Tibetan Pastoralism under Climate and Socio-economic Change: Carbon Footprint Assessment and beyond - Research Plan and Preliminary Results

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Abstract: As the "Third Pole" of the world, the Tibetan Plateau is especially vulnerable to anthropogenic environmental disturbances and climate change variations. With an alpine grassland dominated landscape, nomadic grazing is one of the major anthropogenic activities on the Tibetan Plateau. In this study, we present a research plan with preliminary results that aim to quantify the human carbon footprint in a typical Tibetan nomadic area (Namtso village, Damsung County) through semi-structured interviews and on-site fieldwork, complementary to using existing data, which may suffer from restrictions and inaccuracies due to the special ecological conditions of the Tibetan Plateau and the nomadic characteristic of the inhabitants. After obtaining a detailed first-hand inventory list of the activities of human and grazing animals, the method of systems process analysis and life cycle analysis can be used to calculate the annual carbon footprint of a nomadic grazing unit, as well as the water footprint, energy footprint, and land footprint of the nomadic activities on the Tibetan Plateau. The obtained results will provide a comprehensive dataset and analysis of Tibet's nomadic pastoralist activities, which is conducive to a better understanding of the linkages between the ecological and economic activities on the Earth's third pole and global climate change.

1 INTRODUCTION

The Tibetan highlands host the world's most extensive and elevated area of pastoralism, with an elevation of 3,500 meters to 4,500 meters of altitudes. For millennia, pastoralists have made livings in this harsh and isolated environment (Li et al., 2018). Bounded on three sides by the Himalayan Complex and Taklamakan Desert, this vast mountain-bound alpine grassland has long been fantasized as a hidden arcadia cradled among the peaks of the Orient (Hilton, 1960).

In recent decades, increasing climate changes and socio-economic changes on both global and regional scales have been historically unprecedented. Climate change has become one of the most daunting challenges of the century, in great potential of leading to extreme weathers (Wuebbles et al., 2014), land degradation (Hummel, 2016), water shortages (Gober & Kirkwood, 2010), etc. On the other hand, emerging socio-economic changes such as the expansion of industrial and agricultural land have shaped more and more surfaces of the earth, and have been reported to result in large-scale encroachment upon traditional lifestyles such as pastoralism around the world

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(Tache, 2008), forcing nomadic lifestyle into more and more marginal lands.

Interest in the impacts of these changes on the Tibetan Plateau has resulted in flourishing studies focusing on the transitioning of the "Shangri-La" in the modern world (Feng et al., 2017; Gong et al., 2017; Ma & Zhao, 2016). Regarding the impact of climate change, researches have shown that the Tibetan Plateau is exceptionally vulnerable to climate change due to its special geographical and ecological conditions (Lehnert et al., 2016). In the past 50 years, the Tibetan Plateau experienced three times more global warming rate than other regions (Piao et al., 2011), with supra-regional consequences due to its huge elevated heat surface with sensitive environmental feedback (Duan & Wu, 2005). Therefore, studies on the impacts of anthropogenic activities on the environment of the Tibetan Plateau have been widely carried out to assess the ecological footprints in this region, by using tools such as GIS, environmental modeling, simulated experiments, etc.

Regarding socio-economic changes in Tibetan pastoralism, critical voices on the deteriorated environment due to resource exploitation (Miller, 2000), land encroachment due to urban expansion (Miller, 2000), and settlement due to new housing tracts (Næss, 2013), etc. have been increasingly active. On the other hand, studies have also reported that Tibetan pastoralists have experienced an increase in educational opportunities (Hopping et al., 2016), the rise of women's status (Tsering, 2013), increasing access to medical supplies and healthcare (Xiangbalacuo, 2017), etc.

These literature piece together for the world a mirage of the transitioning "Shangri-La" in the environmental and socio-economic changes of the modern world. However, this pieced vision is blurred by the fragmentation and incoherency of information, with many of these puzzle pieces seemingly contradictory. Furthermore, the vast majority of these studies are either based on calculations using existing data from official sources, or review of historical documents, or environmental simulations carried out remotely, whereas only very few are based on on-site observations or fieldwork surveys. In this study, we aim to conduct on-site fieldwork research to gain first-hand environmental and socio-economic data, processed through systematic and comprehensive modeling to gain an insight into the ecological and socio-economic aspects of Tibetan nomadic life. We aim to assess the carbon footprint, water footprint, land footprint, and energy footprint of the pastoralists in the study region, as well as gaining balance accountings of the living expenses of typical Tibetan nomadic families, by surveying a historically typical nomadic region on the Tibetan Plateau, Namtso (Tibetan: གནམ་མཚོ). The full implementation of this project will encompass the obtaining of a comprehensive dataset of Tibetan nomadic expenses balance accountings through wide-range surveys, emission intensity datasets of GHG emissions through fieldwork experiments, as well as intensity dataset of other ecological elements, such as land, water, energy, etc., thereby calculating a full set of multi-scale ecological footprints of the region and family units. We have so far carried out this project for two years, and have obtained considerable data by conducting on-site interviews in Tibetan households in the permittable climate of the summertime. This paper is a presentation of the research plan and the preliminary results obtained by this project. The rest of this paper is carried out as follows. Section 2 presents the process of data acquisition and accounting process of this paper; Section 3 presents data analysis and results, Section 4 presents preliminary calculations of intensity databases, and Section 5 presents discussions and conclusions.

2 METHODOLOGY

2.1 Study Area

Our study encompasses a village located in the steppe region in the central Tibetan Plateau: Namtso village, Damxung county (30°42'N 90°33'E). Damxung's landscape is long and narrow, stretching 185 kilometers from the northeast to southwest, and 65 kilometers across. This area is approximately 170 kilometers North from Lhasa, with the Nyainqentanglha mountain lying across the route. A valley runs parallel to the Nyainqentanglha mountains in this region to its southeast, and 30% of the county's total area is in the prairie of this valley. Namtso village lies in the northern part of Damxung. It has an altitude of 4,718 meters, southeast bound to the Nyainqentanglha mountain, northbound to low Northern Tibetan valleys, creating a relatively enclosed area of alpine grassland landscape with abundant water reserves. "Damxung" (county) means "select pasture" in the Tibetan language, and "Namtso" (village) means "sky", or "saccade heaven". Namtso has been renowned as one of the most beautiful villages in the Nyainqentanglha mountain range, with film scenes taken in its landscape featured in the 2010 Chinese drama "Shangri-La". Figure 1 shows series of photos of Tibet and Namtso taken by the research team.

Figure 1. (a) Arrival in Tibet, Potala Palace (b) Worshiping Buddhists, Lhasa (c) Setting out to Namtso from Tibet University (d) Two members of the research team crossing over the peak of Nyainqentanglha Mountain range to Namtso, Damxung (e) arrival at research station, Namtso (f) map: Namtso village, Damxung county, Lhasa. [1]

2.2 Interviews

In August 2019 and August 2020, we conducted structured interviews with villagers in Namtso about their material and monetary assets and household expenditures. Interviews were carried out either in Tibetan or Mandarin, depending on the interviewee's preference and their fluency in Mandarin. All interviews were recorded and videoed after informal consent by the interviewees, which are then entirely transcribed. The transcripts will be disclosed upon the completion of the entire project.

We aim to interview the majority of households in the Namtso village, for now, we have interviewed 13 people in the village. We asked open-ended questions about the way they lived, their incomes and expenditures, their daily activities, etc. Some example questions include: "How are the grassland allocated?", "What are the policies regarding grassland?", "How are they implemented?", "How many sheep/horses/yaks do your family own and how much do you consume and sell?", "What are the main products of these animals?", "How many yak meat, mutton, barley, etc. do you consume daily?", "How much do you spend on clothes?", "What are your housing conditions?", "Do you do extra work elsewhere? "How much salary does your job pay?", "How much do you spend on phones and related services?", "How much does education cost?", "How are the elderlies and disabled taken care of in the village?", "What are the common illness in this region, how are they treated, and how much do they cost?", "Are there medical insurance?", etc. In general, we are hoping to gain a panoramic picture of the way they lived, both regarding their economic conditions and ecological circumstances.

2.3 Other Data Sources

This study also intends to field monitor GHG emissions on-site to build an emissions inventory especially applicable to the Tibetan highland climate. We plan to field-monitor fluxes of CO2, CH4, and N2O in the air and soil in the study region, which prove to be the major GHG emissions in the region, due to the active activities such as enteric fermentation, biogas burning, manure management, etc. Multiple sampling points will be set up with static camera obscura-gas chromatography and standard sampling boxes. Land use, water use, and energy use details of the living units will also be monitored. For this preliminary assessment, these data were temporarily obtained from official sources (agriculture, industrial, tertiary, and domestic water use data is obtained from the Provincial Water Resources Bureau (2012), arable land use and pastureland use data are obtained from the "Tibet Statistical Yearbook", and CO2 and energy use data are adopted from the estimations by Shan et al. (2014) (Shan et al., 2017)).

2.4 Accounting Procedures

The following steps present the details in which the accounting process is carried out. This accounting framework can be used to calculate the carbon, water, energy, and land footprint on multiple scales, with access to the corresponding intensity datasets. Step-by-step procedures for this assessment are:

1. Gain a detailed inventory list of the living costs of a family unit, containing material or monetary costs and expenditures per year. This inventory list can include (but not limited to) food expenses, clothing expenses, educational expenses,

[1] Photo (a), (b) and (e): taken by Kuang Chen, August, 2019, (c), (d): taken by driver and guide of the trip, August, 2019, (f): Google Map.

healthcare, insurance, medical, housing, transportation, etc.

2. Calculate the intensity database by using Systems Input-Output Analysis (Chen et al., 2019; Wu et al., 2018). Intensities represent the amount of resources needed/emissions generated to produce a per-monetary unit of goods and services.

3. Locate the sectoral representations of the items from the balance account in the intensity database, then correspond the numerical values of the intensity database with the values of living expenditures.

4. Perform multiplication of the expenditure items with corresponding intensities, obtaining the embodied resource use/generated emissions by the living units.

3 PRELIMINARY RESULTS

Here we show part of the preliminary results from data obtained from the conducted interviews. The case study village has a population of around 200 households, and the typical nomadic family in the village consists of a monogamous marriage of husband and wife with one to three children, in the cohabitation of elderlies, usually from the mother's side. Other variations of family types also exist, such as polyandry families. Figure 2a shows a photo of the Namtso village.

The most important food source in this region includes yak meat, mutton, yak and sheep milk, dairy products such as yogurt, quark, and butter, as well as tea, wine, and Zanba. Diversified diets not usually included in the traditional nomadic diet are also shown to be popular amongst villagers, such as rice, vegetables, purchased packaged foods, etc. (figure 2b-d). Most foods are directly derived from domesticated animals (meat and dairy products), with only very little monetary spending needed on food supply. The major energy source is found out to be yak dung collected on the pastures (figure 2e), which fuel cooking, heating, and other household needs. Portable solar pads are installed in some families for charging electrical devices such as cell-phones. Diesel is used to fueling jeep cars, trucks, and motorbikes used for short-distance transportation, transhumance moving, and daily sheep-herding (figure 2, f-g). Housing is also found to be provided in a self-sufficient manner, including both tents for summertime nomadic grazing (figure 2g) and winter settlement (figure 2h). Tents can be both purchased or made from yak skin, with binding ropes made from sheep fur. Winter residents can be self-built from purchased materials, with little cost and no rent requirements. Garments consist of working clothes such as trainers and boots, fabric capes, and festival clothes made from lambskin and wool. Medication and education are found to be provided free of charge by the village or county, while some opt for extra spending for education in the provincial cities. While food, housing, energy, education, and medicine spending considerably small, phone services are found to be relatively large and sometimes even major spending for the family. With the increasing use of video-based apps with high mobile traffic requirements, no access to Wi-Fi, and no knowledge of monthly service packages, it is found that this spending can amount to more than one-tenth of the total income for some households.

Figure 2. (a) the landscape of the village with sheep dotted across (b) buttered tea heating on a traditional stove (c) from left to right: quark, soft drink, yogurt in the research team's hand (d) from left to right: a bowl of yogurt, two pots of milk, a pack of chocolate bar (e) a pile of collected yak dung to be used for fuel (f) a family in transhumance with three loading trucks (g) a summertime tent with a motorbike

for sheep herding (h) inside the winter house of an interviewed family [2]

Table 1 presents the income and expenditures of a typical family of seven, consisting of husband and wife, three children (2 girls, 1 boy), and two elderly parents from the wife's side (Interview process shown in figure 3a, photo of family shown in figure 3b). Yak is the main source of monetary income in the family, accounting for around 60% of the family's income (figure 3c shows the family's possession of yak). The second-largest bulk of income comes from the selling of animal derivatives such as yak dung, yak fur, and wool, which account for approximately 23% of the total income. Part-time jobs are not taken for monetary payment, but largely "for the chance to explore and have a good time" (transcript No. 2, line 318-319), account for 15% of the total income. The major expenditures of the family largely come from food and garments. Consumption of yak is shown to be the major food source for most families, with no monetary costs as they are directly slaughtered from domesticated yaks. The yearly consumed yak account for less than 3% of the herd owned by the family. Shoes are shown to be a major source of expenditure for the family, as the harsh climatic and geographic characteristics prove to be abrasive to footwear. With an extremely high discarding rate, one pair of shoes can sometimes "only last for ten days" (transcript No.2, line 373-380). Festive clothes are shown to be "luxurious" in modern commercial standards, using more than 20 lambskins to make one piece of festive clothing. While this is free of charge for the nomadic families, at most costing 2000RMB for manual sowing fee, clothing made in this material may cost more than several thousand times as much in the commercial market. The interviewed family own four pieces of this lambskin clothing, worn only once a year at the traditional horse-racing festival. Almost no educational or medical expenses are needed for this family. The children attend school free of charge at the village and county school (figure 3d shows children of the family), and illness are relatively rare, while they are also provided for free at the village clinic, villagers often choose not to use this service, or apply any medical treatment at all.

(a) (b) (c) (d)

Figure 3. (a) Interview process with the interviewees (b) research team with interviewed family in front of their summer tent. (c) a group of yaks owned by a family (d) children in the village playing in a yard and a house. [3]

Table 1. Income and expenditure accountings of a family of seven acquired from interview.

Income source	Accounts
Yak	Sell 5 yaks/year, 40000RMB
Salary	Less than 10000/year, mostly work at home around the year
Yak dung, yak fur, wool	15000RMB/year

Expenditure	Accounts
Yak	Consume 3 yaks/year (free)
Barley, rice, vegetables	Approximately 4000RMB/year
Clothes for festivals	2000 per item (manual service fee), 4 items per family
Shoes	Approximately 12000 RMB per year
Phone service	7000RMB per year
Phone	Approximately 1500RMB/item, 7 items in the family
Housing	Approximately 40000 RMB, self-built, 60 sqm

[2] Photo (a), (b), (d), (e), (g) is taken by Junxian Dai; (c) is taken by Chaohui Li; photo (f) and (h) is taken by Kuang Chen

[3] Photo (a) and (c), taken by Junxian Dai; photo (b) is taken by driver and guide for the trip; photo (f) is taken by Kuang Chen

4 PRELIMINARY ASSESSMENT OF ECOLOGICAL ELEMENTS INTENSITIES

Preliminary assessment of the arable land use, pastureland use, water use, energy use, and CO2 emissions intensities are found to be comparatively low. However, these estimations may suffer from the aggregated level of existing data. Since agricultural activity is the major activity in the studied region (as well as a large proportion of other regions in Tibet), the high aggregation of the agricultural sector in the existing data may provide to be highly inefficient. Furthermore, we find that both energy use data and GHG data in this region is lacking in official reports. All these calls for the dire need for more detailed bottom-up environmental data that specifically apply to the Tibetan region.

5 DISCUSSIONS AND CONCLUSIONS

Through on-site surveys and calculations using existing datasets, the ecological footprints in the studied region are estimated to be extremely small, compared with the living styles of modern urban residence. We observed a large proportion of the pastoralists' daily necessities being made in a self-sufficient manner, with raw materials derived directly from the nearby environment or domesticated animals. The main environmental excretion of the living units mainly includes manure, which is then collected and used as a valuable fuel source for the family, thereby creating a sustainable cycle that has a relatively small impact on the environment.

Regarding the economic aspects of nomadic living style, while the economic income of the pastoralists may be low compared to urban inhabitants, they are without the need of many indispensable expenditures for city residents, such as housing, electricity, and even a large proportion of food. We find pastoralists are influenced by modern socio-economic changes in multiple ways such as settlement housing in wintertime (as harsh climate prevents them from grazing), education of children in village schools, and access to modern appliances such as cell-phones, packaged foods, transportation such as trucks and motorbikes, and purchased garments such as sneakers. In general, they still maintain a pastoral oriented lifestyle vastly different from the modernized and industrialized world.

This preliminary assessment of Tibetan pastoralists under climate and socio-economic change has provided valuable insights both intuitively and quantitatively. However, significant work needs to be done for the completion of the project. The future plans for this project are as follows:

Through these series of assessments, a comprehensive dataset and insight into Tibet's nomadic pastoralist activities can be obtained, which is conducive to a better understanding of the ecological and economic changes taking place on the Earth's Third Pole. Pastoralists are one of the most vulnerable and perceptive groups to climate change and socio-economic change influences, but also may be one of the most sustainable, equitable, and moderate societies. The world has changed dramatically with increasingly acute environmental problems that call for serious contemplation in sustainable development (G. Chen, 1994). In face of the current severe crisis falling upon the entire humanity in the global spectrum, retrospection and ponderation of our current set ways are crucial in our future endeavors to create a better world for all.

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