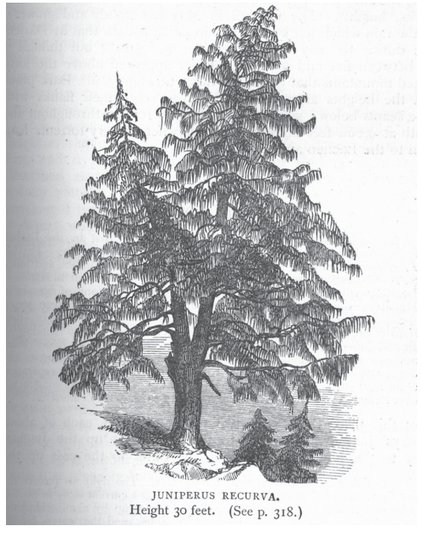
Map 1: Upper Yangtse Watershed

	PINYIN	TIBETAN PINYIN	TIBETAN
Aba			*Ngawa*
Brahmaputra	*Yarlong Zangbo*		
Chungba	*Junba*	*Kyangba*	
Dardsendo	*Kangding*		
Dawu	*Daofu*		
Drango	*Luhuo*		
Ganze	*Ganzi*	*Garze*	*Kandze*
Lhakang Monastery	*Tagong*		
Mekong	*Dza Chu*		*Lancang Jiang*
Min Jiang	*Zhung Chu*		
Nyagchuka	*Yajiang*		
Nyarong	*Xinlong*		
Nyingchi	*Linzhi*		
Qamdo	*Changdu*		*Chamdo*
Rongtrak	*Danba*		
Salween	*Ngu Chu*		*Nu Jiang*
Yalong	*Nya Chu*		
Yangtze	*Jinsha Jiang*		*Dri Chu*

CHINESE PINYIN-TIBETAN PINYIN-TIBETAN TRANSLATIONS


JUNIPERUS RECURVA.
Height 30 feet. (See p. 318.)

Joseph Hooker's sketch of *Juniperus recurva* from *Himalayan Journals*

KARL RYAVEC AND DANIEL WINKLER

LOGGING IMPACTS TO FORESTS IN TIBETAN AREAS OF SOUTHWEST CHINA: A CASE STUDY FROM GANZE PREFECTURE BASED ON 1998 LANDSAT TM IMAGERY

INTRODUCTION

Disastrous floods in central China during the summer of 1998 were partly blamed on decades of intensive clear-cutting of forests in eastern Tibetan cultural areas where most of Southwest China's surviving forests are located. The Chinese government responded in the fall of 1998 by instituting a logging ban in the Tibetan prefectures of Southwest China (NFPP). In this same period, the construction of Three Gorges Dam on the Yangtze river in central China raised concern about increasing sedimentation rates in the new reservoir, linked to land use in the dam's catchment on the upper Yangtze watershed (Map 1). Data on forest cover in China, however, are limited and researchers must use remote sensing imagery to painstakingly assess forest conditions in particular areas. This situation makes it difficult to assess the accuracy of official forest-area figures published in China.

METHODS

Forest clearcutting on the Tibetan Plateau is relatively recent, and it is possible to measure its extent at specific points in time from the distinctive "fishbone" patterns of clear-cuts discernable on medium-resolution satellite images. This study analyses clear-cut patterns apparent in a 1998 Landsat Thematic Mapper (TM) image at 30-meter resolution of part of the eastern Tibetan Plateau in Ganze Tibetan Autonomous Prefecture (TAP) in western Sichuan province to assess logging impacts in a sample location at the time of the 1998 legislation.

Forestry and forest ecology data are provided by Daniel Winkler, who also carried out ground-truthing with hand-held GPS in Yajiang and Litang Counties. Preliminary ground-truthing was carried out in February 1999. Classification results were compared on two consecutive field trips in June and October of the same year. Between July 1997 and April 2002, Winkler also crossed the area of the Landsat scene 9 more times for work related to reforestation and forest conservation projects in Litang, Nyarong, Nyagchuka, Drango, and Sertar in the Ganze Tibetan Autonomous Prefecture in western Sichuan, and Riwoqe County in the Qamdo Prefecture of the Tibet Autonomous Region (hereafter TAR).

FOREST DISTRIBUTION

Presently forest ecosystems are found mainly in the southeastern part of the Tibetan Plateau along river valleys (Map 1). The major rivers, such as the Yangtze and its tributaries the Yalong and Min Jiang, Mekong, Salween and the middle reaches of the Tsangpo / Brahmaputra have deeply incised the plateau. The summer monsoon moves up onto the plateau following the river gorges and brings over 80% of the annual precipitation. Forest ecosystems farther up the plateau receive between 500mm to 800mm/a. Along the outer fringe-annual precipitation increases to 1000mm - 2000mm.

Currently forest ecosystems are most widespread in the southeastern region of the Tibetan Plateau and along its eastern marches. Forest distribution is mainly influenced by precipitation levels and altitude. Treeline reaches 4650m in the Qamdo Prefecture (in the eastern part of the TAR), the highest in the world. In general, in Tibetan core settlement areas most remaining forests are found on steep slopes along the deep river valleys. Valley bottoms, wide ridges, plateaus and rolling hill areas all have been cleared for pastures and agriculture. Thus, forest fragmentation and conversion have a long-standing history on the Tibetan plateau, while fringe areas, such as the Eastern Himalaya, have kept their forest cover nearly intact.

Another important trend in regional forest distribution is apparent especially in areas to the east of the Yangtze in West Sichuan. Here, in the Tibetan Autonomous Prefectures of Ganze and Aba, forest distribution is fragmented to a much higher degree than in the TAR . This fragmentation is a result of logging activities carried out by government agencies since the mid 1950s (see below). Not surprisingly

the current logging ban targets primarily these areas. Within the TAR, where road access to densely populated parts of Han China is more difficult, forest cover shows less fragmentation on average.

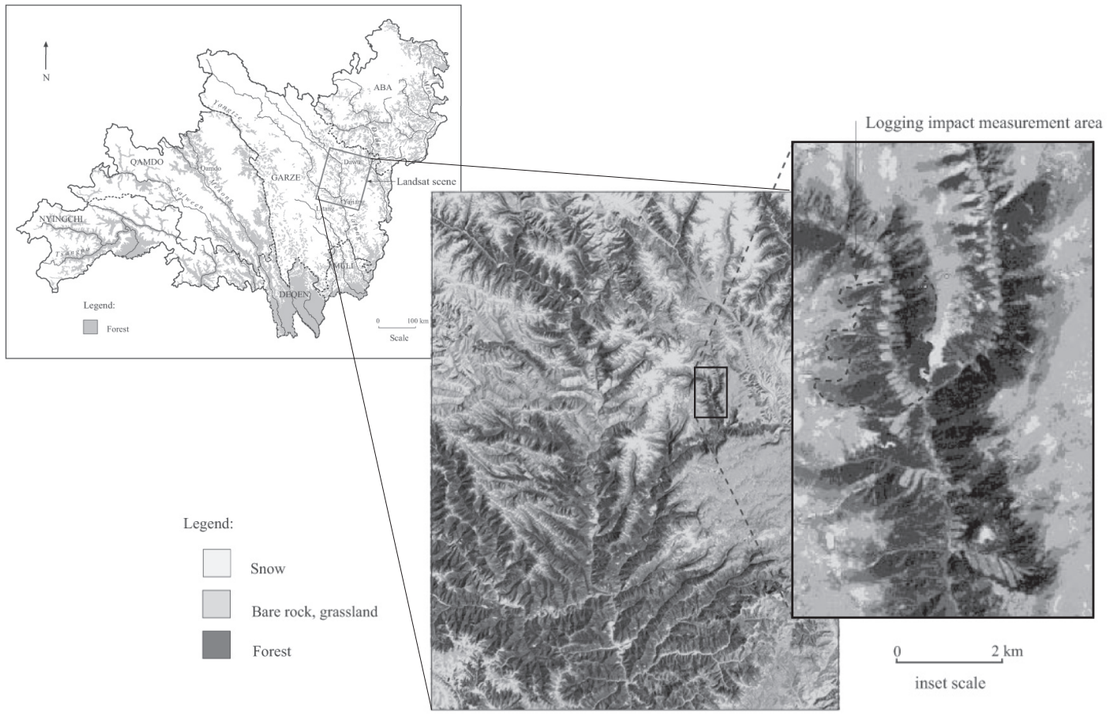
Table 1 presents forestry data of the Tibetan Areas of SW China. Forest area refers to the area classified as such including logged areas, sparse forests and shrublands. Forest cover denotes the portion of the forest area, which has an actual forest cover. According to these figures 35.3% of the area is forest area, although actual forests cover only 17.3 % of the total area. Thus only 49% of the forest area is currently classified as under forest cover. However, this classification is based on post 1950s or later landuse. It does not take into account historical deforestation and pasture creation. The data of Nyingchi and Qamdo, Tibet AR's main forest region, are also included. Forest area in the other TAR Prefectures cover only 1.1% with a standing volume of 131 million m3. Nyingchi and Qamdo contain 84% of TAR's forest area and 90.4% of the standing volume, although their area encompasses only 16.3% of TAR. Please note, these figures only contain the area under Chinese administration and not the claimed areas of India's Arunachal Pradesh, which is included in official TAR statistics, adding about 650 million m3 of standing volume on 3 million ha.

"Forest area" refers to the area classified as forest area including logged areas, sparse forests, and shrublands. "Forest cover" denotes the portion of the forest area, with actual forest cover. According to these figures a third of the area (35.3%) is forest area, although actual forest covers only 17.3 % of the total area. Thus only 49% of the area that is classified as forest area is currently classified as under forest cover. However, this classification is based on post 1950s or later land use. It does not take into account historic conversion of forest to pasture.

Forest statistics for Qinghai Province Prefecture have been omitted, since the forest area is very small. The forest area in Gansu Pronvince's Gannan Tibetan Autonomous Prefecture (4.4 Mio ha) contains 88 Mio m3 of standing timber while covering 18.1% (796,667 ha) of the Prefecture. However, 51.8% (412,673ha) of the forest area is classified as being actually forested (Yang 1993).

Tab. 1: Forest Area, Forest Cover and Standing Volumes in Tibetan Autonomous Areas of Southwest China.

Prefecture (County)	Province (Region)	(1) Total Area	(2) Forest Area		(3) Forest Cover			Standing Volume		
		1000 ha	1000 ha	% of (1)	1000 ha	% of (1)	% of (2)	Mio. m^3	m^3/ha of (1)	m^3/ha of (2)
Nyingchi Pref.	Tibet AR[1]	7,046		60.3	2,169	43.6	71.5	870	3.5	287.0
Qamdo Pref.	Tibet AR[1]	10,601		27.1	1,323	12.0	44.5	364	.3	122.3
Ganzi TAP	Sichuan[2]	14,537		28.8	1,372	9.4	32.8	340	.4	81.2
Aba TAP	Sichuan[3]	8,343	3,029	36.3	1,508	18.1	49.8	415	.7	137.0
Muli County	Sichuan[4]	1,324		58.6	455	34.4	58.6	105	.3	135.3
Deqen TAP	Yunnan[5]	2,387		67.4	820	34.3	50.9	227	.1	141.0
Totals		44,238		35.3	7,647	17.3	49.0	2,321	.5	148.7



Map 2: Landsat Image Showing Logged Areas

Landsat Scene Study Area in Ganze Tibetan Autonomous Prefecture

The study of a Landsat satellite image from April 1998 (Map 2) will exemplify the major processes shaping present forest distribution. Since the logging ban was rigorously enacted that year, forest reduction should only be marginal. With a resolution of 30m, the Landsat image allows most forest areas, except for isolated stands of trees, to be clearly mapped.

The Landsat scene covers the eastern center of Ganze Tibetan Autonomous Prefecture of Sichuan Province including the counties of Nyagchuka and Dawu in the center and Litang, Nyarong and Ganze to the west, as well as Dardsendo and Rongtrak to the east. Elevations range from 2750m in the Yalong valley in the southernmost part of the image, to snow-clad mountain peaks up to 5709m (north of Dawu). The climate is a temperate high mountain semi-humid climate. Owing to the rugged terrain and differences in exposure/aspect, precipitation and evaporation vary greatly, contributing to high biodiversity. For example, forested slopes might receive above 1000mm/a of precipitation, while valley bottoms along the Yalong receive around 500mm to 600mm/a because of local wind patterns known as 'dry valley phenomena' (Yang & Zheng 1990). About 80% of the precipitation is brought in by the southwest summer monsoon, which prevails between the end of May and September. In contrast, winters are arid and very cold.

Traditional Landuse

The eastern Tibetan Khampa culture of Kham (eastern Tibet) developed in relation to a challenging climate and topography. Ancient techniques of agricultural production and pastoralism, the latter the backbone of local production, have been maintained over centuries conserving and extending a delicate resource of grasslands. The lifestyle is based on the seasonal movement of livestock such as yak, sheep, goats and horses between high-altitude summer pastures (above 4000m) and lower winter pastures, often located around homesteads. Below 3800m agricultural settlements are found mostly along river valleys. Agricultural subsistence production focuses on

barley as well as some wheat, potatos, and mustard. The cultivation of fruit trees such as apple and walnuts, two highly marketable crops, has been promoted recently.

Forests were traditionally regarded as a common asset and have been used as a resource for timber and firewood as well as for many non-timber forest products such as medicinal plants and mushrooms. Currently the collection of fungi (*Cordyceps sinensis* and ***Tricholoma matsutake)*** is the main source of local cash income (see Winkler 2003, 2005).

tributed as undergrowth on north-facing slopes.

Juniper forests grow in the subalpine zone on south slopes. When heavily lopped or on adverse sites junipers persist as shrubs. Presently, most south slopes are actually covered by evergreen oak forests (2m - 8m height, ⌀ 0.1m - 0.6m). Often the conifer canopy is missing or extremely fragmented due to selective harvesting, but more commonly due to repeated fire. Oak proliferation is strongly supported by fire and firewood extraction. Clearing south slopes of forests or of unwanted

Tab. 2: The Main Forest Tree Species in Litang, Ganzi TAP, Sichuan.

FOREST TYPE AND ALTITUDE	North-Facing Slope		South-Facing Slope	
	Coniferous	Broad-leaved	Coniferous	Broad-leaved
Montane Warm-Temperate Forests 2700m-3400m	*Abies ernestii* *A. squamata* *Picea balfouriana* *Pinus densata*	Deciduous: *Betula platyphylla* *B.albo-sinensis* *Populus davidiana* *P. rotundifolia*	*Pinus densata* *Picea balfouriana*	Evergreen: *Quercus aquifolioides* *Q. longispica*
Subalpine Cold-Temperate Forests 3200m-4400m	*Abies squamata* *Picea balfouriana* *P. retroflexa* *Larix potaninii* *L. potaninii var. macrocarpa*	Deciduous: *Betula utilis* *B. platyphylla* *Populus kangdingensis* *P. xiangchengensis*	*Picea balfouriana* *Juniperus tibetica* *J. convallium,* *J. saltuaria,* *J. wallichiana*	Evergreen: *Quercus aquifolioides*

Forests

The forest canopy consists mostly of conifers (Table 2) mixed with broadleaved deciduous and evergreen species. Warm-temperate forests are dominated by pine-oak assemblages. North-slopes also have a strong fir-spruce element with birch and aspen; the latter dominate the sub-canopy and initiate forest succession after logging or fire. Cold-temperate forests are mainly fir and spruce with an admixture of larch, birch, and aspen. Fir is more competitive than spruce on north-facing slopes. Spruce claims exposed sites, and often fir dominates later stages of forest succession. Whereas spruce is competitive on north and south slopes, oak dominates south-facing slopes only. Here, junipers occupy exposed subalpine sites. Willows (***Salix*** spp.) and sea buckthorn (***Hippophae rhamnoides***) are common along streams.

Typical cold-temperate spruce-fir forests on north-facing slopes contain trees of a height of 20m - 30m with a diameter of 0.7m at an age of 200 to 300 years with an average volume of 250-300m3/ha. Spruce is a common source of timber. The shrub-layer consists of several species of ***Rhododendron, Lonicera, Ribes,*** and ***Sorbus***. Sclerophyllous oak is also dis-

shrubs to create pastures or improve pasture quality is a common Tibetan land-use practice.

Forest Industry

From the mid 1950s onwards the forestry industry was developed into the economic backbone of Ganze Prefecture to finance road development. Newly established local governments often derived 70% (in the case of Nyarong over 90%) of their cash income from logging. Some local people found employment in the timber industry, but it was primarily Chinese workers and also logging units from lowland Sichuan who were contracted to harvest timber. Most timber had to be sold off cheaply to the state, sometimes below production cost (Zhao 1992). So far, no conclusive figures are available on the full extent of deforestation before the enactment of the logging ban. However, Yang reported in 1986 that the forest area along the Yalong has been reduced from 29.5% to 14% between the mid-1950s and mid-1980s. The forests were viewed as an inexhaustible resource. Accessible forestlands were depleted within three decades. Between 1950 and 1990 reforestation after clearcutting was an exception. Only in the

early 1990s were reforestation efforts and nursery production were stepped up.

The two Tibetan Autonomous Prefectures Ganze and neighboring Aba produced together 120,000,000m3 of timber, which generated 2 billion RMB ($380 million) in taxes and profits (Xinhua Aug. 24, 1998), indicating that Ganze Prefecture alone produced 50-60 million m3. However, this is the production of marketable timber and not the actual amount of timber cut. Logging efficiency was low; Yang (1987) reports a ratio of 3:1 between gross annual timber output and marketable timber. This suggests that anywhere from 150 to 180 million m3 were consumed in Ganze alone. This correlates well to Yang's (1986) figures, who reported that 120 million m3 were consumed in Ganze between the mid 1950s and 1985. Adding an annual consumption of 2.7 million m3 for another 14 years, based on Liu (1994) who reports an annual timber production level of 0.9 million m3 per year in 1990, would raise the amount of timber consumed to about 35 to 40 million m3. This suggests a total consumption of timber of around 200 million m3 in Ganze since the 1950s, an enormous amount compared to its overall standing volume of 340 million m3.

Logging Sustainability: A GIS/Remote Sensing-based Assessment

An assessment of the sustainability of a logging operation depends on the parameters chosen, which vary widely among forest managers, forest policy decision-makers, and forest ecologists. Traditionally, "sustainability" considered timber production alone, requiring that the harvest volume should not exceed the amount of timber growing in a certain area over a given period of time. Economic sustainability of timber harvest has been widely recognized as an important parameter. In recent decades it has been argued that sustainable forest management should at least guarantee the maintenance

gaining ground in China as reflected in the NFPP. However, before the 1998 logging ban, sustainability had not been a management parameter in Ganze Tibetan Autonomous Prefecture.

Within the Landsat image inset area (Map 2), the impact of logging was studied in the Seka valley in Bamei Township, in south Dawu County. Without human disturbance this area of 4.59 km2 would be mostly, if not completely, forested. No sizeable village or cultivated fields are apparent in the image of this area. The pattern of current forest distribution clearly reflects recent logging practices common in Ganze. Old-growth stands, averaging around 200 to 250 years with a standing volume of 250-300m3/ha, are clearcut in patches of 5 to 20 ha in size [see Fig.4]. Cuts are made from the valley bottom upwards, thus minimizing logging road construction. Narrow stands of trees are retained on ridges between clearcuts.

Minimum harvestable age for spruce-fir forests is 80 to 120 years, the harvesting age usually increasing with altitude owing to the shorter growing season. Theoretically, harvesting 1% annually would represent a sustainable logging quota in order to maintain the standing timber volume in a plantation with a rotation of 100 years. This calculation excludes loses to decay, a common practice in calculating plantation volume sustainability. In Litang's natural forests, for example, decay figures 0.4% per year. Also not figured in are potential losses to forest fire, disease, and grazing. Heavy losses to grazing can occur in the first years of regeneration and result in not fully stocked reforested areas, a widespread problem in forest areas close to settlements in the region (Winkler 2002).

These recent clearcuts clearly visible on the Landsat image cover 0.82 km2 of the potential forest area, which also includes some immature stands. Furthermore, 52.7% of Dawu's forest area (see Table 3) is classified as protection forest made up from stands along ridges, rivers, roads and on slopes

Tab. 3: Forest Areas and Management Types (based on Liu 1994)

Administrative Unit	Forest Area		Standing Volume	Timber Forest		Protection Forest	
	total of unit	1000 ha	1000 m^3	1000ha	in %	1000 ha	in %
Garze Prefecture	10.0 %	1,522.4	339,999.4	621.6	40.1	881.2	57.9
Nyagchuka County	19.0 %	128.8	24,105.8	42.6	33.1	86.2	66.9
Litang County	11.3 %	99.5	17,694.8	50.5	50.8	49.0	49.2
Dawu County	9.2 %	31.3	6,680.5	14.8	47.3	16.5	52.7

of watershed functions of the forest ecosystem, and at best protect all other ecological functions including safeguarding wildlife, plant, and fungus populations. This interpretation is

steeper than 35°. Assuming that these 52.7% also apply to Seka valley, less than 30% of the forest area remains harvestable for forestry. The harvested 17.9% represent 37.9% of the harvestable forest area in the analyzed area.

Making a quantitative statement regarding production sustainability can only be an estimate without comparing the analyzed scene to an earlier scene. However limited the benefit is, an attempt should be made here. By taking into account that only relatively new clearcuts can be detected, since otherwise secondary vegetation and/or replanted seedlings will come to cover the area, an estimate of sustainability can be made basing it on the duration of the detection of clearcuts. Assuming that clearcuts can be detected over 5 years, clearcutting 18% of the total forest area equals an annual harvest rate of 3.6%. Assuming clearcuts are detectable over 10 years, the harvest rate equals 1.8%. Since growth increments in Ganze's spruce-fir forests are calculated at 0.6% per year, pre-1998 timber extraction in Seka valley represents a harvesting rate of at least 3 to 6 times above the annual increment, a harvesting quota that does not reflect sustainable management.

Conclusion

Ganze's unsustainable timber exploitation was destined to come to an end. Enforcing a logging ban was the preemptive strike by the central government to avoid imminent resource exhaustion. Local administrations have been forced to restructure their local economies. The impact of the 'Develop the West' program, however, has yet to be seen. For decades, provincial logging quotas prescribed timber harvests beyond sustainable levels because the income derived comprised the mainstay of the cash incomes of impoverished county administrations. Now there is a new dependency for these administrations on outside subsidies. However, the end of logging is not an immediate challenge to local people, since they were not really integrated in the industry to begin with. Former seasonal logging work has been replaced by increased planting. Yet local economies, especially in remote areas, have to fear for their access to markets, since state forest enterprises no longer maintain roads.

It only can be hoped for that the current 'time out' until the conclusion of the first phase of the Natural Forest Protection Project (NFPP) in 2012 is being used to advance the integration of local Tibetan populations in forestry and particularly in reforestation. In the first years of the ban, the integration of locals in reforestation work did not receive sufficient attention. Most forest departments struggled hard to keep their own employees working, with most of them recruited from the lowlands. It is not sufficient to implement local forest protection as a government-prescribed program based on fines as long as plantation protection is diametrically opposed to the local economic reality. Furthermore, the remoteness of the area and the diverging socioeconomic realities of local livestock raising farmers and forestry officials render such programs too often useless. So far, there is no economic incentive for local people, nearly all of them livestock herders, to protect reforestation areas from grazing. Ironically, locals appreciate the extensive clearcuts, although not the occasionally ensuing hazards such as debris flows, and use them as pastures. This is a very pragmatic landuse approach from a herder's perspective, since state-sector logging produced negligible direct benefits for local people. Furthermore, reforestation areas are not fenced in Ganze prefecture due to the relatively high cost of fencing material. Thus, successful forest regeneration is only possible with the cooperation of local people. To assure local cooperation, the forest industry needs to offer substantial and reliable long-term benefits to local people in order to change their attitude towards forest protection. Only if the forests are a reliable and important source of income will locals forgo more immediate benefits from livestock grazing in reforestation areas. The logging ban successfully stopped the mining of forest resources in the Tibetan areas of Southwest China, but it is left to be seen if sustainable forest management will be implemented after the ban is over in 2012.

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