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Land use/cover change in central Tibet, c. 1830–1990: devising a GIS methodology to study a historical Tibetan land decree

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In this study, historical Tibetan tax-related data pertaining to cultivated land in central Tibet are studied by means of GIS and compared with contemporary patterns. A Tibetan land decree from 1830 contains aggregated data on the amount of land-based tax units for estates in 57 districts of central Tibet. The purpose of this study is to devise a GIS methodology to study the potential utility of these data for historical geographical research, and to determine the approximate changes in cultivated land areas between 1830 and 1990. Traditional Tibetan tax data are significant for current efforts to construct historical land cover databases of the Tibetan Plateau region for the study of the human dimensions of global change.

KEY WORDS: Tibet, land use/cover change, GIS, environmental history, agriculture

Introduction to the problem and the data: the c. 1830 Iron Tiger land decree

Historical Tibetan tax-related documents, specifically those pertaining to agriculture, provide important data on human–environment relationships in the past. Geographic information systems (GIS) offer a powerful way to examine these historical data in tandem with physical environmental variables in order to elucidate statistical estimations of past agrarian land use/cover patterns. The purpose of the current research is to reconstruct and map the approximate amounts of cultivated land in central Tibetan districts based on a land decree from 1830, and to compare these amounts with c. 1990 data. The Tibetan title of the decree is the *lcag stag zhib gzhung*[1] (CTP 1989), or the Iron Tiger land decree, named after the year in the Tibetan calendar in which it was compiled (1830: iron tiger). In 1991 the text was translated into Chinese under the title *Tiehu Qingce* (CTP 1991). No English translation has yet been made. The decree lists the land tax units, termed *kang*, for estates in 56 of 58 districts in central Tibet (Figure 1). In addition, the Lhasa valley, directly administered from the Potala Palace in Lhasa, comprised a 59th district.

A satisfactory survey of individual estates within each district is presently beyond our grasp, because a detailed spatial analysis would require historical data on the precise location of each estate, and these data are presently not available. It is also not clear that such a detailed spatial database could be developed, considering that only the names of the estates are listed in the land decree. The locations of most of the 58 districts are well known, however, from various pilgrimage and contemporary tourist guides to central Tibet, and British Survey of India maps compiled during the early twentieth century. In the few instances where the location of a district seat was not clear to me, I found the approximate location according to footnotes in the recent Chinese translation of the land decree.

The *kang* land tax unit is an ambiguous measure. It does not conform to a standard area measurement, such as the *mu* in China, or the hectare. Rather, a *kang* refers to an approximate weight of barley seed sown. Only by calculating from this seed weight is it possible to determine an approximate area of cultivated land in relation to a *kang*. Faced with this ambiguity, I adopted an approximate area measurement for the sake of convenience in this historical GIS survey. By

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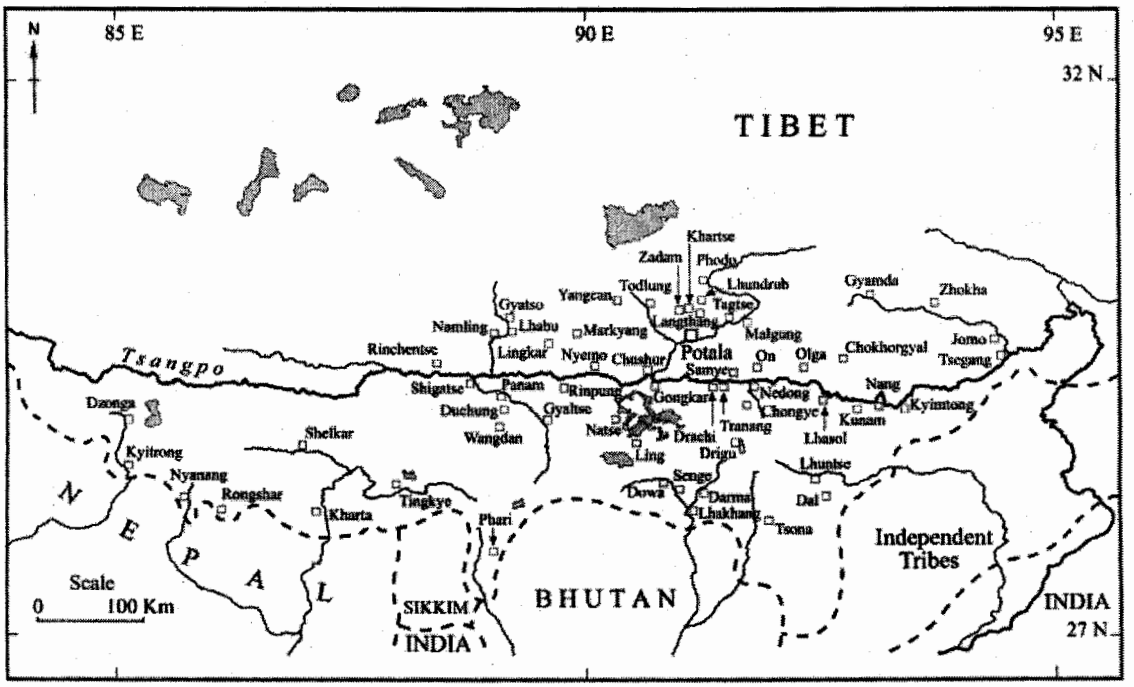

Figure 1 Seats of districts listed in the 1830 Iron Tiger land decree

employing an approximate area measurement, it will be possible to compare levels of change in amount of cultivated land and population densities between central Tibetan districts from 1830 to 1990. In other words, the purpose of this survey is not to establish precise rates of change according to specific amounts of cultivated land in 1830 but, instead, to test several general hypotheses relating to regional patterns of land use/cover change. It is also important to note that not all cultivated land in each district was controlled by estates and taxed by the government, though most cultivated land probably was.

I choose 1990 as a benchmark year because Chinese county-level agricultural data from the 1990s are generally considered of better quality than earlier data. In addition, beginning in the early 1990s, major land reclamation projects, some funded by UN development programs, began in central Tibet, altering long-term land use/cover patterns. However, significant changes had already been wrought during the 30 year period since China's annexation of Tibet in 1959, as seen in some large irrigation-based model state farms showcased by China during its cultural revolution (c. 1966–1976). Owing to these additions in cultivated land areas, it is not possible to differentiate accurately between the extent of change from 1830 to the advent of Chinese rule in Tibet, and subsequent changes, because Chinese agricultural data from the cultural revolution period are generally inaccurate.

It is reasonable to speculate that the core districts of central Tibet, characterized by large tracts of cultivated land along the floors of the broad U-shaped valleys near the cities of Lhasa and Shigatse, may have experienced different rates of change in cultivated land densities than districts in the peripheral forested Himalayan valleys (Plate 1). The question is raised as to whether the core areas had already exhausted available cultivated land based on the limits of indigenous irrigation technology by 1830 or whether significant later expansion occurred? And did the forested Himalayan valleys experience expansions in farmland after 1830, perhaps due to deforestation to bring more lands into cultivation? A comparative study of levels of change across the districts of central Tibet will enable one to learn more about these patterns of land use/cover change based on an approximate (though somewhat arbitrarily determined) standard area measurement for the *kang* tax unit.

Clearly, I am embarking here on a pioneering effort, which, despite its crudeness, will, I hope, raise awareness among the Tibetan studies and land use/cover change communities of the

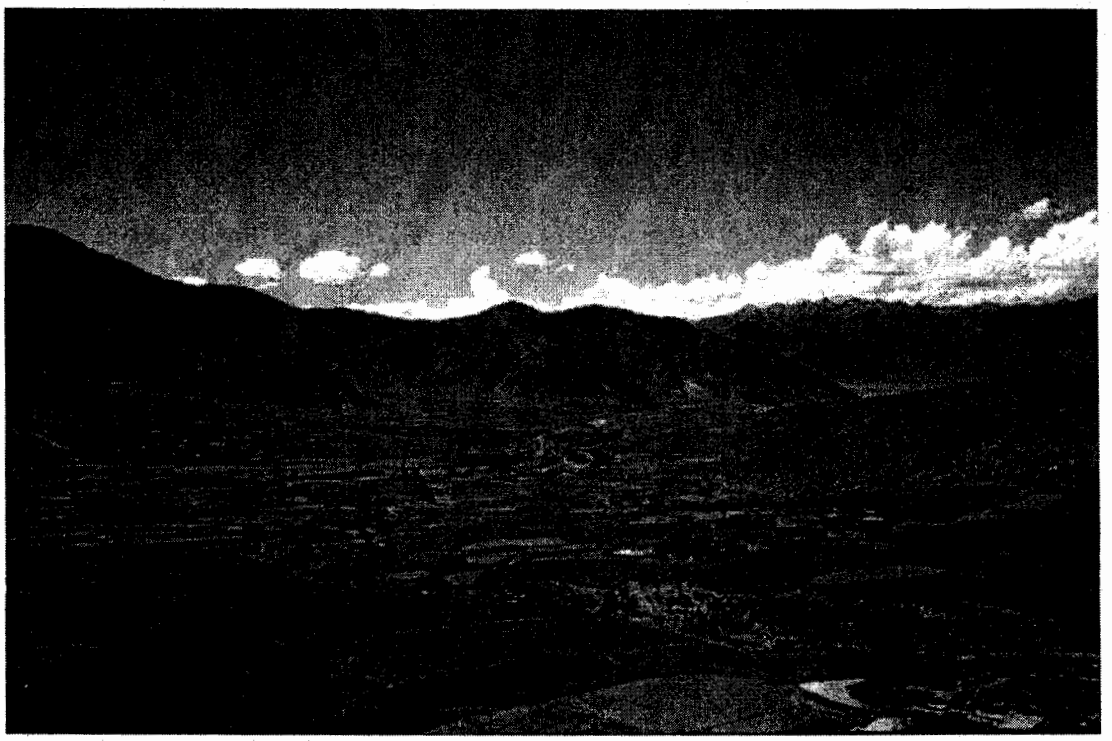

Plate 1 The Gyama valley in central Tibet. This broad U-shaped valley near Lhasa is representative of the central Tibetan landscape. Photograph by Karl E. Ryavec, June 1994

potential research value of historical Tibetan records.

Land use/cover databases

In contrast to the availability of contemporary coarse spatial resolution digital land cover maps for Tibet, there are no historical maps depicting past land use/cover patterns over large areas. Unlike other regions of Asia that were ruled by Western and Japanese colonial powers during parts of the nineteenth and twentieth centuries, and for which large-scale topographic map series were compiled, Tibet was politically independent of, and at the same time of little direct economic importance to, the colonial interests. Since the incorporation of Tibet within the People's Republic of China after 1959, various Chinese map series detailing land cover and topography have been drafted, though most, especially the large-scale sheets, have not been made publicly available. In light of this situation, it is necessary to base GIS studies of historical land use/cover patterns upon available contemporary coarse spatial resolution databases to a great extent.

The original *1:1 000 000 Land Use Map of China* compiled by the Chinese government during the 1980s in 64 sheets comprised the basis for a recent digital land cover database by the Australian Centre of the Asian Spatial Information and Analysis Network at Griffith University in Brisbane, Australia. These databases comprise the *Digital 1:1 000 000 Land Use Map of China* (Figure 2). Though I used these digital land use/cover data in this study, similar data for the entire world based on 1.1 km Advanced Very High Resolution Radiometer imagery carried aboard the US National Oceanic and Atmospheric Administration weather satellites became available during the 1990s. For topographic data, which are important for estimating historical cultivation patterns in Tibet where farming is restricted to low-lying valleys, I used the highest resolution available digital elevation model (DEM) with a nominal spatial resolution of approximately 1 km. These data comprise part of the global 30-arc second DEM produced by the US Geological Survey.

The development of digital land use/cover databases derived from historical topographic map series for Asian regions is still in its infancy. To date,

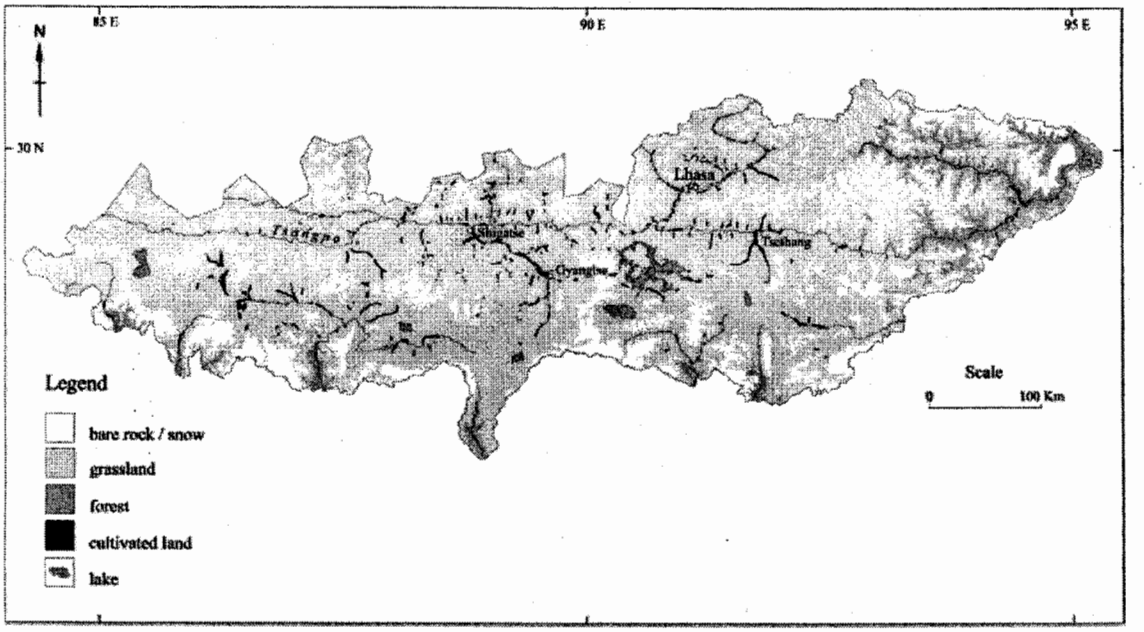

Figure 2 Land use/cover of central Tibet

Himiyama *et al.* (1995 1998) have created digital land use/cover databases pertaining to parts of northeast China and the North China Plain at approximately 1 km resolution from large-scale Imperial Japanese Army topographic maps compiled during the 1930s. Similar temporal databases could also be compiled for most of the former British Indian Empire from the extensive large-scale (i.e. 'One-Inch' or one inch to the mile) topographic map series compiled by the Survey of India during the late nineteenth and early twentieth centuries, though to date such an ambitious project has not been undertaken. Southern Tibetan areas adjacent to India's northern frontier were mapped during the early twentieth century by the Survey of India as part of its medium-scale (i.e. 'Quarter-Inch') topographic map series, but these sheets only depict river courses, settlement points and transportation routes upon crudely represented hill-shading. The inability of the Survey of India to undertake extensive ground surveys in Tibet owing to political reasons and mountainous terrain prevented detailed land use/cover patterns, such as of forest, steppe and cultivated areas, from being mapped. For these reasons, GIS studies of Tibet's historical land use/cover patterns need to follow a different technical approach.

In the absence of detailed historical land use/cover maps, it is possible to start with current patterns and extrapolate backwards in time, scaling agricultural areas according to population figures. Ramankutty and Foley (1998) followed this approach in order to assess the influence of changing land cover on regional climate and carbon cycling. Their database became the first gridded global historic land cover database (Leemans *et al.* 2000). Environmental historians are also contributing to mapping historical land use records with the aim of better understanding past land use/cover patterns. Sluyter (1997) mapped the distribution of land grants for which approximate sizes are known that were awarded to ranchers by the colonial administration in sixteenth-century New Spain (now central Mexico). The resulting grid cells for each land grant were located to within 2–10 km of accuracy, and offer insight into past livestock densities. This study on Tibet seeks to extend the spatial detail of historical land cover databases as they pertain to cultivated land. It does so according to contemporary Chinese county boundaries within which change trajectories in cultivated land areas are estimated from an 1830 tax-related document and 1990 agricultural statistics.

The Tibetan state and land-based tax systems

The origin of the traditional Tibetan state lies in the seventeenth century. In 1642 the fifth Dalai Lama, after a period of strife between the reformist Gelugpa or Yellow Hat sect of Tibetan Buddhism,

which he headed, and older sects, became the ruler of Tibet. This religious involvement in the government was a product of long-term historical development since the introduction of Buddhism in Tibet during the seventh century. The new religious organization of the Gelugpas achieved and extended control so successfully that it functioned as the *Depa Zhung* ('authority centre'), or government, over central Tibet, and wielded vast political power and influence over large parts of bordering Tibetan regions where indigenous or imposed secular governments existed (Ekvall 1964). Official forms of control and organization of the Tibetan state largely originated in, and derived sanctions from, doctrine and religion. Many of these actions were intentional and planned, but even when not planned, rites and observances, although directed solely toward religious purposes, also produced far-reaching secular effects. Many tracts of cultivated land, including the farmers who tilled them, were given by the Tibetan state to the maintenance of monastic centres in order to ensure the successful and continued functions of cults and worship. Herders often had to provide butter produced either by their own herds, or by estate-owned animals which they were required to care for, as a tax-in-kind. Tibet's nobility, whose privileges predated the rule of the Dalai Lamas, also controlled large amounts of land and large herds of livestock.

Under the traditional Tibetan state all landed property was ultimately state property. After the formation of the new Gelugpa state, however, older religious institutions and the nobility retained their traditional agrarian and pastoral holdings. Their estates were now seen as grants from the state dependent upon meeting various tax obligations, though a few large estates in central Tibet were exempt from tax obligations. Farmers and herders outside of the monastic and noble estates continued to pay taxes as a part of their communal responsibility and administration. They did so through their immediate state district office (Tsarong 1998).

Research to date on tax-related documents of indigenous Tibetan polities has focused on historical demography. One of the best examples may be found in Childs' (2000) analysis of an enumeration by households of the nine divisions of Kyirong district in central Tibet near the Nepalese border, compiled in 1958. This unpublished text is in the Library for Tibetan Works and Archives in Dharamsala, India. It enumerates the individuals and landholdings of households subject to government estates, the purpose being to establish how many people were farming government lands and to assess their tax obligations. Unfortunately, the Iron Tiger land decree does not include an enumeration of people, and only lists the *kang* landholdings of each estate.

Study region

The Iron Tiger land decree pertains to tax obligations of estates only in central Tibet, though the Lhasa-based kingdom of the Dalai Lamas controlled a larger area approximating in extent the present Tibetan Autonomous Region. By studying historical changes in agrarian land use patterns across central Tibet, it is possible to examine in depth a traditional theme of cultural geography, namely the establishment and definition of culture areas. Such studies enable one to understand better how study regions selected according to land use/cover data interrelate with geographical questions of a more qualitative research nature.

As Murphy (1991) notes, the regional framework in most empirical studies is presented essentially as a backdrop for a discussion of regional change. Seldom is consideration given to why the region originally came to be a socially significant spatial unit, how the region is understood and viewed by its inhabitants, or how and why that understanding has changed over time. A static view of farming as a subsistence land use activity precludes a full understanding of how, in the long term, agrarian land use in Tibet conditioned indigenous land tenure institutions and is impacted by China's recently introduced economic reforms. A geo-historical perspective enables one to understand better the importance of regions in Tibet's social and economic history.

Tibetans have traditionally subdivided their homeland according to indigenous geographical concepts of upper, middle and lower regions. The densely settled agricultural valleys near Lhasa are traditionally considered as belonging to the middle region of Ü, and those near the city of Shigatse as belonging to the middle region of Tsang. Hence, the combined name of Ü-Tsang has historically referred to central Tibet (Figure 3). This region may be defined in terms of the Tibetan dialect spoken by central Tibetans (Wurm 1987; Moseley and Asher 1994). A shared language, perhaps better than any other variable, points toward social and historical interaction among communities, while common dialects indicate even greater contact. In that nomadic dialects are different from those of farming areas, I define the northern and western limits of central Tibet, for the purposes of this study, according to the limit of cultivation. In doing so, I follow 1990 county and township boundaries. The high, cold Changthang Plateau to the north and west of central Tibet is wholly pastoral.

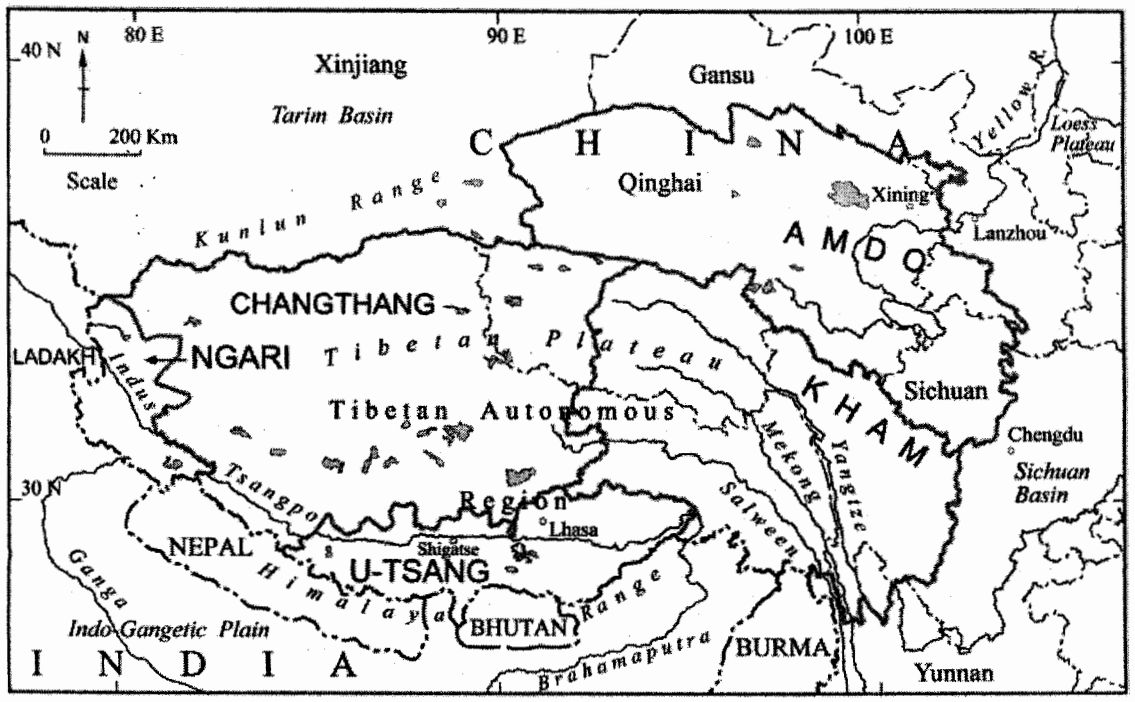

Figure 3 Folk regions of Greater Tibet

The eastern Tibetan Kham and Amdo dialects are spoken by Tibetans in the lower part of Tibet, called Dokham, a term formed by combining the names Amdo and Kham. Amdo consists largely of the grasslands of the Yellow River's upper drainage basin and also includes mountain valleys inhabited by Tibetan farmers from the edge of the Sichuan Basin to the borders of China's northwestern loess region. Kham encompasses the alternating deep forested river valleys and pastoral ranges of the Salween, Mekong and Yangtze river watersheds. Tibet's high, arid western, or upper, region is called Ngari. This region borders on Ladakh in the Indian state of Jammu and Kashmir, and includes Tibetan speakers of the Ngari dialect.

To understand why Ü-Tsang developed as Tibet's cultural and political heartland, one must consider its topography. Surrounded by mountainous steppe, the broad U-shaped valleys of the Tsangpo watershed provide large tracts of land for agriculture below the upper limit of cultivation at approximately 4500 m altitude. The distinguishing feature of the traditional Tibetan peasant economy was that it encompassed both cultivation and herding. The staple crop was barley, but rapeseed for cooking oil, and radishes, turnips and potatoes were also grown. Owing to the semi-arid climate, much use was made of irrigation water, usually channeled directly from streams originating in the high mountains. The main animals reared included sheep, goats, cattle, yak and dzo (a yak–cattle hybrid favoured for ploughing).

The importance of agrarian resources for facilitating the peoples' early settlement and population growth is reflected in Tibet's ancient economic and political divisions. Credible Tibetan history begins in the late sixth century when a line of central Tibetan kings united the scattered clans and tribes of Tibet under the Yarlung dynasty and then in the Tibetan empire. Historical documents from this period describe a military–administrative organization based on regional divisions of *ru* or 'horns'. Each

horn comprises a core agrarian tract of central Tibet, and served to organize military conscription and the administration of agricultural land and pastures under the country's first centralized state bureaucracy (Uray 1960). Central control disintegrated by the tenth century with local control passing into the hands of lay and monastic elites. By the seventeenth century, under the kingdom of the Dalai Lamas, centralized administration was extended to Himalayan valleys peripheral to the 'horns' of central Tibet. The locations of many districts (or *dzong*, the term for a fortress or district headquarters), listed in the Iron Tiger land decree illustrate this bureaucratic territorial expansion. As late as the nineteenth century, Tibetan geographical texts employed the term *Ü-Tsang of the Four Horns* to distinguish the core agricultural zone of central Tibet from peripheral forested Himalayan valleys considered by then also to be part of Ü-Tsang (Ferrari 1958).

During the Mongol period in the thirteenth and fourteenth centuries, the Chinese employed the characters *Wei Tsang* as a phonetic transcription for Tibet based on the Tibetan name of Ü-Tsang (Petech 1990). The Chinese name for Tibet today of *Xizang* (literally 'Western Treasure House') also derives from the earlier name *Wei Tsang*; but this modern name of *Xizang* is problematic as it is often employed to refer to various spatial conceptions of Tibet. Most commonly, the Chinese name *Xizang* is used to refer to the Tibetan Autonomous Region, which, in addition to Ü-Tsang, includes Ngari and large parts of Kham.

Excluded areas

Some traditional central Tibetan districts, mainly those in western Tsang province, are not included in the Iron Tiger land decree. Largely pastoral among them are the districts of Saga, Ngamring and Lhatse (Figure 4). The important monastery of Sakya and its large landholdings are also excluded (Cassinelli and Ekvall 1969). During the Mongol period, the Sakya monks gained political authority over most of Tibet and, despite their short-lived hegemony, they continued to enjoy certain privileges under the Tibetan government. The large noble Lhagyari estate was also free from Lhasa's taxation (Samuel 1993). The Lhagyari family traced its descent from the kings of the Yarlung dynasty and had various privileges with the Lhasa administration as a consequence. Last, the district of Tsona may have included part of the Tawang tract, now in northeast India. I have employed the de facto line of control between China and India (the McMahon line) that follows the crest of the eastern Himalaya from Bhutan to Myanmar for the southeastern boundary of the study region, thus excluding the Tawang tract. The total *kang* land tax units for Tsona do not differ substantially from amounts in neighbouring dzong of similar size (assuming the district did not directly tax the Dawang tract).

Two northern districts listed in the Iron Tiger land decree, Yangcan and Markyang, are wholly pastoral and so did not contain any *kang* land tax units. Because their taxes were based on livestock units, they are not included in the following GIS analysis of agrarian land use/cover patterns and change.

Data for Kharta and Rongshar, two small districts in Himalayan valleys along the Tibet–Nepal border, are listed together. For this reason, I have placed map symbols pertaining to these data at the location of Kharta, the larger of the two, in the upper Arun River valley.

Exploratory spatial data analysis

Tukey's seminal work *Exploratory Data Analysis* (1977) increased awareness of the importance of exploring statistical data to uncover trends that might otherwise go unnoticed. GIS allows exploratory data analysis to be taken to a new level, one which makes possible the examination and understanding of previously unknown spatial relationships. According to Skinner (1994), exploratory spatial analysis may be based on a research methodology that is largely inductive, avoiding a priori decisions as far as possible. Disaggregated data (viewed in relation to landscape features) are themselves allowed to establish levels to regional socioeconomic systems. The *kang* land tax units listed in the 1830 Iron Tiger land decree should not be studied merely as textual records pertaining to places. Rather, by analyzing these historical tax data with GIS we may discover new relationships between socioeconomic and ecological processes. In this way the geo-history of forms of land/use cover across central Tibet may be compared with contemporary patterns.

The spatial distribution of *kang* tax unit amounts by district validates the historical and ecological value of these data (Figure 5). The largest *kang* amounts tend to occur in the core areas of Ü and Tsang. Shigatse has the largest number of *kang*, 3933.5. Phari, which administered the forested Chumbi valley nestled between Sikkim and Bhutan on the southern edge of the Tibetan Plateau, has the smallest number, 34.5 *kang*. Out of the 56 districts in this GIS analysis, Lhasa ranks 49th with 1150 *kang*. The districts with larger numbers of *kang* than Lhasa merit mention as they occur in areas known to have been key centres of Tibetan settlement. Contemporary township-level maps of population density and distribution in central Tibet,

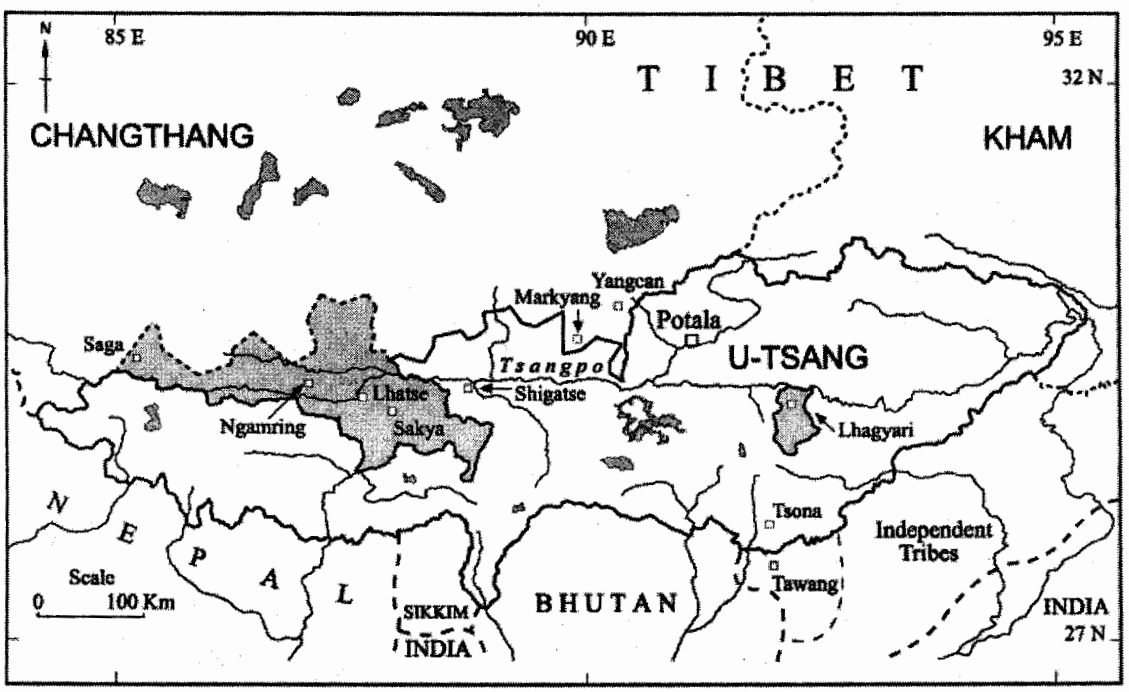

Figure 4 Area covered by the 1830 Iron Tiger land decree

based on 1990 Chinese census data, may be found in Ryavec and Veregin (1998) for reference.

Chongye and Nedong, ranked 50th and 53rd, respectively, administered the important area often referred to as the cradle of Tibetan civilization. Chongye is in the valley of the kings where the tombs of Tibetan kings from the Yarlung dynasty lie under large burial mounds. Nedong, today engulfed by the town of Tsethang on the south bank of the Tsangpo River, lies at the mouth of the Yarlung valley. Tibetan historical legends relate that the first fields were cultivated in the Yarlung valley (Stein 1972). Tibet's oldest royal palace is also found here. This area is now relatively densely settled; hence these historical data offer comparisons with neighbouring areas.

Zhokha and Tsegang, ranked 51st and 54th, respectively, lie in the eastern part of central Tibet known as Kongpo. This is a forested area with lower valley floor elevations than in the core parts of Ü and Tsang; hence, the region has long been famous for its timber, rice and honey. Today the large town of Bayi is located near the former seat of Tsegang district, and the region attracts large numbers of Tibetan and Chinese migrants to work in the timber and food production sectors. The large *kang* assessments in 1830 indicate that the region was probably already relatively densely settled by that time.

Tibet's third largest city, Gyangtse, ranks 52nd. The district of Gyangste was an important grain producing area of Tsang thanks to the large tracts

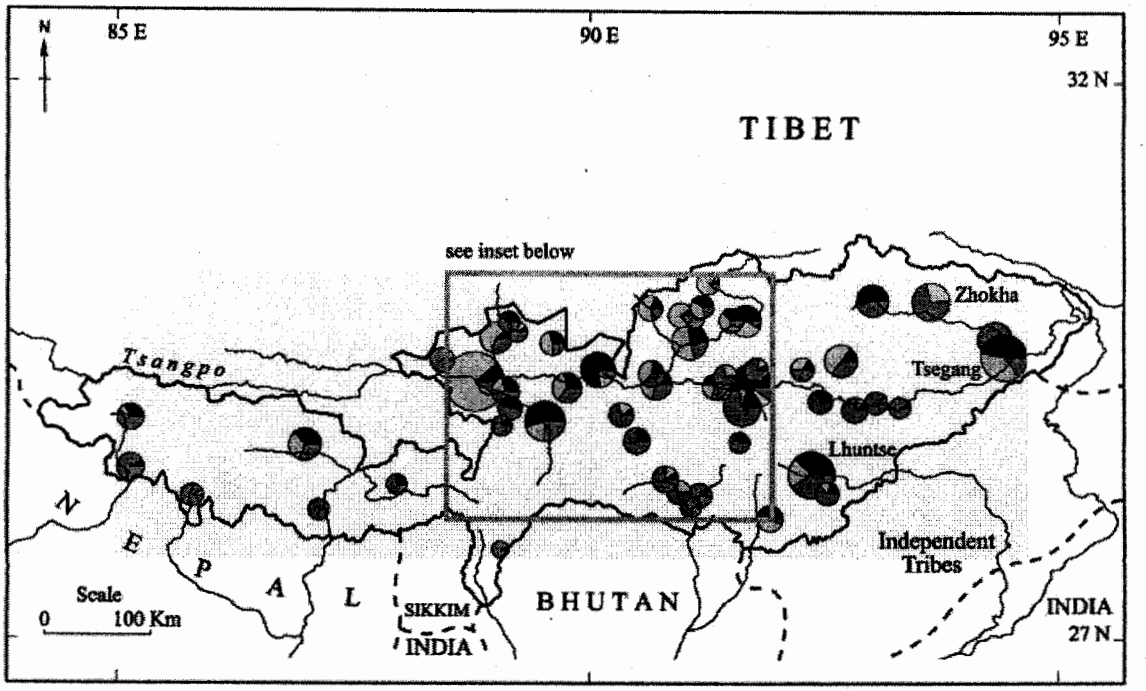

Figure 5 Amounts and distribution of *kang* tax units listed in the 1830 Iron Tiger land decree

of farmland watered by the Nyang River which converges with the Tsangpo at Shigatse. Incidentally, the acropolis fortress of Gyangtse presents one of the best surviving examples of Tibetan *dzong* architecture in central Tibet today.

Lhuntse, with the second largest number of *kang*, ranks 55th. This pattern is not surprising considering that Lhuntse lies in a broad semi-arid valley north of the eastern Himalaya. Though the districts peripheral to the core areas of Ü and Tsang tend to lie in forested Himalayan valleys, this trend is actually not always true, but depends on how local geological processes have worked to incise river valleys along the southern edge of the Tibetan Plateau. Lhuntse is a good example of a large agrarian tract with local geo-ecological conditions comparable to those in Ü-Tsang proper. East of Lhuntse the main river watering the district plunges

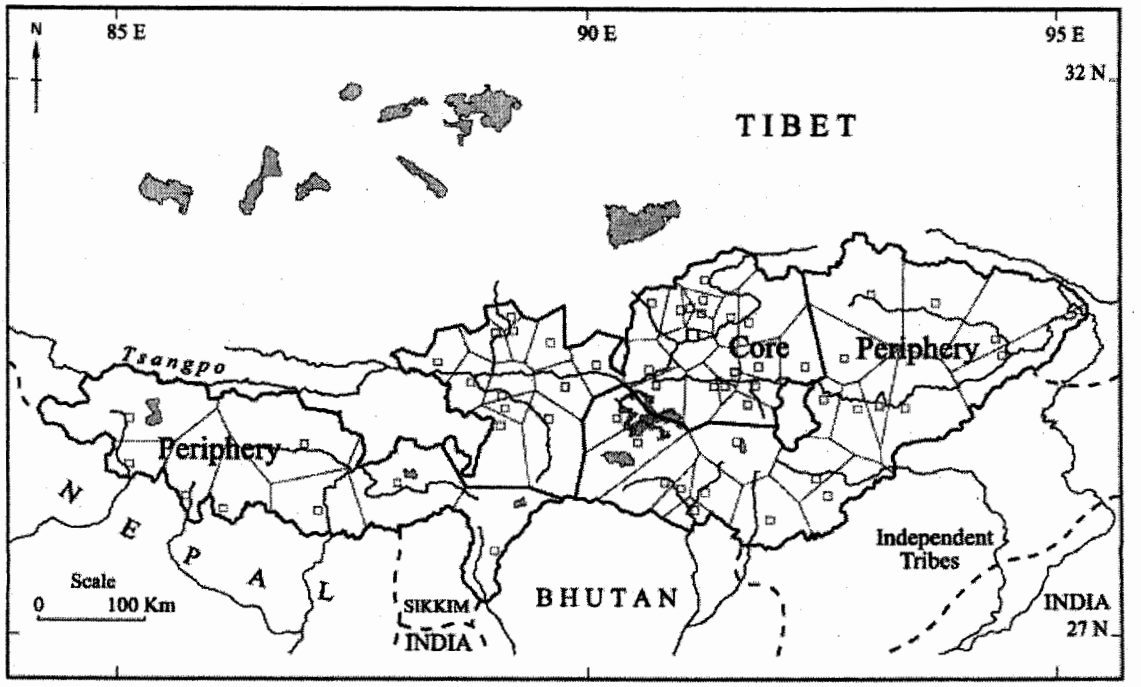

Figure 6 Districts of the 1830 Iron Tiger land decree represented by Thiessen polygons, and separated into core and periphery areas

into forested Himalayan gorges in the vaguely defined southeastern boundary zone of Tibet.

In addition to graduating the cartographic symbols used according to the total number of *kang* in each district, Figure 5 also depicts the proportion of *kang* in each district according to proprietorship: state government, monastic and noble. The Tibetan government directly administered 38.7 per cent of all farmland (according to total *kang* amounts), the largest share in the area covered by the Iron Tiger land decree. Monastic landholdings ranked second with 31.1 per cent, and the nobility followed with 30.2 per cent. These findings corroborate other estimates. According to a former official of the Tibetan government quoted in Goldstein (1989), monastic and lay estates accounted for slightly more than 50 per cent of the total land including Kham (eastern Tibet), and for a greater percentage of central Tibet.

It is also important to examine the relative densities of *kang* tax units per specific land area because the total number of *kang* does not give a clear indication of the relative proportion of cultivated land to total land area. As noted above, some of the peripheral districts have large totals of *kang*; but, as these districts tended to be larger in area than the core districts of Ü and Tsang, it is not clear if large *kang* amounts necessarily correlated with high levels of cultivated land density. To approach this problem, *kang* tax units may be analyzed in relation to the amount of potential arable land stratified by elevation.

In the first part of the analysis, each district's administrative seat was located on medium-scale US topographic maps (series 1501, 1:250 000) and digitized for inclusion in the GIS database. Due to the lack of historical maps and related data pertaining to c. 1830 district boundaries, approximate boundaries were derived using Thiessen polygons. For a given district seat location, the district is defined as the set of locations that are closer to that seat than to any other seat. This methodology creates a partitioning of the study area into 'proximal zones' by approximating actual district boundaries (Figure 6). Additionally, a combination of contemporary Chinese county and township-level boundaries were used to approximate an outer boundary to the study region. Finally, the boundary of Chusum county was employed as the best available approximation of the limits of the noble Lhagyari estate, an unstudied enclave, within the study region itself.

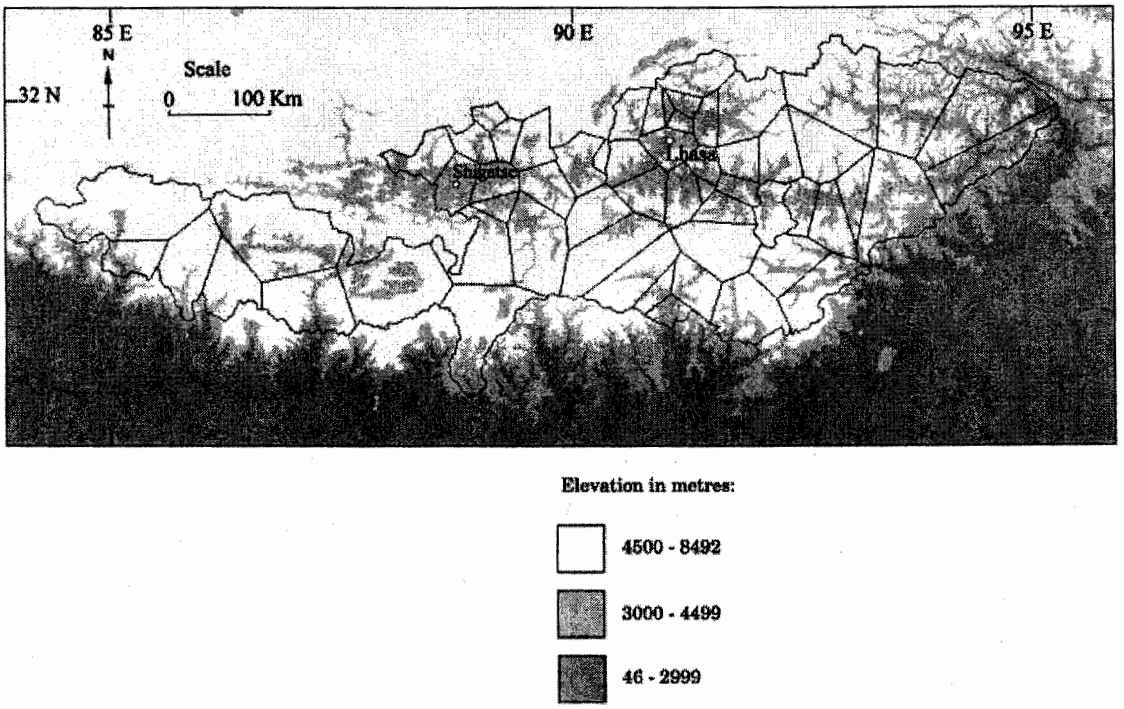

Figure 7 1830 District boundaries in relation to elevation

The 57 Thiessen polygons were overlaid against a recent land cover database of China, and a digital elevation model (DEM), to determine the specific land cover types as a percentage of the total area within each township (Figure 7). Note that the 1830 land decree combines the *kang* totals for Kharta and Rongshar districts; hence the above-mentioned total of 56 districts, although the individual districts seats included in the GIS total 57. The purpose of these GIS operations is to determine the amount of land within each estate below the aforementioned 4500 m.a.s.l. altitude limit to cultivation in central Tibet and to exclude water bodies from the area of potential farmland zones.

The original *1:1 000 000 Land Use Map of China* (Wu 1990) was used as the basis for the digital version by the Australian Centre of the Asian Spatial Information and Analysis Network at Griffith University in Brisbane, Australia. All land cover polygons from the map were scanned and vectorized to produce the database. The original map project was commissioned by China's State Planning Commission in 1978. Most of the land use data were derived from extensive aerial photography conducted during the late 1970s and early 1980s. Field trips were made to carry out ground checks of data in areas that were difficult to interpret. The mapping was first done on a provincial basis at scales of 1:100 000 and 1:500 000. The maps were then generalized to produce the final 64 sheets of the *1:1 000 000 Land Use Map of China*. In this generalization process no polygons smaller than 4 km^2 were depicted. Work was completed in 1988. The result was the first detailed set of maps showing the land use status of all of China.

The GIS methodology allows land cover types to be determined within the below 4500 m.a.s.l. altitude zone of each district. Non-potential farmland categories from the land cover database (lakes and wide stretches of open water in the Tsangpo River) have been excluded from each district, thus defining an area that more accurately reflects potential farmland. The total Iron Tiger land decree study region comprises 170 712.6 km^2, of which potential farmland comprises 51 183.6 km^2, or approximately 30 per cent.

The total numbers of *kang* tax units correlate positively with potential farmland in the 56 districts. The moderate *P*-value of 0.370, however, may indicate that much of the land below 4500 m.a.s.l. in peripheral forested Himalayan valleys is erroneously considered potential farmland in the GIS when, in fact, it may consist of steep slopes not suited to cultivation. In light of this possibility, I have

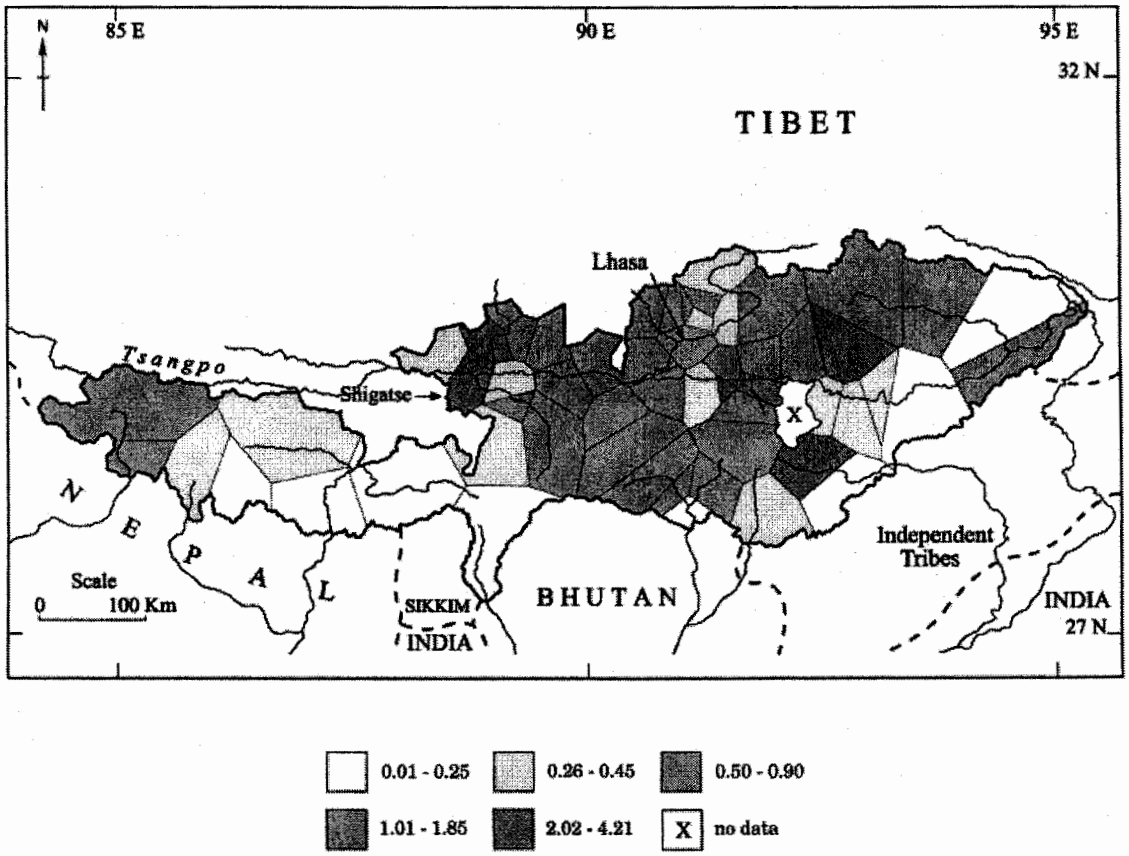

Figure 8 Potential farmland (*kang* km^{-2})

re-examined the statistical correlation between *kang* amounts and potential farmland in only those districts comprising the core areas of Ü and Tsang (Figure 6). In this area a much stronger positive correlation with a *P*-value of 0.640 is observed. These findings provide support for the hypothesis that the *kang* land-based tax units listed for each estate, and aggregated by district, in the 1830 Iron Tiger land decree are of high quality and, when analyzed with GIS, offer important new perspectives on historical patterns of land use/cover in central Tibet.

A map of *kang* per square kilometre (*kang* km^{-2}) of potential farmland reveals a spatial pattern consistent with the hypothesis that key centres of Tibet's population in the core area of central Tibet exhibited the highest levels of cultivated land density in 1830 (Figure 8). Levels range from a low of 0.02 *kang* km^{-2} in Phari district, to 4.2 in Chokhorgyal. The mean value is 0.89 *kang* km^{-2}. Lhasa has an above average amount of 1.01 *kang* km^{-2}. In addition to Chokhorgyal, five other districts have more than 2 *kang* km^{-2}: Shigatse and Namling in Tsang, Nedong and Tranang near the cradle of Tibetan civilization in the Yarlung valley, and Lhuntse to the south.

The next section of this paper will focus on devising a methodology to determine an approximate area measurement for the *kang*, and to compare rates of change from 1830 to 1990 in amount of cultivated land among different areas of central Tibet. This will help test several of the main hypotheses in this study.

Methodology and findings of cultivated land area estimation

The method of land taxation in Tibet was different from methods employed by state bureaucracies in traditional Chinese and Indian peasant-based civilizations. The *kang*, a basic unit of measurement of land for taxation purposes, was calculated by the

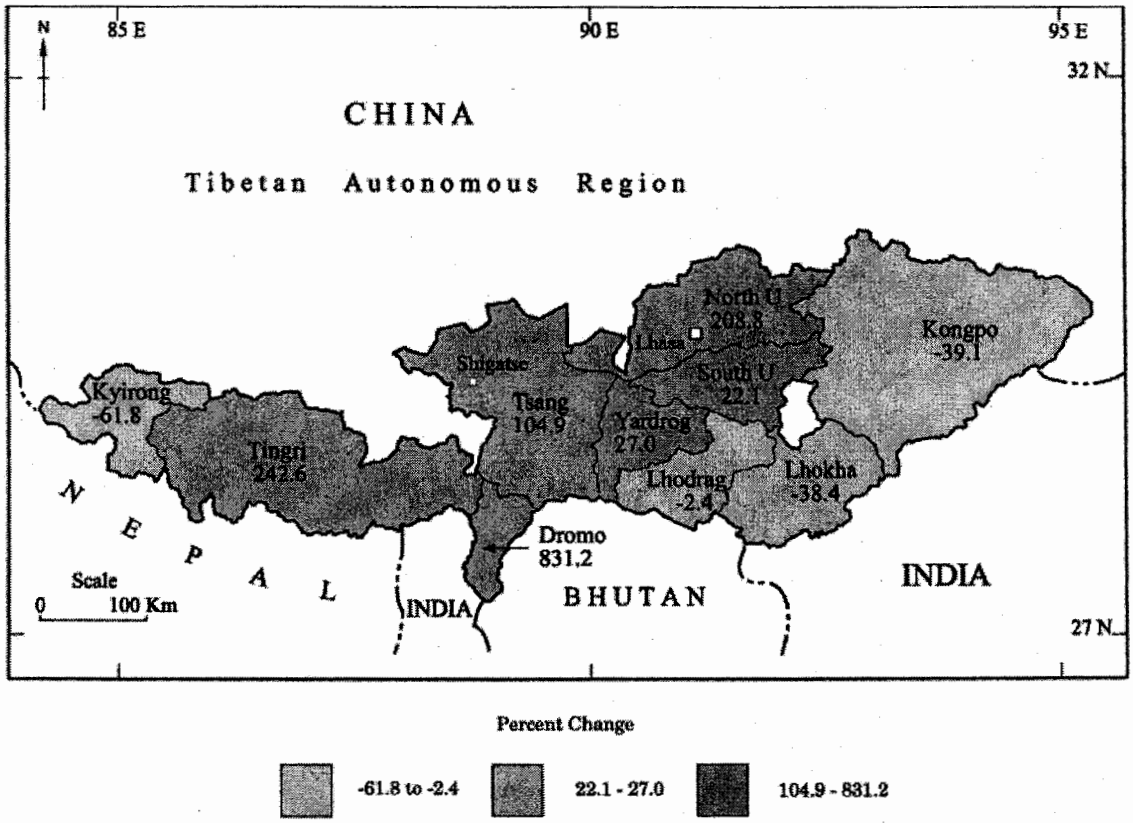

Figure 9 Per cent change in cultivated land area, 1830–1990

amount of barley seed normally sown in a given area, though the actual land size was related to other variables such as soil fertility and local climatic conditions (Gelek 1986). For these reasons, it is foolish to believe that the *kang* in the 1830 land decree may be precisely defined according to a standard area of measurement. It is possible, however, to derive an approximate measure to facilitate applied research. Such an approximate measure, it is reasonable to speculate, may allow major regional patterns of change in cultivated land areas between 1830 and 1990 to be discerned, though not analyzed in terms of definitive rates of change. Rather, spatial differences in the rates of change, such as positive growth in some areas and negative growth in others, may shed light on which parts of central Tibet experienced significant expansion or relative stagnation in cultivated land areas.

The first step in this GIS analysis is to match up those 1830 districts whose areas can be fairly accurately compared to 1990 county units. Contemporary geo-referenced administrative units are available for Chinese counties according to c. 1990 boundaries. Also, the finest spatial resolution for disaggregated Chinese agricultural data, including the key variable of total area under cultivation used in this study, is that of county-level data (SSP 1991). Ten major areas can be defined based on 1990 county boundaries within which *kang* tax records from specific 1830 districts most likely apply (Figure 9). These ten areas approximate various groups of districts as they existed in 1830. The boundaries of these districts, I assume, generally followed mountain crests. The delineations may not be perfect, but until the locations of each 1830 estate (and thus the approximate limits of each district's administration for land taxation purposes) are known, it is not possible to devise a more accurate method.

For each of the ten areas, the 1830 *kang* totals were calculated. According to Bell (1928), the quantity of seed required to sow a *kang* in Tibet prior to 1959 averaged about 40 *kay* (1 *kay* = 28 lbs or 12.6 kg). Whereas the *kang* was the

Table 1. Change in cultivated land, 1830–1990 (amounts listed in km^2)

Area	1830	1990	% change
North Ü	123.49	381.33	208.8
South Ü	142.52	174.00	22.1
Tsang	216.68	444.01	104.9
Kongpo	180.58	110.00	-39.1
Lhokha	72.46	44.66	-38.4
Lhodrag	31.44	30.67	-2.4
Yardrog	18.36	23.33	27.0
Dromo	0.86	8.00	831.2
Tingri	33.08	113.33	242.6
Kyirong	22.11	8.67	-60.8
Total	841.59	1338.00	59.0

fundamental land measurement unit for taxes, the basic measure of weight for payment was the *kay*. Although there were many different local *kay* units which varied considerably in volume, the Tibetan government maintained a standardized *kay* unit, the *bo*, which it used in the collection of its taxes, which was equivalent to somewhere between 27 and 33 lbs (12.2–14.9 kg) for 1 *kay* of barley (Goldstein 1971). In Das' (1902) *Tibetan–English Dictionary* the *kay* is defined as equal to 30 lbs (13.5 kg). For the sake of convenience in the GIS analysis I will adopt a figure of 28 lbs (12.6 kg), in conformity with the usage of Tibetan farmers today.

Based on these figures, one may multiply the total number of *kang* in each area by 40 to calculate the number of *kay*. The *kay* may then be multiplied by 28 to arrive at the total weight of barley seed sown (in lbs). Next, it is necessary to decide how much seed was sown, on average, in each field. Noting that Tibetan farmers in the vicinity of Lhasa today sow an average of 27–34 lbs (12.2–15.4 kg) of seed per *mu* (though these figures apply to barley grown with chemical fertilizers and may not reflect average amounts during the pre-modern period), I have, for the sake of convenience adopted an average figure of 30 lbs (13.5 kg) of seed sown per *mu* (i.e. a standard land measurement in China today equal to 0.0667 ha). Last, the estimated 1830 cultivated land areas were converted from *mu* to square kilometres for comparison with 1990 figures on the total area under cultivation. This specific methodology results in one *kang* as the average tax levied on 2.49 ha or 0.025 km^{-2}.

The disaggregated data display a striking spatial pattern, indicating that the core areas of central Tibet witnessed the highest relative increases in cultivated land since 1830, while most peripheral areas either declined or achieved lower levels of increase (Figure 9). On average, central Tibet's cultivated land increased by 59 per cent over the 160 year period (Table 1).

Two factors may explain the negative rates of change recorded for peripheral areas:

1 the *kang* area estimation methodology is insufficiently accurate; or
2 contemporary Chinese agricultural data under-reports cultivated land areas.

As far as the first factor is concerned, it is possible that the *kang* was smaller than the 2.49 ha calculated above. It is also possible that the forested V-shaped valley environments in peripheral Himalayan areas encourages under-reporting of cultivated land areas by the local government. Incentives to under-report would be to obtain a lower quota of cereals to be delivered to the state at the fixed price, and reductions in taxes. Smil (1999) notes that multiples (commonly between 1.25 and 1.5) of *mu* of less productive slopeland are often credited in China as equal to 1 *mu* of more productive farmland. This practice resulted from a recognition of the inherent differences in land quality during the initial division of land among peasants after the break-up of the communes during the early 1980s, and the wish by authorities to counter such disparities. It is reasonable to speculate, in the absence of high-resolution land use/cover maps, that the peripheral Himalayan valleys have a higher percentage of cultivated slopeland than the broad U-shaped valleys in the core parts of central Tibet where most cultivation occurs on well-irrigated valley floors.

The only exception to this pattern is the Chumbi valley (referred to in this analysis by its Tibetan

name of Dromo), nestled between Sikkim and Bhutan. Dromo records the highest rate of growth in cultivated land at 831.2 per cent. A possible explanation for this trend might be that significant amounts of new lands were cleared for cultivation. The valley provides an important source of timber for the Tsang province of central Tibet, and it is possible that deforested areas have been cultivated. It is also possible that the district of Phari in 1830 did not control all of the farmland in the valley and that the 1990 data offer a more accurate picture of the total area under cultivation over the past two centuries.

Significant cultivated land increases in the core areas of central Tibet may reflect that fact that the bulk of the population is concentrated here. The area referred to as Tingri, after a Tibetan folk name for part of the region, includes some Himalayan valleys, though most of it consists of semi-arid steppe and relatively densely settled broad valleys characteristic of central Tibet. The question is raised as to how much of these increases occurred after China's annexation of Tibet and how much before. Due to the propaganda-like quality and inflated figures of Chinese agricultural data from the 1950s through the 1970s, it is not possible to answer this question. Perhaps a geo-archaeological survey of a sample estate and its component village(s) and fields could shed some light on this question.

Conclusion

The 1830 Iron Tiger land decree is significant for research on land use/cover change in central Tibet. This present study contributes toward a better understanding of how GIS may be used to explore and map data from historical Tibetan tax-related documents pertaining to cultivated land. The pioneering methodology presented here, however, only scratches the surface in terms of how these historical data might improve upon the spatial and temporal detail of historical land cover databases of the Tibetan Plateau region. Further efforts are needed to locate and translate additional Tibetan land decrees. Gelek (1984) notes that the introduction to the 1830 Iron Tiger land decree states that it was compiled because a previous land decree from the eighteenth century became inadequate due to the rapid increase in new lands put under cultivation. This previous land decree is not available and could still be in an archive in Tibet.

The data, methods and findings of this study indicate how economic history and environmental history are inescapably intermeshed with one another. GIS is an important tool for the exploratory spatial analysis of historical tax-related data compiled by various bureaucracies of indigenous Tibetan polities to uncover previously unknown patterns of land use/cover in terms of the human dimensions of global change.

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I would like to thank Joseph Schwartzberg for detailed and insightful commentary on this manuscript which comprises a chapter of my PhD thesis on land use change in Central Tibet. Thanks also to two anonymous reviewers for their remarks.

Note

1 Tibetan words and place names are phonetically transcribed according to the general rules of the Wylie system (Wylie 1959) in this article, and on the accompanying figures, in order to provide a reasonable approximation of their sound as spoken by Tibetans. Chinese words are romanized according to the Pinyin system, which reflects standard Mandarin pronunciation.

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