retreating Glaciers and Permafrost Thawing

Recent studies have shown that glacial melting and thawing of permafrost on the Tibetan Plateau will lead to a large scale release of GHGs in the atmosphere and would bring further changes in the already warming climate.

The permafrost layers and the seasonally frozen soils on the Tibetan Plateau were well preserved over a long time by low winter air temperatures. Its seasonal thawing and refreezing have also played a vital role in balancing the delicate alpine vegetations, until now.


Permafrost degradation on the Tibetan Plateau

With the significant increase in the mean cold season average temperature,[52] the permafrost layers and seasonally frozen grounds are slowly degrading leading to increased microbial decomposition[53] of previously frozen organic carbons. This results in the release of carbon dioxide and methane from terrestrial ecosystems to the atmosphere. Such feedbacks from the thawed permafrost and *thermocast* cannot be offset by the present ecosystem mechanisms.

In general, the permafrost thawing occurs (*gradually*) as the thickness of the soil active layer increases. Higher summer temperature, warmer winters and infiltration of precipitation leads to the degradation of permafrost by increasing its active layer. Schur *et al* (2008), say that the transfer rates of carbon to the atmosphere are always higher after the permafrost are thawed compared to the organic carbon stored in permafrost. And the emissions to the atmosphere are controlled by the size of the carbon pool emerging from permafrost and by the dominant continuous processes of microbial decomposition. Such decomposition of permafrost carbon in presence of oxygen will primarily release CO_2 and in an absence of oxygen will release CH_4 (*methane*) and CO_2.[54]

Thermocast: *Refers to land surface that forms as ice-rich permafrost melts.*

GHGs Emission from Shrinking Lakes and Wetlands

With the total area of 133,000 sq km, the fresh water wetlands of the Tibetan Plateau could easily be transformed into a source of GHGs if the warming climate continues. The subsequent release of CO_2, CH_4 and NO_2 (*nitrogen dioxide*) from these contracting wetlands further adds up to the yearly GHGs emission. According to Jin *et al* (*who conducted their study at Qinghai Huashixia Permafrost Station, about 70 km from Matoe; Ch: Maduo*),[55] thaw season was considered a significant period for methane emission from the fresh water wetlands. They estimated the methane emission from the wetlands amounting to 0.7–1.05 Tg (*equivalent to 0.8 million tons*) per year (*during the 150–210 days of thawing season*). Consistent with that, in a separate study,[56] the annual NO_2 emission from the wetlands of Tibetan Plateau are estimated at (0.022–0.025) Tg. In short, with respect to Global Warming Potentials (GWP) of CH_4 and NO_2, the Tibetan Plateau will emit approximately 26 million tons of CO_2 yearly to the atmosphere, which could even rise higher (*in time*) in accordance with the prevailing condition, i.e. early and prolonged permafrost thawing season. Adding up the total GHG emission of CO_2 (316.02 g CO_2/m^2)[57], CH_4 and NO_2 from the Tibetan Plateau wetlands in a year (*irrespective of their atmospheric stability and in terms of CO_2 GWP*), it sums up to approximately 68 million tons of CO_2. Roughly equivalent to CO_2 emitted by 10 million average automobiles (50km/day) for two months in China (212 g CO_2/km).[58]

Loss of Carbon Sinks from Degraded Grasslands

The rise in ground temperature due to the permafrost degradation is among the climate warming-driven changes documented on the Tibetan Plateau. This warming climate influences the emission of soil carbon from the grasslands and meadows. Wang *et al* (2008), has reported that, the changes of grassland vegetative cover from 1980-2000 was responsible for losing 1.8 Tg C (1.8 million tons of C) from 0-0.3m depth of the soil of which 65% accounts for the LFOC.[59]

Impacts on the Tibetan Plateau

The Tibetan Plateau is currently experiencing the impacts of Climate Change in its worst form, with the current warming of the mean air temperature further enhancing this warming process, there

***NO_2* (Nitrogen dioxide):** *310 times more GWP than Carbon dioxide* is further input of GHG from the climate feedback and ongoing human activities. As a result, the glaciers are retreating, grasslands are degrading, lakes and wetlands are shrinking, rivers are drying. The immediate costs of the climate change impacts are borne by those innocent herders and villagers who have been living in harmony with nature for generations. Julia Klein,[60] points out that climate warming is an unusual environmental problem since the primary GHG emitters driving these changes can be far distant (*due to the large spatial disconnect between drivers and recipients*) from the most vulnerable recipients of the climate change effects.

> **According to the China National Climate Change Assessment Report published in early 2007, scientists from twelve different departments (*including China's Ministry of Science and Technology*), foresee a 5-10% reduction in agricultural output by 2030, more droughts, floods, typhoons and sandstorms, and a 40% increase in the population threatened by plague.**

The report also mentioned the possibility of damage to the recently built Tibetan railway.[61]

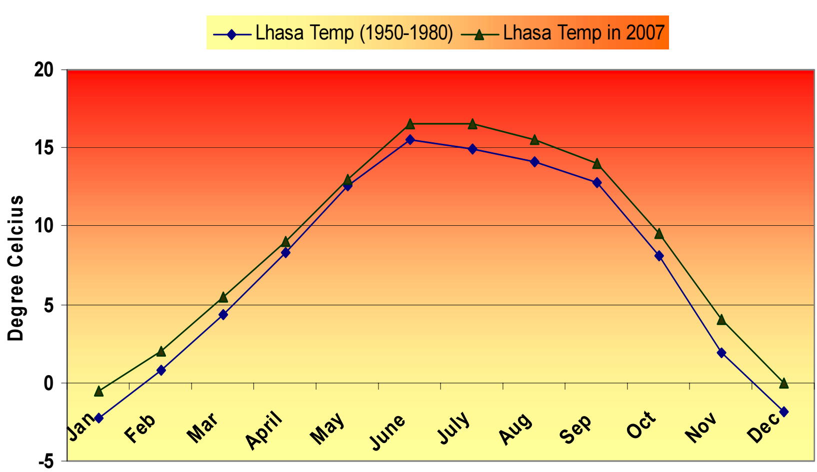
Critical components of Tibet's ecosystem are undergoing major transformations due to climate change. It has led to the reduced flow in many rivers that are a primary source of Asia's water systems. Abnormal weather conditions due to climate change such as non-sequential rainfall, delayed in milking season, reduced growth of calf, etc., has made subsistence farming and herding more unpredictable, thus impacting the livelihoods of a majority of Tibetans. Frequent landslides are causing land-use disruptions in the region. In addition, glacial lake outbursts and floods have increased in recent years.

Rise in Temperature

According to the Intergovernmental Panel on Climate Change (IPCC), the average temperature of the Earth's surface has risen by 0.74°C in the past century (1906-2005), and over the last 50 years, temperatures in Earth's Polar Regions of Arctic and Antarctica rose by 0.2°C and 0.5°C per decade. It was observed that the increase in air temperature was more significant in cold season than in warm season leading to rise in the Mean Annual Ground Surface Temperature (MAGST). Increase in the mean cold season air temperature plays a major role in changing the landscapes dominated by seasonally frozen grounds[62] especially on the Tibetan Plateau. A separate study by H. Jin *et al* (2007)[64] indicated that the ground temperature on the Tibetan Plateau at the shallow soil depths in transition and quasi-stable permafrost zone has been increasing noticeably, as a result leading to the shrinkage of permafrost boundaries. For instance, along the main Siling Lhasa Highway—SLH (*Ch: Qinghai–Tibet Highway–QTH*), the southern lower limit of permafrost have moved 10 km northward and the northern lower limit has moved 3 km southward. They also reported that the ground temperature (*at the depth of 6-15 m*) at Kunlun Pass have increased (0.2-0.4) °C in the past 15 years (1982-1997).

The Tibetan Plateau has experienced a sudden rise(s) in temperature since the early 1970s, long before the signs of global warming were generally recognized.[63]

According to Phil Mckenna (*a freelance environmental writer*), the Tibetan Meteorological Bureau (2007) indicated that the annual mean temperature in the "Tibet Autonomous Region" ("TAR") is rising at a rate of 0.3°C each decade, twice the global average.[66] In this regard, Tibet is considered as the third pole of the Earth where the climate change is as dramatic as it is on the Polar Regions.



Average air temperature in Lhasa (capital city of Tibet), 1950 – 1980 & 2008

Now the average temperature in Lhasa[67] (*the capital city of Tibet*) for 2008 was recorded 8.75°C. Comparing this data with the mean average (7.4°C) for 30 years[68] (1950–1980) clearly indicates that the Tibetan Plateau is heating up. This warming has led to an increasingly early seasonal melt of glaciers and permafrost. The rise in temperature will also have its effect on the rate of evaporation from the rivers and watershed areas intensifying the desertification process.

According to China National Climate Change Programme (2007),[65] the air temperature on the Tibetan Plateau is predicted to increase by 2.2-2.6 °C by 2030. This in turn will melt the region's glaciers and permafrost at an accelerating rate.

According to Immerzeel (2008)[69], eco-payment for the Tibetan farmers could solve the future water crisis up to certain extent. This should be the future discussion agenda for the Copenhagen decision makers.

At first glance, the warming of a cold plateau might seem benign. But a more detailed look at the specific impacts of climate change suggests alarming consequences.

In recent years, Tibet has experienced extreme weather phenomena such as snowstorms and windstorms. In 2007, the Ngari prefecture in Western Tibet experienced nine continuous days of gale force wind and dust storms, a 20-year record high. In June of the same year, most areas in Ngari reported an average temperature increase of 1 to 2°C and an average decrease in precipitation by 20 to 90 percent.[70] In the arid regions of upper Tibet, this has been disastrous. In January 2002, counties in Ngari Prefecture were worst hit by the blizzards and the snow was as deep as 120 cm.[71] Also back in 1997, in northeastern Tibet, a snowstorm disaster affected some 58,000 herders in Yushul Prefecture and Golog Prefecture in September following a dry summer in the same year.[72]

Glacial Retreat

Many glaciers in Tibet are retreating due to the ongoing changes in the climatic variables over the plateau. In a more recent study,[73] covering the sensitivity to change of cold glaciers, it was indicated that changes (*rise*) in the air temperature affects the glacier runoff more sensitively than other variables. The warmer air coupled with less snow and more rain would significantly increase the glacial runoff. In other words, less snow and more rain would mean decrease in the surface albedo (*resulting in more solar heat absorption and more glacial runoff*). Chinese scientist also predicts that 2/3rd of the present glacial cover will disappear by the end of this century. And most of all, to further increase the current worries, there has been no net accumulation of snow since 1950 over these mountains.[74] According to Jane Qui (2008),[75] 82% of the Tibetan Glaciers have already retreated in the past half century. In the past 40 years, Tibet's glaciers have shrunk by 6,600 sq km (as of year 2006). It is estimated that they are currently melting at a rate of 7% per year. Gou *et al* (2006), has developed a tree-ring width chronology from Qiemuqu valley showing that trees in the area recorded glacier variations on the northeastern Tibetan Plateau.[76] They also indicated that the glaciers on the edge of the mountain regions are more sensitive to climate change; as a result a dramatic retreat of glaciers on the Eastern and Southern part of the plateau were observed.

Furthermore, it was also reported that the dramatic retreat of all the glaciers on the Tibetan Plateau in the 1990's is related to the continuous warming on the plateau since 1980s.[77] An increasingly concerned United Nations has warned that Tibet's glaciers could disappear within the next 100 years.[78] In the short run the glacier melt may increase water availability, but eventually when the base flow from glaciers will cease, it will have a drastic impact on the river hydrology. Such glacial meltdown will not only make a significant impact on the Tibetan Plateau, but also for those nations that are downstream and which depend on permanent glaciers for a reliable supply of water.

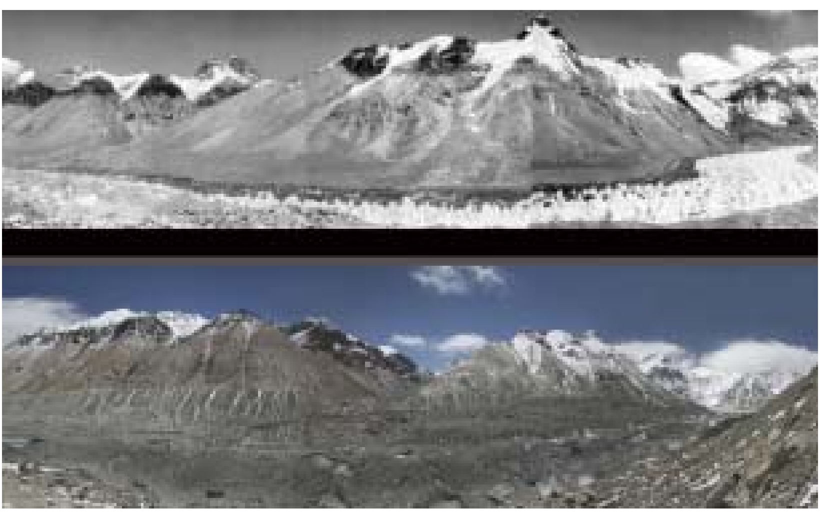
According to a UN climate report, the Himalayan glaciers that are the sources of Asia's biggest rivers—Brahmaputra, Yangtze, Mekong, Salween, Yellow, Indus, and Karnali—could disappear by 2035 as temperatures rise.[79]

The melting of glaciers and the permafrost in recent years has destabilized hillsides and resulted in landslides. For example, Pareechu, a tributary of the Sutlej in Tibet, was blocked by a massive landslide in the Tibetan area, forming a natural but unstable rockfall dam. In the years 2000 and 2005 Pareechu lake burst in Tibet causing heavy destruction of livelihoods, infrastructure, and socio-economic assets in the basin, particularly in Kinnaur and Shimla districts in Himachal Pradesh, India.[80]

Similarly, on April 9, 2000, a super-large landslide occurred along Zhamu Creek, South east Tibet. Consequently, a landslide dam was formed and the Yidwong Tsangpo (*Ch:Yigong Zangpo*)—a tributary of Yarlung Tsangpo was blocked.[81] On June 10 of the same year, the dam broke caused flash floods, causing the deaths of 30 people and the disappearance of more than 100 others. This flash flood in five downstream districts of Arunachal Pradesh in Eastern India, left behind 50,000 people homeless and damaged more than 20 big bridges along with other infrastructure. The total economic loss was estimated at more than 1 billion rupees (22.9 million USD).[82]

The scale of glacial melting can be seen at Rongbuk glacier on the northern slope of Mt. Everest (*Tb: Jhomolangma*). Between 1966 and 1997, this glacier receded by up to 270m in its middle, 170m at its eastern side, and 230m at its far-east side. A glacier cliff in east Rongbuk, which was recorded as being at 5600 m above sea level in 2002, has now totally disappeared.[83]

Similarly, the Zepu glacier of southeast Tibet has thinned by more than 100 m in the last three decades.[84] According to one study, glaciers on the edge of the Tibetan Plateau melt faster than those in the middle. During the last 30 years, glaciers in the eastern



Rongbuk glacier on the northern slope of Mt. Everest (1968 – 2007), Image courtesy: John Novis, Greenpeace

Some recorded GLOF events in Tibet

No	Date	River Basin	Lake	Cause of GLOF
1	August 1935	Boqu	Tara-Cho	Dam Piping
2	10 July 1940	Kangboqu-Ahmchu	Qunbixiama-Cho	Ice avalanche
3	10 July 1954	Nianchu	Sangwang-Cho	Glacier avalanche
4	1964	Boqu	Zhangzangbo	Piping
5	25 August 1964	Gyrong	Longda	Not known
6	21September1964	Bumchu(Arun)	Gelhaipco	Glacier surge
7	26September1964	Nyang	Damenlahe-Cho	Ice avalanche
8	1968	Bumchu	Ayaco	Not known
9	1969	Bumchu	Ayaco	Not known
10	18 August 1970	Bumchu	Ayaco	Not known
11	23 July 1972	Xibaxiaqu	Poge-Cho	Ice avalanche
12	24 June 1981	Yarlung Zangbo	Zari-Cho	Ice avalanche
13	11 July 1981	Boqu	Zhangzangbo	Glacier surge
14	27 August 1982	Bumchu	Jinco	Glacier surge
15	14 July 1988	Palong Zangbo	Mitui-Cho	Ice avalanche
16	4 July 2005	Chu Ngon (Qingshui)		Avalanche

Kunlun Mountain have lost 17% of their mass—ten times more than those in central Tibet.[85]

Rapidly melting glaciers create glacial lakes. In many places glacial lakes have formed in the area near the foot of retreating valley glaciers. According to the (2009) International Centre for Integrated Mountain Development (ICIMOD), they have identified 8790 glacial lakes in some parts of the Hindu Kush-Himalayas. Out of these 204 glacial lakes were considered to be potentially dangerous, that are likely to burst out leading to a glacial lake outburst floods (GLOF).[86] Such outbursts are sudden and disastrous.

From 1930 to 2002, there have been 15 GLOFs in the "Tibet Autonomous Region".[87] In nine of these GLOF events, the debris entered into Nepal, India and Bhutan, causing serious losses of life and property.[88]

A joint research project was conducted on Bumchu (Ind: Arun) basin by ICIMOD, the Chinese Academy of Science Cold and Arid Regions' Environmental and Engineering Research

Institute (CAREERI), and the Bureau of Hydrology of Tibet (BHT) in 2003. The research states that, "According to the statistics of 1988, there are 230 glacial lakes with an area of 19.214 km^2 in the Poiqu basin (Bhote-Sun Koshi) and Rongxer basin (Tama

Halong glacier on the Amnye Machen in (1981 and 2005); image courtesy: John Novis, Greenpeace

Koshi). The present study shows 354 lakes with 25,831 km^2 area."[89]

The report acknowledges that despite studies done on GLOFs, details of glacial lakes and GLOF events are still lacking in the Hindu Kush-Himalayas.[90]

Recently, collapses of Amnye Machen glaciers in a major Tibetan mountain range in northeastern Tibet have also been reported.[91] One particularly massive collapse occurred in March 2004 when ice, boulders and snow avalanched down the mountain into the Chu Ngon river (Ch: Qingshui), forming a block-lake. In July 2005, the lake burst and the ensuing GLOF dramatically affected the land and people living downstream.[92]

Permafrost Degradation

Permafrost degradation due to the warming climate has changed the regime of water retention and regulation by producing more runoff in areas of permafrost, leading to more evaporation. It has also prolonged the seasonal thawing period significantly leading to many interconnected ecological changes and technological worries. Locally, this degradation results in the gradual desertification of grasslands and loss of native species.

In general, permafrost plays an important role in regulating water and has a significant influence on maintaining the plateau's high-elevation ecosystems. Active layer of permafrost undergoes thawing in the summer, helping to drain away water into the wetlands and vast grasslands. Studies have indicated that the freeze and thaw cycles in the Earth's surface intensify the heat and water exchange between the atmosphere and ground surface. This, in turn, affects the climate—as it does in East Asia.[93] For instance, with the rise of 0.052°C /y (*air temperature*), the permafrost area on the Tibetan Plateau will reduce about 195,000 km^2 (13%) and over 700,000 km^2 (46%) within next 50 and 100 years respectively.[94] This is a huge reduction.

In part, solar radiation is also responsible for accelerating the thawing process. Tibetan areas below 5000 m receive radiation higher than all part of China,[95] about 251.2–360.1 J/ cm^2. This in turn will lead to the rise in the daily maximum temperature, at times reaching above 0°C even in cold winter months, Nov–Feb. Such instances lead to the frequent and strong thawing–freezing processes in the active layer. H. Jin *et al* (2008 & 2000)[96,97] in their study along the highway corridor have found that the heat accumulation under the asphalt road bases resulted in increased thaw depths too great to be frozen and, consequently, resulting in the transformation of vertically connected permafrost into disconnected phase. An excavations in the Kunlun Pass (35°40′ N, 94°02′ E; 4715 m) in September 1997 indicated that the oil pipeline, which pump oil to Lhasa with a diameter of 168 mm built in 1973 along the SLH, has induced a summer thaw depth of much higher magnitude (140–150 cm) compared to the nearby areas that reached only 90 cm. Consistent with that, due to the thaw settlement, the bridges and water conduits have also been damaged considerably.

Recent studies show that permafrost thawing in many regions of the Tibetan Plateau influence both hydrological regimes and vegetation, as well as engineered structures.[98,99,100,101] According to Cheng and Wu (2007) the permafrost thawing on the Tibetan Plateau is more forceful than in Alaska.[102] The conditions of permafrost degradation, as observed[103] (*in 1999 or earlier*) at the arid Amdo Huashixia Permafrost Station about 70 km from Matoe; (Ch: Maduo) was such that the active layers were oversaturated by water either from glacial runoff or rainfall during the thawing season. As mentioned in their study[104] the most of the permafrost restoration along the QTEC (*Ch: Qinghai Tibet Engineering Corridor*) affected by climate warming is generally impossible even with the assistance from artificial barriers preventing the escape of the water from the ice in the thawed/thawing permafrost.

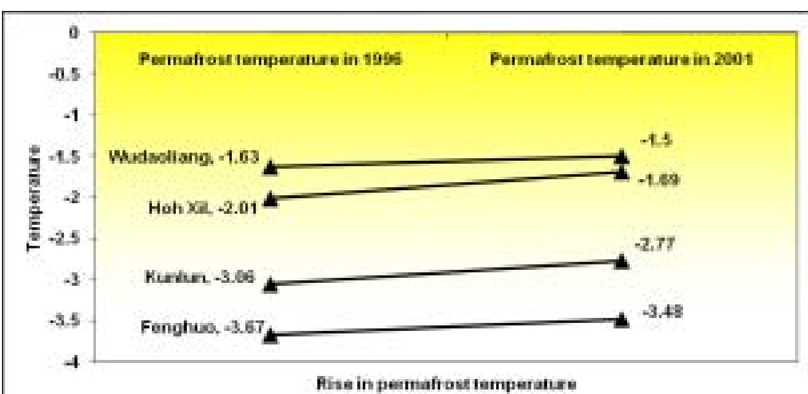
The speed of warming of the frozen earth is alarming.

In July 1975, drilling records indicate that permafrost found in Amdo (Ch: Qinghai) at a depth of 3.5 m was 6.5 m thick. In July 1989, however, no frozen layer was detected in the same site: it had completely thawed.[105] In a separate study, the degradation of permafrost has resulted in severe grassland degradation in Nagchu (Ch: Naqu) area north of Lhasa.

According to some researchers the base of sporadically distributed permafrost in the source region of the Machu (Yellow River) climbed around 50-70m in elevation between the 1970s and 1990s.[106]

Rise in the permafrost table and the temperature are also recorded on the Tibetan Plateau in many places.

Permafrost temperature at the source areas of the Yangtze and Yellow Rivers rose by 0.11–0.14 °C between 1980 and 1998 and



Permafrost temperature taken at 6m depth (1996 -2001): Adapted from Guodong Cheng and Tonghua Wu (2007) the soil active layer thickness increased at rates ranging from 2 to 10 cm/yr. These changes in permafrost affect moisture contents in the soil, carbon exchange between the underground and the atmosphere. The behavior of permafrost on the Tibetan Plateau is therefore of great importance for ecosystem on the plateau.[107]

Permafrost degradation also leads to the lowering of the water table, lake water levels and the shrinking of wetland and grassland. This greatly affects farmers, for whom the growing season begins well before the rains of summer. The snow cover and frozen ground in winter melts sooner as climate change causes the plateau to warm sooner and stay unfrozen longer. A warmer plateau in farming regions means that soil is warmer for a longer time period, which means that the soil is drier – which can affect barley production rates. The future food security is threatened. Hunger looms.

Data collected by Cheng and Wu (2007), indicate that there is a close relationship between the occurrence of sandstorms in China and the minimum freezing depth (*of Permafrost*) in the Tibetan Plateau. The lesser the depth of permafrost, drier the top soil becomes and gets blown away in the form of sandstorms towards the windward side. The sands of the plateau can be transported by westerly winds to eastern China and even places as far away as the North Pacific.[108]

According to Nan *et al* (2003), by 204*0* (*with the average increase in the mean annual ground temperature over the Tibetan Plateau of 0.4 to 0.5°C*) most of the permafrost will disappear based on the analyses of air temperature and fluctuation in the precipitation over East Asia.[109]

Contraction of Lakes and Wetlands

There used to be thousands of lakes in Tibet. The Tibetans consider most of them to be sacred usually the abode of goddesses. They believe that water from these lakes has a healing power, which cures diseases and pains. Most of these lakes have no outlet, and depends entirely on local streams and underground sources to maintain their water level. These lake levels are mainly controlled by the warming climate and human activities. Already a large number of these lakes in Tibet have disappeared.[110] The surface water of Lake Nam Tso (*in Northern Tibetan Plateau*), has decreased by 38.58 km^2 from 1970 to 1988. This is a rate of 2.14 km^2/ year.[111] The drop in water levels in the lake was once gradual, but now it is accelerating. The Plateau has been slowly drying for a long time, but now at a faster rate.

Contraction of Tso Ngonpo (Ch: Qinghai Hu)

This great lake is currently at the mercy of climate warming, its standing water level, according to Sun *et al* (2008)[112], has decreased by 3.62 m from the year 1959 till 2005, with an average decreasing rate of 7.8 cm/year. Correspondingly, the surface area of the lake water has decreased from 4548 km^2 (1959) to 4206 km^2 (2005), with an average declining rate of 7.06 km^2/ year. This decline in the watershed areas has led to extensive erosion by wind. They also indicated that the total sandy land in the watershed areas of Tso Ngonpo (*based on remote sensing data for 1977, 1987, 2000 and 2004*) has increased from 587.4 km^2 in 1977 and 660.7 km^2 in 1987, to 697.6 km^2 in 2000 and 805.8 km^2 in 2004. Furthermore, over the period 1959-2000 the extreme high temperature days have increased significantly at the rate of 2.9 days/decade and extreme low temperature days have decreased significantly at the rate of 3.3 days/decade. This in turn might have resulted in the increased rate of lake water evaporation. According to Yang Li *et al* (2007),[113] the variation of lake level was highly positively correlated to surface runoff and precipitation and negatively to evaporation. In other words, from their water balance study of the lake, the total input of water to the lake (*from mean annual precipitation, surface runoff water inflow and groundwater inflow*) was about 840 mm and the evapora-

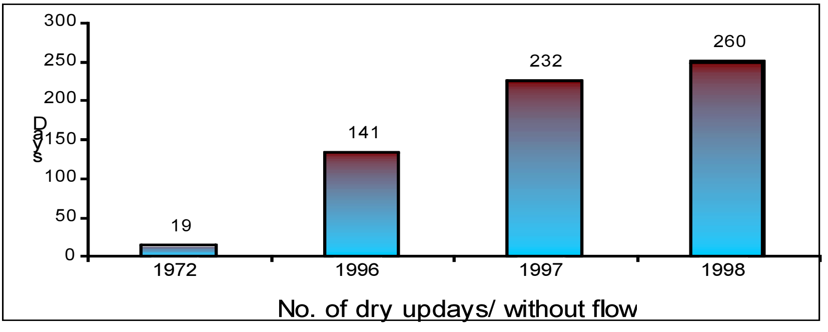
Contraction of Tso Ngonpo; image courtesy: NASA 1994 tion was 924 mm.

This decline in the lake level of Tso Ngonpo has led to many environmental problems in this watershed such as grassland degradation, water quality deterioration and sandy land expansion. This lake was once a haven for various species of bird, including the black-necked crane, Siberian swan, and Western sandpipers, all of whom came to rest there in the summer. However, within the last decade, the rise in temperature and the receding waterline have caused a number of them to disappear from its shores.[114] The fall in water levels also means that an island refuge in the lake, free from predators, is now connected by a land bridge. It is no longer safe for birds to nest there.

Similarly, according to Song Shutao (2007), the wetlands on the plateau have shrunk more than 10 percent overall in the past 40 years, with wetlands of the Drichu (Yangtze)'s origin contracting an alarming 29 percent, said the report by scientists from the Chinese Academy of Sciences. Overall, wetlands on the Tibetan Plateau have diminished by 10% in the last four decades. The biggest shrinkage has occurred at the source of the Yangtze and Yellow Rivers: there, wetlands have shrunk by 29 percent.[115]

Decrease in the Rivers run-of

The flow regimes of the rivers in Tibet are changing. China's effort to use these rivers for commercial purposes is increasing the threat of disaster at a faster rate than anyone has predicted.



Source: Lester Brown, China's Water Shortage Could Shake World Food Security, World Watch 1998, And Eric Zusman, The River Runs Dry: Examining Water Shortages in the Yellow River Basin, 2000

For example, Machu (Yellow River), on which some 300 million people in China depend, is quickly drying up. The river has often failed to reach the Yellow Sea; its natural destination. Also in

2006, the upper section of Drichu (Yangtze River), which, as it runs to the sea, provides water for approximately 500 million people, sunk to its lowest level in over 80 years.[116]

The Sengye Khabab (Indus river), whose basin drains four countries (Afghanistan, India, Pakistan and Tibet) and on which 178 million people—mainly in Pakistan—depend, faces a similar threat from climate change: 70 to 80% of its water is fed by Tibetan glaciers. The river is home to the Indus River dolphin, one of the rarest mammals in the world.[117] The dolphin will become extinct if the water flow from the glacier melt is greatly reduced. In Pakistan alone the river irrigates about 36 million acres.[118]

In March 2007, WWF (World Wide Fund For Nature) named the world's top ten rivers which are at greatest risk. Four of these originate from the Tibetan Plateau.

They are Sengye Khabab (Indus), Drichu (Yangtze), Gyalmo Ngyulchu (Salween) and Zachu (Mekong). The Drichu (Yangtze) is confronting a pollution crisis, while dam construction is threatening the survival of the Salween and overfishing threatens the Mekong, climate change is the factor affecting the river Indus.[119] Most of the damming of these rivers is in Tibet, as they fall from the Plateau.

Personal water usage at the Indus Basin is already far less than the minimum requirement recommended by the UN for human health and survival.[120]

While many rivers are badly affected by climate change, their mismanagement may also contribute to climate change. According to International Rivers Network, large dams contribute to global warming, because static water promotes methane—producing rotten vegetation and animals.[121] According to the World Commission on Dams, the Chinese government increased the number of large dams from 22 in 1950 to 22,000 in 2000. And, while plans to divert water from the Yangtze and Brahmaputra rivers to the fast-drying Yellow River will improve its flow through the most populated areas of China, it will also deprive millions of people who currently depend on the Yangtze and Brahmaputra for their water.

Impacts on Plant and Animal Species

The UN's Inter-Governmental Panel on Climate Change (IPCC) predicts that a global temperature increase by 1.5 to 2.5 °C will lead to the extinction of 20-30% of the Earth's species.[122]

The warming climate over the Tibetan Plateau has led to the degradation of permafrost layers which in turn has resulted in the loss of soil moisture, species competition for survival, extinction of the native species and subsequent domination by more resistant species. According to a study conducted at Tsojang Tibet Autonomous Prefecture (Ch: Haibei) by Dr Julia Klein and her team (2008), there have already been considerable losses among the plant species that were traditionally abundant on the Plateau. Overall, a reduction of 27% of plant species occurred between 1999 and 2001. More specifically, 21% of medicinal plants and non-medicinal plants lost 40% of species due to warming.[123] This greatly affects the viability of pastoral nomadism, because grazing maintain a wide biodiversity of grasses. That biodiversity is now shrinking.

More recent studies have indicated that the persistent degradation of a permafrost over the Tibetan Plateau has significantly lowered the upper-water table and caused the drying of ground surface. The grassland and meadows are now dominated by *Kobresia* and *Stipa.*

Warming also hinders the growth of medicinal forbs (*for instance Gentiana Straminea*). Meanwhile, the number of non-palatable forbs such as *Stellera chamaejasme* that are useless to livestock has increased, crowding out the traditional nutritious grasses of the plateau resulting in reduced rangeland quality.[124]

According to Hongyan Xie (2008), a PhD student whose research focused on a poppy known as meconopsis, one of the highest growing flowering plants on the earth, they have decreased in the alpine region of Tibet. With temperatures increasing, plants that prefer warmer climates are able to occupy the once-cold habitat of the poppy, pushing it out of existence.[125]

As a result, putting pressure on local wildlife such as the grass-dependent Tibetan antelope, and the carrying capacity of the grassland.[126] In contrast to this warming climate, extreme cold temperature and snow storm in Karze (*Ch: Ganzi)* in eastern Tibet about -29°C (*record low for 27 years*) resulted to the death of 5,500 Tibetan gazelles. This freezing weather has also affected severely the local residents and animals.[127]

Yet another recent severe snowstorm in Lhoka prefecture (Ch: Shannan) left nine dead and hundreds trapped. Over 144,000 yaks and sheep were killed in what was called the worst snowstorm on record in Tibet.[128] Such extreme climate driven episodes, if occurred frequently would not only wipe out those protected wildlife (*even if they are under the supposed supervision of the State Forestry Administration*) but would also create greater collateral damages to the Tibetan farmers and their crops.

These reductions in species numbers (*flora and fauna*), and the likely increase in extreme weather events, will put even more species to the brink of extinction.

Degradation and Desertification of Grasslands: Exclusion of Pastoral Nomads

In general, many factors are responsible, over a long period of time for the prevailing condition of the Tibetan Plateau's alpine grasslands and meadows. Apart from the natural climate warming and its feedback, various anthropogenic factors past, present and future on the Tibetan Plateau are responsible for speeding up this

As far as Tibetan pastoral nomads are concerned, changes are already occurring. The warmer and drier climate has degraded their usual pastures, so more and more herders are left with no option but to take their herds to higher and harsher grasslands.

degradation. According to Feng Y. *et al* (2008)[129] the probelm is casued by changes in land use of grassland during the different time periods throughout the past 30 years.

In brief, the overall plan during those periods of *Collectivization* and *Household Responsibility* was to maximize the agricultural production (*more famously known as winter crop*) from the grasslands. During that era[130], almost 20 million hectares of grassland in

Collectivism: *Forcing the peasants to organize themselves into millions of production units (known as collectives) and to pool their land and other significant means of production.*

Household Responsibility: *Or 'The Responsibility Contract': That an individual household, or a set of households with the land lease to the government, they assumes the task of production for and payment to the government. For the farmers: Virtually free from any interference from either the collective or the government, the Chinese peasants devoted their hearts and souls to the land under their control and made every effort to provide whatever consumers were demanding.*

Tibet and Inner Mongolia were converted to croplands, by state-owned farms, state-owned forestry operations, and other state-owned enterprises. They were all labeled "Newly Claimed Virgin croplands" in the 1950s and the trend continued over the last few decades. These grasslands are now severely degraded due to this conversion.

Today, we know that, for the past three decades or more (*in the process of increasing the agricultural outputs*) Tibetan Plateau's alpine grasslands (*with its permafrost soil*) has been plowed and exposed to hazardous chemical fertilizers. Once these natural grasses above the permafrost soil are destroyed, it is very difficult to replenish under the same condition with the current warming climate and its feedback.

As of today, to the Chinese leaders and for some researchers, the innocent herders and the nomads were the scapegoat for anthropogenic activities related to grassland degradation. To offset this issue (*despite all the other mitigations*) in the name of modernization or for easy governance, these nomads and herders were forced to move into permanent settlements. This localization or the policy of 'Sedentarisation' has not only taken the pride of the nomads but also made them dependent on the central government for future aid. According to experts, officials have resettled about 100,000 families, almost half the Tibetan population in Amdo (Ch: Qinghai). In "Tibet Autonomous Region", officials said that they would spend $80 million to resettle most of its nomads by 2009. In August 2008, officials from Gansu Province said it would spend $189 million to relocate 74,000, almost all the nomads in its Kanlho Tibetan Autonomous Prefecture (Ch: Gannan TAP).[131]

In her recent talk at Wilson Centre, Katherine Morton, a China Specialist in Australia National University, said that approximately 700,000 Tibetan nomads have been settled since 2000.[132]

Some of the newly moved nomads interviewed by EDD clearly expresses the deprivation of their aesthetic values and helplessness state at that time, when they were left with no other options but to move into concrete barrack housing. This type of development or modernization if it comes at the cost of losing ones freedom or the mobility of the nomads, then certainly this is more than just protecting the grasslands. Professor Amartya Sen (*Economist, 1998 Nobel laureate*) argued in his classic work "Development as Freedom"[133] that development is "not the mere accumulation of goods but the enhanced freedom to choose, to lead the kind of life one values".

Does Exclusion of Grazing Improve the Grassland?

For different researchers,[134,135,136] the degradation of Tibetan Plateau grassland is due to many factors such as permafrost degradation, irrational human disturbance mining, road construction, conversion to cropland, gold collection, overgrazing etc, climate warming and drying. Interestingly, apart from the other assumptions leading to the degradation of Tibetan Plateau grasslands, Julia Klein *et al* (2004)[137] has shown clearly in their field research work at Haibei Research Station north of the Qinghai capital Siling (Ch: Xining) that grazing (*simulated by clipping*) is practically reversing the grassland degradation. According to their study, global warming and grazing cancel each other and there were no significant effect on ANPP (Above Ground Net Primary Production), in fact those control samples (*unclipped grasses*) showed less ANPP. They have indicated that grazing prolongs/extends the growing season and improves the plant C:N ratio (carbon to nitrogen ratio). Their study indicated the following points;

- Grazing can alter the age structure of leaves and regenerate older plants.
- It also helps to keep the expansion of invasive plants under control.
- Species richness in the clipped plots remains stable whereas the species richness in the surrounding, unclipped plots decreases.
- In the absence of grazing, there is faster decrease in the species richness compared to warming with grazing
- Grazing can increase the rangeland productivity and can reduce the negative effects of warming on both vegetation production and quality.

Once the grasslands are degraded, desertification takes over in tune with the warming climate. The snapshot taken in the year 2008 clearly shows the extent of desertification near Gang Rinpoche (Mt. Kailash).

Desertification is now a major issue for Tibet, especially in the northeast, the source region of the Machu (Ch: Yellow) and Drichu (Ch: Yangtze) Rivers. From the field evidence and analysis of remote sensing images (as of year 2004), the area of grassland degradation and soil erosion at the source area of Drichu has reached 106,300 km^2, accounting for 67% of the total area.[138] According to UNDP report (2007),[139] Tibet's grasslands are being turned into desert at a

Desertification near Mt. Kailash (Tibet)

rate of 2,330 km^2 each year. In a separate study conducted by Yang M. *et al* (2004) [140], the expansion of the desertification in Qinghai has now grown to 10.95% of the total provincial area.

Other human induced factors;

- Infrastructure development such as highways, new townships for settlers and railroad tracks
- Reclamation of communal land, the traditional pastures of semi-nomads, under a new policy to allow commercial development
- Growing rapeseed on low-lying pastures—particularly by Chinese settlers and military units—around the pastoral plains of Amdo's Tso Ngonpo (Lake Kokonor)
- Uncontrolled gold mining and illegal harvesting of wild medicinal herbs on grasslands with the connivance of local authorities
- Elimination of indigenous predators leading to the loss of natural checks on the population growth of pest species

Food Security and Human adaptations

We have recently seen a fall in crop productivity over the world. In fact in six of the last eight years world grain yield has fallen short of consumption which leads to the rise in its price to the highest level in 2008.[141]

As the world population grows at the rate of 70 million per year, demand for more grain has aggravated the situation. Furthermore there would be more diversion of grain for bio-fuel production.

Water shortages are the most immediate cause for shrinkage in the world's food supply. Intensive groundwater mining (drilling of millions of irrigation wells) has resulted in the fall of water tables in China, India, and the United States (the three largest grain producers).[142]

In China and India, 60 to 80 percent of the grain harvest comes from irrigated land, particularly faced with aquifer depletion. In North China plain, where over half of the country's wheat and a third of its corn grow, the water table is falling fast. This consequently led to reduced harvest of 103 million metric ton in 2008 compared to 111 million metric tons in 1997. Production of rice also dropped 6 percent from 127 million to 119 million tons in the same period of time. China is already importing nearly 70 percent of its soybeans and will soon be importing large quantities of grain as well.[143]

According to a study published by the U.S. National Academy of Sciences, a team of scientists from several countries confirmed that one degree Celsius temperature rise would reduce wheat, rice and corn production by 10 percent. Apart from this, glaciers melting due to rise in temperature would also affect agriculture in the long run.[144]

One of the biggest challenges for subsistence agriculture and food security concerns not just a warming climate but also an uncertain climate regime. Studies show that this climate uncertainty will affect the critical seed planting during spring and harvesting during the fall.

Many regions of Tibet have long experienced food shortages and poverty. This has been reported through interviews given by Tibetans from Tibet in a Tibetan Centre for Human Rights and Democracy (TCHRD) report called Impoverishing Tibetans.[145] Official Chinese statistical yearbook data on actual food consumption shows that Tibetan farmers and nomads eat much less than the towndwellers in Tibet. Factors such as high taxes and interest rates on loans oblige Tibetans to face crop shortages and more importantly extreme weather contribute to food shortages in Shigatse and Lhoka, which is one of the few cultivation zones in Tibet.

Unfortunately, climate change seems to be inevitable, and the processes needed to mitigate its impacts are many and will take a long time. We have to learn to live with the consequences. And moreover the amount of CO_2 present in the Earth's atmosphere today is enough to have a continued greenhouse effect for the next 50 years even without any further emissions. To make best use of the positive effects of climate change, without further damaging the environment, is the most intelligent strategy we have available. Many international organizations have urged communities to adapt to climate change in order to reduce their vulnerability.

Positive Impacts

The impacts of climate change are not always necessarily negative, at least in the short term. For example, in Drakgo county (Ch: Luhuo) in Sichuan people can now grow chili peppers. Previously the climate was too cold for the plant to grow.[146] Also, herders in the Tibetan Plateau have felt more comfortable in winter in the last few years. Tsewang, a Tibetan shepherd, proudly said "Yes, it's definitely getting warmer, fewer animals died of the cold this year."[147] For him, the rise in nighttime winter temperatures is a positive thing.

Dr. Tej Partap, (*co author of a book "Making Tibet Food Secure: Assessment of Scenarios," former head of Mountain Farming Systems, at the ICIMOD, currently serving as the vice chancellor of the CSK Agriculture University of Himachal Pradesh*), found that, over the last few years, climate warming has allowed Tibetan rapeseed plantations to climb a kilometer in elevation. He also discovered that, back in 1990, those crops that are grown in greenhouses such as corn, maize and pulses can now be cultivated in the open air. He further argues (*in tune with the climatic warming*) that barley is no longer an economically sustainable crop in Tibet and new crops and vegetables that show good adaptive responses to climate change should be introduced.[148] For instance, Tashi Tsering (*Ph.D researcher on Tibetan water resources at the University of British Colombia),* saw that the people of Spiti (*an area in India that shares same geographical features with the Tibetan Plateau*) cultivated green peas instead of black peas, as a way of adapting their crops and have been so far able to financially survive climate change.[149]

According to Lauren Sacks and Cynthia Rosenzweig (2002),[150] adaptations require investment in regional and national agricultural infrastructure and policy changes at the regional and national level to assure food security to those farmers who are affected by such events. Since Tibetans are not in charge of their own affairs, this level of adaptation is out of their reach.

Due to Tibet's high altitude, barley is traditionally its primary crop. Indeed, the main staple food in Tibet is Tsampa, or roasted barley flour. However, in recent years there have been developments in agricultural production and changes in local food consumption. The last few decades have seen the development of infrastructures such as roads, telecommunication and urbanization in Tibet. These changes have brought many non-Tibetans into Tibet, along with their alien lifestyles. A number of new crops and vegetables have been introduced to feed these newcomers, whose lifestyles demand greater variety and increased energy consumption.

Although Tibet is not suitable for wheat cultivation due to its current mean annual temperature regime, many argue that global warming will make the area suitable for cultivation of wheat and other crops. These crops will require crop irrigation the most even though it has the lowest SCIR (Seasonal Crop Irrigation Requirement) under the current climate condition.[151]

Anthropogenic Factors: Human Causes of Degradation and Climate Change

The onset Permafrost degradation: Construction of SLH

The construction of Siling Lhasa Highway—SLH (*Ch: Qinghai–Tibet Highway – QTH*) was about 530 km in 1954 without an environmental impact assessment led to severe degradation of the permafrost soil, its vegetative mat along the highway and also its adjoining areas. This damaged vegetative mat led to the loss of organic matter and carbon in the soil and the melting of the warm permafrost layer under the topsoil. This layer of permafrost maintains a water reserve at the topsoil layer for plants and as it gets depleted it will be difficult to restore vegetation naturally due to lack of soil moisture and its nutrients.[152] This roadway construction initiated the onset of warming/thawing of the underlying permafrost and the destruction of the adjacent and nearby vegetation initiated similar warming/thawing processes in those areas.[153] Based on the field survey (1990), thaw settlement along the SLH accounted for 83% of the road damage.

The next major degradation of permafrost, which resulted in far more short–term and long–term environmental damage than the initial SLH construction, took place during the road width expansion and reconstruction (*placement of an asphalt pavement surface*) from 1973– 1984.[154,155] For instance, at Huashixia Permafrost Station in the Yellow and Yangtze source area a 1 km-long ditch, was excavated in 1988 for slope stream interception during the rehabilitation of the National Highway 214. However, the excavation resulted in the thawing of ice-rich permafrost along the highway and subsequently induced a retrogressive thermal slumping. The ditch was enlarged to 50-350 cm in depth and 200-500 cm in width.[156] According to Wang and French (1995), approximately 30% of the SLH has to be repaired every year due to damage cause by frost action.[157]

The current permafrost degradation (*along the SLH*) is mainly due to the *surface disturbances* over the past several decades, while the global warming have played a secondary role in speeding up the degradation.[158,159, 160] Consistent with that, H. Jin *et al* (2008 & 2000) [161,162] in their study, along the SLH corridor have found that those areas covered by asphalt road surface showed significantly greater depths of permafrost layer and higher Mean Annual Ground Temperature (MAGT). In other words, the road construction/ renovation have resulted in a faster degradation of the permafrost layer, compared to the natural state. For instance, at Kunlun Shan Mountains, the maximum depth of the permafrost table under the asphalt road surface was 5.2 m compared to only 2.8m under the normal state; and the MAGT ranging from -1.0 to -0.2°C under the asphalt road and -2.5 to -3.5°C for the normal state. In a separate study by Wei *et al* (2006),[163] they found an arc shaped thaw slumping area near Fenghuaoshan Mountain measuring up to 73 m wide and 103 m long by 2003 with the total volume of the failure about 10,000 m^3 caused by the repairing of SLH. Their survey results showed that the thaw slump has been active for more than 10 years compared to the general thaw slumping life year of 3-5 years and it will further remain active until the ice rich permafrost has disappeared. The thaw is unstoppable.

Grassland Degradation: Intensive Farming

Degradation of alpine grasslands over the Tibetan Plateau (*starting from 1949 till 2006*) is a sad story. Long before the global warming issues were of concern, Tibetan nomads and herders used to live in harmony with the nature. The arrival of the People's Liberation Army (PLA) in Tibet in 1949 was a turning event. From the early years of 1950s, the Chinese policy to boost agricultural production was a centerpiece of the development strategy. Mao's disastrous campaign in 1958, The Great Leap Forward was advertised as a technological revolution in which developing agriculture

Surface degradation associated with thaw of ice-rich permafrost on the Tibetan Plateau. As melted ice drains away the soil slumps and collapses

was to have priority. This resulted in extensive destruction of forest and grasslands. Mao Ze-dong in his land reform policy 'Collectivism' was unpopular in the countryside from day one. The peasants felt that the new arrangement had rendered them inferior to urban residents, whose welfare was provided for under the government budget while theirs was at the mercy of the cadres, weather or the quality of the land. Nevertheless, the peasants could not offer any open opposition to the new arrangement. What they did instead, because every collective member got more or less the same share of the harvests, regardless of differences in individual contributions, was to shirk and to be very careful to do no more than others did. Consequently, agricultural productivity was low and the resultant food shortages haunted the government.[164] These conditions also led to the emergence of food grain shortages for the first time in Tibet's history.[165] In Amdo (Ch: Qinghai), about 670 km^2 of

Surface disturbances: *Conversion of Grassland to Cropland and vice versa; Golmud to Lhasa Oil Products Pipeline 1972–1977; 110-kVTransmission Line installed in 2005–2006; Qinghai–Tibet Railway (GLR) was construction 2001–2006; The design of a new express highway from Xi'ning to Lhasa is already under way with the beginning of construction anticipated within a few years.*

grassland were converted to cropland and nomadic herders were forced to assume an agricultural lifestyle which was unfamiliar to them and unsuited to local conditions. Consequently, the official term used for conversion of pasture to farmland was "reclamation". In Amdo, this took desertification to a point beyond control. The first state farms in Tibet, founded by the PLA in 1952 to the west of urban Lhasa and just east of the borders of Toelung Dechen county, had historically been land used primarily for grazing sheep owned by the Tibetan Government. This land appropriation by PLA soon went beyond Lhasa to Shigatse, Chamdo, Tingkye, Kongpo and Ngari.[166] The Cultural Revolution of 1966–1976 further intensified this commune system to the extent that private ownership of land and animals ceased altogether. After the death of Mao in 1976, Deng seized that chance and reintroduced '*Household Responsibility*' which in turn led[167] to more aggressive farming and conversion of more Tibetan Plateau grasslands to croplands.

According to Wu *et al* (1999),[168] China's agricultural economy has undergone a rapid transformation in the last 15 years. Beginning[169] in the 1980s, farmers were permitted by the state to sell surplus produce on the open market. This created incentives to increase agricultural productivity and to adopt green revolution technologies (intensive application of fertilizer and pesticide together with improved hybrid seeds). The National Environmental Protection Agency (NEPA) in Beijing reported that the use of fertilizers in China rose from 25.9 million tons in 1990 to 33.1 million tons in 1994. Despite the increased use of fertilizer, only 30% of fertilizers applied to agricultural crops are used effectively.[170] The period, 2001 to 2006 marks another era[171] when the Croplands were converted back into Grasslands.

China's Global Climate Footprint

Energy-related environmental issues in China are mainly due to the production and utilization of coal. In general, coal contains 2-3% sulphur by mass and burning 1 tons of coal consumes about 80,000 moles of carbon producing 1800 grams of CO_2. Use of coal on a massive scale has resulted in air pollution, whilst over-consumption of biomass has led to ecological damage in rural areas. Rapid economic development and industrialization have exacerbated the situation. China assumes an important position in global energy consumption and environmental protection, so energy-environment initiatives benefit not only China, but also the whole region.[172]

Although, the most recent—and the only—official GHG inventory published by the Chinese government dates back to 1994 but International Energy Agency (IEA) estimated that China's GHG emissions for 2005 to be 7,527 million tons CO_2 (increase in 152% compared to 1990 emissions), of these emissions, about 78% were CO_2, 13% CH_4 and 8% N_2O. Furthermore, China's increasing carbon dioxide emissions—up 8% from 2006 to 2007 accounted for two-thirds of the growth in all global CO_2 emissions in 2007.[173] According to the preliminary estimates by Netherland Environmental Assessment Agency (MNP)[174] for 2006, China topped the list of CO_2 emitting countries leaving behind USA by 8%, it was estimated that total of 6200 Megaton of CO_2 were emitted, the major contribution was from the cement manufacturing industries (*accounting for almost 20% of the total emission*).

Coal meets about two-third of China's energy demand and without any doubts, with its relatively abundant reserves, it will continue to be the chief source of fuel for quite some time. And the country is building an average of one new coal-fired plant every week. According to one latest report[175] on China, coal provided 70% of total energy, with petroleum contributing 20%, gas 3%, and hydroelectric and nuclear the remaining 7%. Compared to United States, China now consumes about twice as much coal each year even though its total energy demand in 2007 was about 21% less. According to Gordon Feller,[176] 'China continues to rely upon coal for nearly 70% of its energy needs, consuming 22.5% more coal than other advanced countries. It has set a compulsory goal to reduce industrial pollutants by 2% but the record in the first half of 2006 showed an increase of 3-4 percent. This increase in pollutants was largely due to the rapid rate of unregulated economic growth; from January to September 2005, Chinese industries grew by 17.2%, while heavy industries increased by 18.2 percent. He further argued that the market still favors traditional (and unclean) sources of energy, such as coal, and for many, achieving high GDP numbers through large-scale investments in energy, construction and other heavy industrial sectors remains the priority. The loan[177] from The World Bank ($710 million) to help rebuild areas hit by 2008 earthquake in the Tibet/China border zone of Sichuan will further boost the construction industries in consuming more coals to produce more cement. Even though it is good to finance reconstruction projects in the infrastructure, health and education sectors in the two most-affected Chinese provinces. But what is troubling is that the Chinese energy intensity[178] is 25% as efficient as the United States and the European Community.

Apart from the heavy industries, Small and Medium Industries (SMI) are one of the main emerging industries in the Asian regions. According to Asian Regional Research Programme in Energy, Environment and Climate (ARPEEC),[179] the SMI sector accounts for more than 85% of the total manufacturing establishments in the Asian region. Using the weighted specific emission factor, they estimated that the annual CO_2 emissions from the foundry and brick-making sectors in China add up to over 213 million tons per year. In the end, as a result of all these activities, who will be affected by the GHGs and the brown clouds produced?

Studies on aerosols, snow, ice and soils have shown relatively high amounts of anthropogenic pollutants (such as Lead, Chromium, Nickel, Copper, Arsenic, Zinc and organochlorine pesticides) in the Himalayan ranges and the Tibetan Plateau, these pollutants are transported over the Tibetan Plateau by both winter monsoon (westerly jet stream) and East Asian summer monsoon (easterly jet stream).[180,181,182]

Chinese soot is causing more problems than CO_2 and the Chinese cannot stop their gigantic manufacturing machine. Also, millions of Chinese workers have come into the big cities to work and China has to create millions of jobs to keep the workers satisfied and this means enormous clouds of soot belching into the atmosphere that is floating to the California shores and causing environmental fallout.

Resource Extractions and Mining

China's dream of becoming an industrialized nation and the sheer urge of chasing that dream has knowingly (or unknowingly) devastated many grasslands and permafrost soils in the Tibetan Plateau. Apart from oil and natural gases, the huge reserves of mineral ores (*such as Copper, Iron, Gold, Magnesium, Lithium, Silver, Diamonds, Asbestos and Potash*) have kept the miners busy on the Tibetan Plateau since 1950. According to 2007 Atlas of China large iron ore and non-ferrous metal deposits have been discovered on the Tibetan Plateau during seven years of intensive geological survey.[183]

It was estimated that the Plateau holds about 30-40 million tons of Copper reserves; 40 million tons of zinc, and several billion of tons of iron. The scientists have also not failed to warn that the mining should be measured in order not to damage the fragile ecosystem.

Large-scale copper mining in Tibet is due to begin in 2010. The Western Mining Co, (*China's seventh-largest copper miner*) have recently announced that by 2010, the smelting plant at Yulong[184] copper mine is expected to meet the production capacity of 20,000 tons of refined copper, compared to 2,000 tons in 2008.[185] Yulong copper mine is among the largest mines of its kind in the world with an area of 1,870 km^2. The mine is notably the second largest mine in Asia with a proven deposit of 6.5 million tons of copper in ore form and another 10 million tons of prospective reserves.

Mining is a significant emitter of GHGs. At a typical copper mine, around 125 tons of ore are excavated to produce just one ton of copper.[186] Imagine how the landscape at Yulong mine would look after it has reached the production capacity of 20,000 tons of copper annually. A total of 2.5 million tons of soil will be excavated yearly. The whole permafrost laden soils would be destroyed. In short, mining activities will not only destroy the natural landscapes, polluting water and poisoning aquatic lives but also inject more GHGs in the atmosphere.

Sulphur Dioxide (SO_2) emission results when the ores containing sulphides (FeS_2, CuS, $CFeS_2$ *and* NiS) are roasted in air during the metal extraction.

What will copper mining, concentration and smelting in Tibet mean? Stephen *et al* (2005), reported that at the Karabash copper smelting town (in the southern Ural Mountains of Russia) was affected by SO_2 emissions, measured in thousands of tons per year, and fall-out of metal-rich particulates from the smelter, acid drainage from old mine workings, and leachates from waste dumps and tailings dams. The people living in the town show high rates of congenital defects, central nervous system disorders, cancer and other diseases. Two-thirds of the children suffer from lead, arsenic or cadmium poisoning and many suffer from asthma, respiratory diseases and skin disorders. Vegetation is almost absent from the hills immediately downwind of the smelter and in the Sak-Elga River valley to the south of the town. There are now plans to modernise the plant to improve sulphur capture and reduce dust emissions.[187]

In a separate, more recent study by Vincent *et al* (2008),[188] they found that, the heavy metal (*Cadmium- Cd*) contamination from copper smelters have a significant impact at both the population and individual levels of genetic structuring of the aquatic species. Their study demonstrated that metal contaminants associated with mining activities have evolutionary impacts on the genetic makeup of yellow perch populations. Besides Cd pollution, these regions are also affected by zinc (Pb) and nickel (Ni) contamination. A separate study revealed an elevated concentration of Pb in the tributary to the Gyalmo Ngulchu (*Salween River*) and relatively high concentrations of Ni were identified in a tributary of the Drichu (*Yangtse*).[189] Even though the origin of these elements is not clearly known, but it could be highly related to the mining activities.

Those engineers paid little attention to the effects byproducts of milling and smelting had on the surrounding environment when the dirt and rock that covers the ore are removed.

From the environmental perspective alone there is no way we could imagine the irreversible destructions to the landscape caused by these activities in terms of water, air and land pollution. There are mining sites on the Tibetan Plateau that are exploited since 1950 such as, Menyuan mine (*in the Tsojang prefecture, Amdo*) for its copper deposits. Extraction of copper and iron ore dominates the mining chart in terms their excavated resource. Other than these two ores, *Chromites* are mined intensively at Norbusa mine. About 80% of China's total Chromite demand is met from Tibet.[190] In fact, Tibet holds the largest reserves of Lithium (80% globally) and ranks amongst the top for its copper deposits.[191] According to China Chemical Reporter[192] (2008), there has been heavy investments on the Tsaidam Basin (*Ch: Qaidam Basin*), mostly concentrating on mineral extractions and natural gas extractions. However sadly, there is no clear indication as to how these would be carried out with minimum destruction to the fragile environment and the health of the concerned miners and local residents. For instance, China Chemical Report says, a 10 billion m^3/year natural gas capacity construction project in Sebei Gas Field (*located in the east of the Tsaidam Basin*) was recently launched in Gormo, Qinghai province. It is one of the four large gas fields in China. The proven gas geological reserves amount to 300 billion m^3. On available information, this project would be soon drilling 951 production wells and more than 1500 km of gas pipelines will be installed. Obviously, this is yet another wake up alarm to the Tibetan villag-

***Chromites**: Chief element for the production of stainless steel, refractory furnaces, electrodes, etc,.*

ers, apart from its copper smelters. The impacts of the drilling foot prints on the landscape and its associated GHG emission becomes secondary to the water contamination they would be facing. The drillers are using the latest technology '*Hydraulic Fracturing*' which was considered safe by USEPA since 2004[193] but numerous cases has been reported in USA regarding the water contamination mainly with *Benzene*. The recovered water in the drilling process is usually stored in open pits for later treatments, if the treatment is delayed or the recovered water is poorly managed, the *secret-toxic* chemicals contained in the recovered water could seep into the water table. Theo Coldorn, in his written testimony[194] (*widely referenced by many EPA scientist and state level regulatory agencies*) has mentioned that drilling fluid contains carcinogenic agents (2-BE) used for lubricating the fracking fluids down in the well.

Compared to the present coal derived energy, gas is indeed a cleaner fuel and would greatly offset total GHG emission in the Tibetan Plateau but the whole operation should be conducted -in order not to spend billions in recharging the ground water during the post mining periods. Thus, it is highly recommended to use steel tanks for holding the wastewater (recovered water) and to employ *BAT* and E3ST.

Recommendations

It is said that anthropogenic factors cause climate change. If human behavior is to blame for changes in our climate, then human effort can also restore climatic stability. Due to its unique geographical location and high altitude, Tibet faces rapid changes in its weather patterns and ecosystems in more extreme ways than do most other parts of the world.

In recent years, a lack of communication and an absence of treaties between countries situated along the same rivers have led to

Hydraulic Fracturing: *This process shoots vast amount of water, sand and chemicals several miles underground to break apart rock and release the gas.*

Benzene: *Chemical believed to cause aplastic anemia and leukemia in human cells*

Secret toxic*: So far the chemicals used in this drilling operation have not been released due to trade secrets and market competition. However, such chemicals used are considered toxic even in trace amounts according to many recent studies.*

BAT*: Best Available Technology*

E3ST*: Energy Efficient and Environmentally Sound Technologies* flash floods, which have occasionally ravaged human settlements.

I. It is therefore very important that information on cross-boundary issues, such as water, be shared among the affected countries. Countries sharing rivers such as Mekong should sign trans-boundary river treaties, promote ecosystem management of water resources and watershed systems, and oblige China to do the same.

II. Furthermore, it would be beneficial to both Tibetans and the world community to make the Tibetan Plateau an exploitation-free international observatory zone. This was done in Antarctica, where people are now able to conduct surveys and collect data on changes in climate and the ecosystem. If we could do this in Tibet, the data could be disseminated internationally, potentially curbing global warming.

Extensive studies have been carried out at the source regions of the Drichu (*Yangtze*) and Machu (*Yellow River*), as they both flow into China. We should also prioritize research studies on other climate change sensitive areas in Tibet. When they are done, other victims of climate change will be able to prepare themselves for potential natural disasters.

III. The Chinese government has announced plans to settle some 80 percent of Tibetan herders and farmers permanently by 2010. Without herders and their livestock on the rangeland, grasslands in Tibet will not only lose their indigenous plant species; they will also be more prone to invasion by so-called exotic species as well. According to scientific research done by Dr Julia Klein and her team in Tibet, stopping grazing entirely will cause loss of plant species at the rate faster than grazing with warming. Beijing's policies on Tibet's grassland therefore need to be reconsidered in order to slow down the losses of plant species. Nomads can be integral to rehabilitating degraded pastures, instead of excluding them.

IV. Monitoring glacier changes and retreat cannot be done properly by people who come to the glacier area once or twice a year. As suggested in many seminars and conferences, local people should be trained and deployed in monitoring and surveillance of these sensitive areas because they are the ones who feel and witness changes every day. These locals, once in charge, should be assisted with required training and occasional updating. This will not only produce precise and consistent data but also empower the locals with job opportunities and skills.

V. Climate change has made weather and seasonal climate prediction increasingly uncertain, which is why disaster management and aid services should be located in near proximity to avoid maximum damage. This case is very evident in Lhoka, when the lack of immediate relief aide caused major loses.

The very survival of millions of people and thousands of plant and animal species in Tibet and neighboring countries depend on Tibetan water resources. The impact of climate change on Tibetan water sources raises real concerns for millions of downstream water users.

Furthermore workshops should be conducted to create awareness on types of hazards that climate change could bring about and promote safety preparation. This will help improve human responses to extreme events, thus minimizing risks.

VI. Enforce environmental policies by tying GHG reduction into the current economic model. Since the emission of GHG's is currently an externality in the free market, the effects of pollution are not directly experienced by the individuals participating in the transaction, i.e. the loggers and those that buy the wood. Instead, the carbon emitted to extract the lumber, and the carbon not being absorbed by the lost forest carbon sink are then placed upon the surrounding communities by raising the average temperature and decreasing the amount of water and arable land in the region. Third parties bear the costs that are being excluded from the economic person to person deal. For China, to truly practice free market economics, the system that has been increasing its GDP over the years, it would need to eliminate these external costs that give unjust advantages to those who exploit them.

By integrating a carbon tax on each ton of carbon emitted through fossil fuel consumption and deforestation in China, it would place some of the third party external cost on those initially accountable and quell the excessive and negligent actions that have caused massive environmental impacts on the Tibetan plateau. The funds generated from the tax can then pay for mitigation and adaptation efforts on the Tibetan plateau, especially grassland rehabilitation and reforestation.

A regional or national cap and trade system would have a similar effect. Through applying a commodity value, parallel to the economical reasons for mining and logging in the first place, to each ton of carbon being emitted, money can be saved through GHG reductions. This can be accomplished by setting a maximum amount of carbon emission allowed in China, a supply, and then applying a price on each ton within that ceiling, a demand. Therefore, a company has the economic incentive to deplete fewer trees due to the fact that if they are trying to reach a sales goal, and are being charged per ton of carbon emitted through their practices, the bottom line can justify less negative consumption.

Conclusion

The very survival of millions of people and thousands of plant and animal species in Tibet and neighboring countries depend on Tibetan water resources and the monsoon rains Tibet generates. Tibet has experienced rapid changes in its climate in terms of precipitation patterns, rates of glacial shrinkage, and extensive desertification. The impact of climate change on Tibetan water sources raises real concerns for millions of downstream water users.

Many countries of the world are now engaged in negotiating a replacement for the Kyoto Agreement, the first attempt at a global response to a global problem, which is due to expire December 31, 2012. Now (7-18 December, 2009), World leaders meet at United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen, Denmark. They might come up with new legally-binding UN treaty or extension to the Kyoto Protocol. However, since Tibet is not a state, Tibetans have no seat in these negotiations and must rely on others to voice their concerns on the global consequences of industrialisation.

If Tibet's grasslands are maintained and improved, through a combination of nomadic work and state/donor finance, they will form a part of the solution to a global problem. This is a far better alternative than excluding nomads, and will enable grasslands to recapture carbon while also sustaining human livelihoods.

Much effort is needed on the ground in Tibet to restore wetlands, adapt farm and pastureland, and preserve forests before the impacts of climate change makes it more difficult to save ecosystems. Through state and people working together, desertification may also be reversed.

The alternative, of remaining inactive will only exacerbate global problems, by degrading pasture to bare rock—a process from which the soil may take centuries to recover, if it ever recovers at all. The ongoing degradation of huge areas of plateau grassland is a loss not only to Tibetan livelihoods but also to our global capacity to capture and store carbon.

> "Our understanding of global climate change would be incomplete without taking into consideration what's happening to the Tibetan Plateau." Scripps atmospheric scientist Veerabhadran Ramanathan in Nature, 2008[195]

Endnotes

[1] *Jane Q., China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008*

[2] *Walter Immerzeel, Jetse Stoorvogel and John Antle, Can Payments for ecosystem services secure the water tower of Tibet? Agricultural systems 96 (2008) 52-63*

[3] *Clifford Coonan, Global warming: Tibet's lofty glaciers melt away, The Independent, 17 November, 2006, http://www.independent.co.uk/environment/climate-change/global-warming-tibets-lofty-glaciers-melt-away-424651.html*

[4] *Barnett, T.P., Adam, J.C., Lettenmaier, D.P., 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature 438, 303–309.*

[5] *Jane Qiu, China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008*

[6] *Barnett, T.P., Adam, J.C., Lettenmaier, D.P., 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. Nature 438, 303–309.*

[7] *WWF China, 'Melting-glaciers-on-the-Tibetan-Plateau',* http://www.panda.org/wwf_news/features/?108360/Melting-glaciers-on-the-Tibetan-Plateau

[8] *Environment and Development Desk, 'TIBET, A Human Development and Environment Report' (2008), EDD, DIIR, Central Tibetan Administration, Dharamsala, HP, India, ISBN 81-86627-68-5v*

[9] *Walter Immerzeel, Historical trends and future predictions of climate variability in the Brahmaputra basin, Int. J. Climatol. 28: 243–254 (2008), Published online 29 May 2007 in Wiley InterScience, DOI: 10.1002/joc.1528*

[10] *Environment and Development Desk, 'TIBET, A Human Development and Environment Report' (2008), EDD, DIIR, Central Tibetan Administration, Dharamsala, HP, India, ISBN 81-86627-68-5*

[11] *Ibid*

[12] *WWF China, 'Melting-glaciers-on-the-Tibetan-Plateau',* http://www.panda.org/wwf_news/features/?108360/Melting-glaciers-on-the-Tibetan-Plateau

[13] *Wang Genxu, Li Yuanshou, Wang Yibo, Wu Qingbo, Effects of permafrost thawing on vegetation and soil carbon pool losses on the Qinghai–Tibet Plateau, China, Geoderma 143 (2008) 143–152*

[14] *Jane Qiu, China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008*

[15] *Jin, H. J., Shuxun Li, Guodong Cheng, Wang Shaoling, Xin Li, Permafrost and climatic change in China, Global and Planetary Change 26 (2000) 387–404*

[16] *Jin, H. J., X. L. Chang, and S. L. Wang (2007), Evolution of permafrost on the Qinghai-Xizang (Tibet) Plateau since the end of the late Pleistocene, J. Geophys. Res., 112, F02S09, doi:10.1029/2006JF000521*

[17] *Meixue Yang, Shaoling Wang, Tandong Yao, Xiaohua Gou, Anxin Lu & Xuejun Guo, Desertification and its relationship with permafrost degradation in Qinghai-Xizang (Tibet) plateau, Cold Regions Science and Technology 39 (2004) 47– 53*

[18] *Edward A. G. Schuur, James Bockheim, Josep G. Canadell, EugeniE Euskirchen, Christopher B. Field, Sergey V. Goryachkin, Stefan Hagemann, Peter Kuhry, Peter M. Lafleur, Hanna Lee, Galina Mazhitova, Frederick E. Nelson, Annette Rinke, Vladimir E. Romanovsky, Nikolay Shiklomanov, Charles Tarnocai, Sergey Venevsky, Jason G. Vogel, and Sergei A. Zimov, Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle, BioScience • September 2008 / Vol. 58 No. 8, pp. 701- 714*

[19] *Wang Genxu, Li Yuanshou, Wang Yibo, Wu Qingbo, Effects of permafrost thawing on vegetation and soil carbon pool losses on the Qinghai–Tibet Plateau, China, Geoderma 143 (2008) 143–152*

[20] *Ding Yongjian, Lui Shiyin, Xie Chanwei, Zhang Yong, Wang Jian, Yellow River at Risk, An Assessment of the Impacts of Climate Change on the Yellow River Source Region, Greenpeace, 2005*

[21] *Huakun Zhou,Xinquan Zhao,Yanhong Tang, Song Gu and Li Zhou, Alpine grassland degradation and its control in the source region of the Yangtze and Yellow Rivers, China Grassland Science 51 (2005) 191–203*

[22] Guodong Cheng and Tonghua Wu, Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau, Journal of Geophysical Research, Vol. 112, 2007

[23] Jane Qiu, China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008

[24]Evelyne Yohe and Laurie J. Schmidt, Riding the permafrost express, National Snow and Ice Data Center DAAC, http://nasadaacs.eos.nasa.gov/articles/2005/2005_permafrost.html

[25] Environment and Development Desk, 'TIBET, A Human Development and Environment Report' (2008), EDD, DIIR, Central Tibetan Administration, Dharamsala, HP, India, ISBN 81-86627-68-5

[26] Yuanhe Yang, Jingyun Fang, Yanhong Tang, Chengjun Ji, Chengyang, Zheng, Jinsheng He and Biao Zhu, Storage, patterns and controls of soil organic carbon in the Tibetan grasslands, Global Change Biology (2008) 14, 1592–1599, doi: 10.1111/j.1365-2486.2008.01591.x

[27] Jin, H. J., Shuxun Li, Guodong Cheng, Wang Shaoling and Xin Li, Permafrost and climatic change in China, Global and Planetary Change 26 (2000) 387–404

[28] Ibid

[29] Wang Genxu, Li Yuanshou, Wang Yibo, Wu Qingbo, Effects of permafrost thawing on vegetation and soil carbon pool losses on the Qinghai–Tibet Plateau, China, Geoderma 143 (2008) 143–152

[30] Jiangwen Fan & Huaping Zhong &Warwick Harris & Guirui Yu & Shaoqiang Wang & Zhongmin Hu & Yanzhen Yue, Carbon storage in the grasslands of China based on field measurements of above- and below-ground biomass, Climatic Change (2008) 86:375–396

[31] China daily, China's vital wetlands shrinking due to climate change, http://www.chinadaily.com.cn/china/2007-07/17/content_5437231.htm

[32] Jin, H. J., WU Jie, CHENG Guodong, Nakano Tomoko and SUN Guangyou, Methane emissions from wetlands on the Qinghai-Tibet Plateau, Chinese Science Bulletin Vol .44 No. 24 December 1999

[33] Jin, H. J., Shuxun Li, Guodong Cheng, Wang Shaoling and Xin Li, Permafrost and climatic change in China, Global and Planetary Change 26 (2000) 387–404

[34] Ding, W. X., Cai, Z. C and Dexuan Wang, Preliminary budget of methane emissions from natural wetlands in China, Atmospheric Environment 38 (2004) 751–759

[35] Ding, W. X. and Cai, Z. C. 2007. Methane emission from natural wetlands in China: Summary of years 1995–2004 studies. Pedosphere. 17 (4): 475–486

[36] Wetland in Tibet Absorb 78,800 tons of Carbon Dioxide Every Year, China Climate Change Info-net, February 14, 2006, http://www.ccchina.gov.cn/en/NewsInfo.asp?NewsId=4349

[37] Zhang Fawei, Liu Anhua, Li Yingnian, Zhao Liang, Wang Qinxue and Du Mingyuan, CO_2 *flux in alpine wetland ecosystem on the Qinghai-Tibetan Plateau, China, Acta Ecologica Sinica, 2008, 28(2), 453-462*

[38] Wetland in Tibet Absorb 78,800 tons of Carbon Dioxide Every Year, China Climate Change Info-net, February 14, 2006, http://www.ccchina.gov.cn/en/NewsInfo.asp?NewsId=4349

[39] Ding, W. X. and Cai, Z. C. 2007. Methane emission from natural wetlands in China: Summary of years 1995–2004 studies. Pedosphere. 17 (4): 475–486

[40] Jin, H. J., WU Jie, CHENG Guodong, Nakano To moko and SUN Guangyou, Methane emissions from wetlands on the Qinghai-Tibet Plateau, Chinese Science Bulletin Vol .44 No. 24 December 1999

[41] Ding, W. X. and Cai, Z. C. 2007. Methane emission from natural wetlands in China: Summary of years 1995–2004 studies. Pedosphere. 17 (4): 475–486.

[42] Ding, W. X., Cai, Z. C and Dexuan Wang, Preliminary budget of methane emissions from natural wetlands in China, Atmospheric Environment 38 (2004) 751–759

[43] Sudip Mitra, Reiner Wassmann and Paul L. G. Vlek, An appraisal of global wetland area and its organic carbon stock, CURRENT SCIENCE, VOL. 88, NO. 1, 10 JANUARY 2005, pp. 25– 35

[44] Ding, W. X. and Cai, Z. C. 2007. Methane emission from natural wetlands in China: Summary of years 1995–2004 studies. Pedosphere. 17(4): 475–486

[45] Ding, W. X., Cai, Z. C and Dexuan Wang, Preliminary budget of methane emissions from natural wetlands in China, Atmospheric Environment 38 (2004) 751–759

[46] Jane Qiu, China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008

[47] Guodong Cheng and Tonghua Wu, Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau, Journal of Geophysical Research, Vol. 112, 2007

[48]Lin Zhao, Chien-Lu Ping, Daqing Yang, Guodong Cheng, Yongjian Ding and Shiyin Liu, Changes of climate and seasonally frozen ground over the past 30 years in Qinghai–Xizang (Tibetan) Plateau, China, Global and Planetary Change 43 (2004) 19–31

[49] Yihui Ding, Ying Sun, Zunya Wang, Yuxiang Zhu and Yafang Song, Inter-decadal variation of the summer precipitation in China and its association with decreasing Asian summer monsoon, Part II: Possible causes, Int. J. Climatology. (2009), DOI: 10.1002/joc

[50] DUAN Anmin, WU Guoxiong and and LIANG Xiaoyun, Influence of the Tibetan Plateau on the Summer Climate Patterns over Asia in the IAP/LASG SAMIL Model, Advances in Atmospheric Sciences, Vol. 25, No. 4, 2008, 518–528

[51] Y. F. Qian, Y. Q. Zheng, Y. Zhang and M. Q. Miao, Response of China's summer monsoon climate to snow anomaly over the Tibetan Plateau, Int. J. Climatol. 23: 593–613 (2003);*

[52] Lin Zhao, Chien-Lu Ping, Daqing Yang, Guodong Cheng, Yongjian Ding and Shiyin Liu, Changes of climate and seasonally frozen ground over the past 30 years in Qinghai–Xizang (Tibetan) Plateau, China, Global and Planetary Change 43 (2004) 19–31

[53] Edward A. G. Schuur, James Bockheim, Josep G. Canadell, EugeniE Euskirchen, Christopher B. Field, Sergey V. Goryachkin, Stefan Hagemann, Peter Kuhry, Peter M. Lafleur, Hanna Lee, Galina Mazhitova, Frederick E. Nelson, Annette Rinke, Vladimir E. Romanovsky, Nikolay Shiklomanov, Charles Tarnocai, Sergey Venevsky, Jason G. Vogel, and Sergei A. Zimov,
Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle, BioScience • September 2008 / Vol. 58 No. 8, pp. 701- 714

[54] Ibid

[55] Jin, H. J., WU Jie, CHENG Guodong, Nakano Tomoko and SUN Guangyou, Methane emissions from wetlands on the Qinghai-Tibet Plateau, Chinese Science Bulletin Vol .44 No. 24 December 1999

[56] Jin, H. J., Shuxun Li, Guodong Cheng, Wang Shaoling and Xin Li, Permafrost and climatic change in China, Global and Planetary Change 26: (2000) 387–404

[57] Zhang Fawei, Liu Anhua, Li Yingnian, Zhao Liang, Wang Qinxue and Du Mingyuan, CO_2 *flux in alpine wetland ecosystem on the Qinghai-Tibetan Plateau, China, Acta Ecologica Sinica, 2008, 28(2), 453-462.*

[58] Feng An and Amanda Sauer, IEA/UNEP Workshop on Automobile CO_2 *Reduction and Fuel Economy Improvement Policies, 13 October, 2004, Shanghai, China, (Accessed Feb,2009)*
http://www.autoproject.org.cn/english/new_advance_en/Pew.pdf

[59] Wang Genxu, Li Yuanshou, Wang Yibo, Wu Qingbo, Effects of permafrost thawing on vegetation and soil carbon pool losses on the Qinghai–Tibet Plateau, China, Geoderma 143 (2008) 143–152

[60] Julia Klein, TRIN-GYI-PHO-NYA: Tibet's Environment & Development Digest, Tibet Justice Center, January, 2005, Vol. 2, No. 6

[61] Lin Erda, Xu Yinlong, WU Shaohong, Ju Hui, MA Shiming,
China's National Climate Change Assessment Report, 2007

[62] Lin Zhao, Chien-Lu Ping, Daqing Yang, Guodong Cheng, Yongjian Ding and Shiyin Liu, Changes of climate and seasonally frozen ground over the past 30 years in Qinghai–Xizang (Tibetan) Plateau, China, Global and Planetary Change 43 (2004) 19–31

[63] Wang Jiaquan, "Roof of the World" Testifies Early Global Warming, Worldwatch Institute, June 21, 2007

[64] Jin, H. J., Shuxun Li, Guodong Cheng, Wang Shaoling and Xin Li, Permafrost and climatic change in China, Global and Planetary Change 26: (2000) 387–404

[65] China's National Climate Change Programme, National Development and Reform Commission, People's Republic of China, Printed in June 2007

[66] Phil Mckenna, Tibet is warming at twice global average, NewScientistEnvironment, July 24, 2007.

[67] www.msnweather.com

[68] Manfred Domros and Peng Gongbing, "The observation period covers the recent meteoro-logical standard period from 1950-1980, either completely or partly for a number of years with available data": From The Climate of China (Berlin, Heidelberg, New York: Springer-Verlag, 1988)

[69] Walter Immerzeel, Jetse Stoorvogel and John Antle, Can Payments for ecosystem services secure the water tower of Tibet? Agricultural systems 96 (2008) pp 52-63.

[70] Xinhua News Agency, Ngari prefecture in Tibet sees more abnormal weather phenomena in 2007, January 11, 2008

[71] Xinhua News Agency, Relief Rushed to Snowstorm Victims in Tibet, May 1, 2002

[72] Oxfam,First situation report: snowstorms in Qinghai and Tibet of the Peoples Republic of China, Hong Kong, January 9, 1998

[73] Koji Fujita, Takeshi Ohta and Yutaka Ageta, Characteristics and climatic sensitivities of runoff from a cold-type glacier on the Tibetan Plateau, Hydrological Processes, 21, 2882–2891 (2007)

[74] Natalie M. Kehrwald, Lonnie G. Thompson, Yao Tandong, Ellen Mosley-Thompson, Ulrich Schotterer, Vasily Alfimov, Ju¨rg Beer, Jost Eikenberg, and Mary E. Davis (2008) Mass loss on Himalayan glacier endangers water resources, Geophysical Research Letters, Vol. 35

[75] Jane Qiu,China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008

[76] *Gou Xiaohua, Chen Fahu, Yang Meixue, Jacoby Gordon, Peng Jianfeng and Zhang Yongxiang A comparison of tree-ring records and glacier variations over the past 700 years, northeastern Tibetan Plateau, Annals of Glaciology, Volume 43, Number 1, September 2006 , pp. 86-90*

[77] *Ibid*

[78] *Clifford Coonan, Global warming: Tibet's lofty glaciers melt away, The Independent, 17 November, 2006, http://www.independent.co.uk/environment/climate-change/global-warming-tibets-lofty-glaciers-melt-away-424651.html*

[79] *Kishan Khoday, Climate Change and the Right to Development. Himalayan Glacial Melting and the Future of Development on the Tibetan Plateau, UNDP, May 7, 2007*

[80] *Regional Glacial Lake Outburst Floods (GLOFs) Risk Reduction in the Himalayas Initiative, UNDP, May 2008, http://pamirtimes.files.wordpress.com/2008/06/monthly_update-may_08.doc*

[81] *Yanjun Shang, Zhifa Yang, Lihui Li, Daan Liu, Qiulin Liao and Yangchun Wang, A super-large landslide in Tibet in 2000: background, occurrence, disaster, and origin, Geomorphology, Volume 54, Issues 3-4, 5 September 2003, Pages 225-243*

[82] *MA Dongtao, TU Jianjun, CUI Peng, and LU Ruren, Approach to mountain hazards in Tibet, China, Chengdu Institute of Mountain Hazards and Environment, Chinese Academy of Sciences & Ministry of Water Conservancy, Sichuan (2004)*

[83] *Yang, X. Zhang, Y. Zhang, W. Yan, Y. Wang, Z. Ding, M. Chu, D, Climate Change in Mt. Qomolangma Region since 1971, www.tibetmagazine.net/en*

[84] *Howard W. French, A Melting Glacier in Tibet Serves as an Example and a Warming, The New York Times, November 9, 2004*

[85] *Jane Qiu, China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008*

[86] *International Center for Integrated Mountain Development (ICIMOD, 2009) http://www.climatechallengeindia.org/Download-document/224-Climate-change-in-the-Himalayas*

[87] *Pradeep M Kool, Melting of Himalayan Glaciers, ICIMOD(Adapted version)*

[88] *MA Dongtao, TU Jianjun, CUI Peng, and LU Ruren, Approach to mountain hazards in Tibet, China, Chengdu Institute of Mountain Hazards and Environment, Chinese Academy of Sciences & Ministry of Water Conservancy, Sichuan (2004)*

[89] *Wu Lizong, Che Tao, Jin Rui, Li Xin (CAREERI), Gong Tongliang, Xie Yuhong (BHT), Tang Guon, Liu Yingmei (Northwest University), Pradeep Kumar Mool, Samjwal Ratna Bajracharya, Kiran Shakya, Gauri Shankar Dangol (ICIMOD), Poiqu (Bhote-Sun Koshi) and Rongxer (Tama Koshi) Basins, Tibet Autonomous Region, PR China. Inventory of Glaciers and Glacial Lakes and the Identification of Potential Glacial Lake Outburst Floods (GLOFs) Affected by Global Warming in the Mountains of Himalayan Region. ICIMOD, CAREERI, BHT, Lanzhou, Gansu, China (2004)*

[90] *Ibid*

[91] *Ding Yongjian, Liu Shiyin, Xie Changwei, Zhang Yong, Wang Jian, Yellow River at Risk, An Assessment of the Impacts of Climate Change on the Yellow River Source Region, Greenpeace, 2005*

[92] *Ibid*

[93] *Guodong Cheng and Tonghua Wu, Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau, Journal of Geophysical Research, Vol. 112, 2007*

[94] *NAN Zhuotong, LI Shuxun & CHENG Guodong, Prediction of permafrost distribution on the Qinghai-Tibet Plateau in the next 50 and 100 years, State Key Laboratory of Frozen Soil Engineering, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China, 2003*

[95] *Meixue Yang, Shaoling Wang, Tandong Yao, Xiaohua Gou, Anxin Lu & Xuejun Guo, Desertification and its relationship with permafrost degradation in Qinghai-Xizang (Tibet) plateau, Cold Regions Science and Technology 39 (2004) 47– 53*

[96] *Hui-jun Jin, Qi-hao Yu, Shao-ling Wang and Lan-zhi Lü, Changes in permafrost environments along the Qinghai–Tibet engineering corridor induced by*

anthropogenic activities and climate warming, Cold Regions Science and Technology 53 (2008) 317–333

[97] *Jin, H. J., Shuxun Li, Guodong Cheng, Wang Shaoling and Xin Li, Permafrost and climatic change in China, Global and Planetary Change 26: (2000) 387–404*

[98] *Evelyne Yohe and Laurie J. Schmidt, Riding the permafrost express, National Snow and Ice Data Center DAAC, http://nasadaacs.eos.nasa.gov/articles/2005/2005_permafrost.html*

[99] *Huakun Zhou,Xinquan Zhao,Yanhong Tang, Song Gu and Li Zhou, Alpine grassland degradation and its control in the source region of the Yangtze and Yellow Rivers, China Grassland Science 51 (2005) 191–203*

[100] *Guodong Cheng and Tonghua Wu, Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau, Journal of Geophysical Research, Vol. 112, 2007*

[101] *Jane Qiu, China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008*

[102] *Guodong Cheng and Tonghua Wu, Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau, Journal of Geophysical Research, Vol. 112, 2007*

[103] *Jin, H. J., WU Jie, CHENG Guodong, Nakano Tomoko and SUN Guangyou, Methane emissions from wetlands on the Qinghai-Tibet Plateau, Chinese Science Bulletin Vol .44 No. 24 December 1999*

[104] *Hui-jun Jin, Qi-hao Yu, Shao-ling Wang and Lan-zhi Lü, Changes in permafrost environments along the Qinghai–Tibet engineering corridor induced by anthropogenic activities and climate warming, Cold Regions Science and Technology 53 (2008) 317–333*

[105] *Ibid*

[106] *Ding Yongjian, Liu Shiyin, Xie Changwei, Zhang Yong, Wang Jian. Yellow River at Risk, An Assessment of the Impacts of Climate Change on the Yellow River Source Region, Greenpeace, 2005*

[107] Guodong Cheng and Tonghua Wu, Responses of permafrost to climate change and their environmental significance, Qinghai-Tibet Plateau, Journal of Geophysical Research, Vol. 112, 2007

[108] Ibid

[109] Nan Zhuotong, Li Shuxun & Cheng Guodong, Prediction of permafrost distribution on the Qinghai-Tibet Plateau in the next 50 and 100 years, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China, 2003

[110] Nico van Wageninggen, Sa Wenjun, The Living Plateau Changing lives of herders in Qinghai, ICIMOD, 2001

[111] Jiahua Zhang,, Fengmei Yao, Lingyun Zheng and Limin Yang Evaluation of Grassland Dynamics in the Northern-Tibet Plateau of China Using Remote Sensing and Climate Data (2007), http://www.mdpi.org/sensors/papers/s7123312.pdf

[112] Yong Liang Sun, Xiaoyan Li, Lianyou Liu, Heye Xu and Dengshan Zhang, Climate change and sandy land development in Qinghai Lake Watershed, China, Front. Environ. Sci. Engin. China 2008, 2(3): 340–348, DOI 10.1007/s11783-008-0045-5

[113] Xiao-Yan Li, He-Ye Xu, Yong-Liang Sun, Deng-Shan Zhang and Zhi-Peng Yang, Lake-Level Change and Water Balance Analysis at Lake Qinghai, West China during Recent Decades, Water Resource Management (2007) 21:1505–1516.

[114] Craig Simons, Amid Fears Of Global Warming, China Weighs Profits and Pollution, Cox News Service Washington Bureau, April 8, 2007 http://www.coxwashington.com/hp/content/reporters/stories/2007/04/08/BC_CHINA_WARMING08_COX.html

[115] Song Shutao, Climate change sucks water from China's two longest rivers, Xinhua News Agency, July 15, 2007; http://news.xinhuanet.com/english/2007-07/15/content_6377992.htm

[116] Kishan Khoday, Climate Change and the Right to Development. Himalayan Glacial Melting and the Future of Development on the Tibetan Plateau, UNDP, May 7, 2007

[117] Wong, CM, Williams, CE, Pittock, J, Collier, U and P Schelle, World's top 10 rivers at risk, WWF International, Gland, Switzerland, March 2007

[118] Riaz Ahmad Khan, Advisor to Ministry of Water and Power, Doubling Water Financing and Results, Conference on ADB's Water Financing Program 2006-2010, September 26, 2006

[119] Wong, CM, Williams, CE, Pittock, J, Collier, U and P Schelle, World's top 10 rivers at risk, WWF International. Gland, Switzerland, March 2007

[120] Ibid

[121] Marszalek Jessica, World's dams are 'contributing to global warming', http://www.news.com.au/story/0,23599,22360233-2,00.html (accessed September 4, 2008)

[122] Zhang Tingting, China to integrate biodiversity and climate change, March 7, 2008, http://www.china.org.cn/environment/news/2008-03/07/content_11878359.htm (accessed September 4, 2008)

[123] Julia A. Klein, John Harte and Xin-Quan Zhao, Decline in Medicinal and Forage Species with Warming is Mediated by Plant Traits on the Tibetan Plateau, June 20,2008

[124] Julia A. Klein, John Harte and Xin-Quan Zhao, Experimental warming, not grazing, decreases rangeland quality on the Tibetan plateau, Ecological Applications, 17 (2), 2007

[125] Hongyan Xie, Why Tibetan poppies have the blues, Science Wise, Vol. 2, March\April 2008 http://sciencewise.anu.edu.au/issues/ScienceWise_Vol5_No2.pdf *(accessed September 4, 2008)*

[126] Claudia Delpero, Melting glaciers on the Tibetan Plateau, July 10, 2007, WWF http://www.panda.org/news_facts/newsroom/features/index.cfm?uNewsID=108360

[127] Snow disaster kills 5,500 Tibetan Gazelles, http://www.china.org.cn/environment/news/2008-03/15/content_12678376.htm

[128] Snowstorms kill nine, trap hundreds in Tibet , Nov 1, 2008 http://www.earthtimes.org/articles/show/239602,snowstorms-kill-nine-trap-hundreds-in-tibet.html

[129] *Y. Feng, Q. Lu, T. Tokola, H. Liu and X. Wang, Assessment of grassland degradation in Guinan county, Qinghai province, China, in the past 30 years, Land Degradation & Development. (2008), DOI: 10.1002/ldr*

[130] *UNDP. 2002. China Human Development Report: Making Green Development, Oxford University Press, 2002*

[131] *Maureen Fan, For China's Nomads, Relocation Proves a Mixed Blessing More Opportunities, But Loss of Control, Washington Post Foreign Service, September 20, 2008*

[132] *Katherine Morton, Climate Change on the Tibetan Plateau: A New Security Challenge, Woodrow Wilson Center, Washington DC, February 12th, 2009 http://www.wilsoncenter.org/ondemand/index.cfm?fuseaction=Media.play&mediaid=A98B9EA0-B257-1FBB-7079F3FB8A24667F*

[133] *Amartya Sen, Development as Freedom, (2000)*

[134] *Huakun Zhou,Xinquan Zhao,Yanhong Tang, Song Gu and Li Zhou, Alpine grassland degradation and its control in the source region of the Yangtze and Yellow Rivers, China Grassland Science 51 (2005) 191–203*

[135] *Meixue Yang, Shaoling Wang, Tandong Yao, Xiaohua Gou, Anxin Lu & Xuejun Guo, Desertification and its relationship with permafrost degradation in Qinghai-Xizang (Tibet) plateau, Cold Regions Science and Technology 39 (2004) 47– 53*

[136] *P. Yan, G. R. Dong, Z.Z. Su and D.S Zhang, Desertification problems in the Yangtze River source area, China, Land Degradation & Development. 15: 177–182 (2004)*

[137] *Julia A. Klein, John Harte and Xin-Quan Zhao, Experimental warming causes large and rapid species loss, dampened by simulated grazing, on the Tibetan Plateau, Ecology Letter, (2004) 7: 1170-1179*

[138] *P. Yan, G. R. Dong, Z.Z. Su and D.S Zhang, Desertification problems in the Yangtze River source area, China, Land Degradation & Development. 15: 177–182 (2004)*

[139] *Kishan Khoday, Climate Change and the Right to Development. Himalayan Glacial Melting and the Future of Development on the Tibetan Plateau, UNDP, May 7, 2007*

[140] Meixue Yang, Shaoling Wang, Tandong Yao, Xiaohua Gou, Anxin Lu & Xuejun Guo, Desertification and its relationship with permafrost degradation in Qinghai-Xizang (Tibet) plateau, Cold Regions Science and Technology 39 (2004) 47– 53

[141] Eric deCarbonnel, the geopolitics of food scarcity, February 13, 2009

[142] Ibid
[143] Ibid
[144] Ibid
[145] 'Impoverishing Tibetans', TCHRD Publications, 2000
http://www.tchrd.org/publications/topical_reports/impoverishing_tibetans-2000/index.html

[146] Zhang Kejia, Zhang Kejia, 20 August, 2007
http://english.biodiv.gov.cn/zyxw/200708/t20070820_108138.htm

[147] Tibetan shepherds welcome climate change, by Richard Spencer at the Karo-la Pass in Tibet, Telegraph, 16 Feb 2007

[148] In a personal interview with Dr. Tej Partap on 31 May 2008 at his office in CSK Agriculture University, Palampur, Himachal Pradesh

[149] In a personal interview with Tashi Tsering at the DIIR Studio, CTA, Dharamsala, Himachal Pradesh

[150] Lauren Sacks and Cynthia Rosenzweig, Climate Change and Food Security, available at
http://www.climate.org/2002/topics/agricul/index.shtml

[151] Junguo Liua, Hong Yanga, The impacts of climate change on seasonal crop irrigation requirement of wheat in China, Accessed at http://wwc2008.msem.univ-montp2.fr/resource/authors/abs434_article.pdf

[152] Zhou Jinxing, Yang Jun, Peng Gong, Constructing a green railway on the Tibet Plateau: Evaluating the effectiveness of mitigation measures, Transportation Research Part D 13 (2008) 369–376

[153] Hui-jun Jin, Qi-hao Yu, Shao-ling Wang and Lan-zhi Lü, Changes in permafrost environments along the Qinghai–Tibet engineering corridor induced by

anthropogenic activities and climate warming, Cold Regions Science and Technology 53 (2008) 317–333

[154] *Ibid*

[155] *Tingjun Zhang, T. Harry W. Baker, Guo-Dong Cheng and Qingbai Wu, The Qinghai–Tibet Railroad: A milestone project and its environmental impact, Cold Regions Science and Technology 53 (2008) 229–240*

[156] *Jin H. J., WU Jie, CHENG Guodong, Nakano Tomoko and SUN Guangyou, Methane emissions from wetlands on the Qinghai-Tibet Plateau, Chinese Science Bulletin Vol .44 No. 24 December 1999*

[157] *Baolai Wang and Hugh M. French, Implications of Frost Heave for Patterned Ground, Tibet Plateau, Arctic and Alpine Research, Vol. 27, No. 4, 1995, pp. 337-344*

[158] *Tingjun Zhang, T. Harry W. Baker, Guo-Dong Cheng and Qingbai Wu, The Qinghai–Tibet Railroad: A milestone project and its environmental impact, Cold Regions Science and Technology 53 (2008) 229–240*

[159] *Environment and Development Desk, 'TIBET, A Human Development and Environment Report' (2008), EDD, DIIR, Central Tibetan Administration, Dharamsala, HP, India, ISBN 81-86627-68-5v*

[160] *Y. Feng, Q. Lu, T. Tokola, H. Liu and X. Wang, Assessment of grassland degradation in Guinan county, Qinghai province, China, in the past 30 years, Land Degradation & Development. (2008), DOI: 10.1002/ldr*

[161] *Hui-jun Jin, Qi-hao Yu, Shao-ling Wang and Lan-zhi Lü, Changes in permafrost environments along the Qinghai–Tibet engineering corridor induced by anthropogenic activities and climate warming, Cold Regions Science and Technology 53 (2008) 317–333*

[162]*Jin, H. J., Shuxun Li, Guodong Cheng, Wang Shaoling and Xin Li, Permafrost and climatic change in China, Global and Planetary Change 26: (2000) 387–404*

[163] *Ma wei, Nui Fujun, Akagawa Satishi and Jin Dewu, Slope instability phenomena in permafrost regions of Qinghai-Tibetan Plateau, China, Landslides (2006) 3:260-264*

[164] Wu, Douglas. 2000. China's Quiet Property Rights Revolution. Cato Policy Report, vol. 22 (6).

[165] Environment and Development Desk, 'TIBET, A Human Development and Environment Report' (2008), EDD, DIIR, Central Tibetan Administration, Dharamsala, HP, India, ISBN 81-86627-68-5v

[166] *Environment and Development Desk, 'TIBET, A Human Development and Environment Report' (2008), EDD, DIIR, Central Tibetan Administration, Dharamsala, HP, India, ISBN 81-86627-68-5v*

[167] *Y. Feng, Q. Lu, T. Tokola, H. Liu and X. Wang, Assessment of grassland degradation in Guinan county, Qinghai province, China, in the past 30 years, Land Degradation & Development. (2008), DOI: 10.1002/ldr*

[168] Wu, C., C. Maurer, Y. Wang, S. Xue and D.L. Davis. 1999. Water Pollution and Human Health in China. Environmental Health Perspectives, vol. 107 (4): 251-256.

[169] Wu, Douglas. 2000. China's Quiet Property Rights Revolution. Cato Policy Report, vol. 22 (6).

[170] Wu, C., C. Maurer, Y. Wang, S. Xue and D.L. Davis. 1999. Water Pollution and Human Health in China. Environmental Health Perspectives, vol. 107 (4): 251-256.

[171] Y. Feng, Q. Lu, T. Tokola, H. Liu and X. Wang, Assessment of grassland degradation in Guinan county, Qinghai province, China, in the past 30 years, Land Degradation & Development. (2008), DOI: 10.1002/ldr

[172] Energy, Environment and Climate Change Issues: China, A study by the Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC), 2000[177]CRS Report RL34659, China's Greenhouse Gas Emissionsand Mitigation Policies, Jane A. Leggett, Jeffrey Logan and Anna Mackey, September 10, 2008

[173] See CRS Report RL34659 'China's Greenhouse Gas Emissions and Mitigation Policies' by Jane A. Leggett, Anna Mackey & Jeffrey Logan, September 10, 2008

[174] Netherland Environmental Assessment Agency (MNP), China now no. 1 in CO2 emissions; USA in second position,

http://www.mnp.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissionsUSAinsecondposition.html

[175] *See CRS Report RL34659 'China's Greenhouse Gas Emissions and Mitigation Policies' by Jane A. Leggett, Anna Mackey & Jeffrey Logan, September 10, 2008*

[176] *Gordon Feller, China's Energy Demand, May 19th, 2007*
http://ecoworld.com/features/2007/05/19/chinas-energy-demand/

[177] *http://news.bbc.co.uk/1/hi/business/7888041.stm*

[178] *Gordon Feller, China's Energy Demand, May 19th, 2007*
http://ecoworld.com/features/2007/05/19/chinas-energy-demand/

[179] *Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, China, Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC), ISBN 974-8257-00-2*

[180] *Cong, Z.Y., Kang, S.C., Liu, X.D., Wang, G.F., 2007. Elemental composition of aerosol in the Nam Co region, Tibetan Plateau, during summer monsoon season. Atmospheric Environment 41, pp. 1180 -1187.*

[181] *Balerna, A., Bernieri, E., Pecci, M., Polesello, S., Smiraglia, C., Valsecchi, S., 2003. Chemical and radio-chemical composition of fresh snow samples from northern slopes of Himalayas (Cho Oyu range, Tibet). Atmospheric Environment 37, pp. 1573-1581.*

[182] *Xiao, C.D., Kang, S.C., Qin, D.H., Yao, T.D., Ren, J.W., 2002. Transport of atmospheric impurities over the QinghaieXizang (Tibetan) Plateau as shown by snow chemistry. Journal of Asian Earth Sciences 20, pp. 231-239.*

[183] *Organization of Asia-Pacific News Agencies , 14 February 2007,*
http://www.oananews.org/

[184] *Yulong copper mine: In Jomda (Ch: Jiangda) County, Chamdo (Ch: Qamdo) Prefecture, "TAR"*

[185] *China Tibet Information Center, Tibet smelter at Yulong Copper Mine, 31, January 2009,*
http://eng.tibet.cn/news/today/200810/t20081017_433139.htm

[186] UNEP/GRID-Arendal, Vital graphics,Waste from Consumption and Production - A threat to natural resources, http://www.grida.no/publications/vg/waste/page/2858.aspx

[187] Stephen J. Brooks, Valery Udachin and Ben J. Williamson, Impact of copper smelting on lakes in the southern Ural Mountains, Russia, inferred from chironomids, Journal of Paleolimnol (2005) 33: 229–241

[188] Vincent Bourret, Patrice Couture , Peter G.C. Campbell ,and Louis Bernatchez, Evolutionary ecotoxicology of wild yellow perch (Perca flavescens) populations chronically exposed to a polymetallic gradient, Aquatic Toxicology 86 (2008) 76–90

[189] Xiang Huang, Mika Sillanpaa, Bu Duo and Egil T. Gjessing, Water quality in the Tibetan Plateau: Metal contents of four selected rivers, Environmental Pollution 156 (2008), pp. 270-277.

[190] Environment and Development Desk, 'TIBET, A Human Development and Environment Report' (2008), EDD, DIIR, Central Tibetan Administration, Dharamsala, HP, India, ISBN 81-86627-68-5

[191] The Economic Influences-Benefits of the Qinghai-Tibet Railway, http://www.china.org.cn/english/features/Tibet/173746.htm (accessed 30 Jan,09)

[192] China Chemical Reporter - an English magazine, http://www.ccr.com.cn/

[193] United States Environment Protection Agency (USEPA), Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, EPA 816-R-04-003, June 2004

[194] TEDX, The Endocrine Disruption Exchange, Written testimony of Theo Colborn, PhD, President of TEDX, Paonia, Colorado before the House Committee on Oversight and Government Reform, hearing on The Applicability of Federal Requirements to Protect Public Health and the Environment from Oil and Gas Development, October 31, 2007.

[195] Jane Qiu,China: The third pole: Climate change is coming fast and furious to the Tibetan plateau, naturenews, Published online July 23, 2008

ABBREVIATION & DEFINITION

GDP	Gross Domestic Product
SOC	Soil Organic Carbon
LFOC	Light Fraction Organic Carbon
TOC	Total Organic Carbon
CO2	Carbon Dioxide
GHGs	Greenhouse Gases
CH4	Methane
IPCC	Intergovernmental Panel on Climate Change
SLH	Siling-Lhasa Highway
QTH	Qinghai-Tibet Highway
ICIMOD	International Centre for Integrated Mountain Development
GLOF	Glacial Lake Outburst Flood
CAREERI	Cold and Arid Regions' Environmental Engineering Research Institute, Chinese Academy of Sciences, Lanzhou
EDD	Environment and Development Desk
BHT	Bureau of Hydrology of Tibet
QTEC	Qinghai Tibet Engineering Corridor
WWF	World Wide Fund for Nature
ANPP	Above Ground Net Primary Production
TCHRD	Tibetan Centre for Human Rights and Democracy
SCIR	Seasonal Crop Irrigation Requirement
MAGT	Mean Annual Ground Temperature
PLA	People's Liberation Army
NEPA	National Environmental Protection Agency
IEA	International Energy Agency
MNP	Netherland Environmental Assessment Agency
SMI	Small and Medium Industries
ARPEEC	Asian Regional Research Programme in Energy, Environment and Climate
C	Carbon
M3/S	Cubic Metre Per Second, a Measure of the Flow of a River

THE DALAI LAMA

ENDORSEMENT

Right now our greatest responsibility is to undo the damage done by the introduction of fossil carbon dioxide into the atmosphere and climate system during the rise of human civilisation.

We know that we have already exceeded the 350 parts per million that is a safe level of carbon dioxide in the atmosphere. In doing so, we have ushered in a global climate crisis. This is evident from the frequent extreme weather events we witness around us, the unprecedented melting of the Arctic sea-ice and of the great Tibetan glaciers at the Earth's *Third Pole*.

It is now urgent that we take corrective action to ensure a safe climate future for coming generations of human beings and other species. That can be established in perpetuity if we can reduce atmospheric carbon dioxide to 350ppm. Buddhists, concerned people of the world and all people of good heart should be aware of this and act upon it.

December 20, 2008

Environment and Development Desk
Department of Information and
International Relations (DIIR)
Central Tibetan Administration
Dharamshala - 176215
H.P. INDIA