

ROLE OF TIBETAN WOMEN IN CARBON BALANCE IN THE
ALPINE GRASSLANDS OF THE TIBETAN PLATEAU.
A REVIEW *

Zhanhuan Shang, Andrew White, A. Allan Degen, Ruijun Long

Abstract

Males and females often contribute differently to the ecosystem as a result of their different roles and labour responsibilities. This is especially true in remote areas like the Tibetan alpine grasslands, where women handle most household chores and agricultural labour. Within this framework, women are involved physically in carbon balance to a much greater extent than are men. The collection and use of livestock dung for fuel (dung-fuel) and the production of livestock commodities are two female activities that are extremely important in the carbon cycle in grassland ecosystems. More than ninety per cent of fuel in the alpine grassland areas in China comes from livestock dung, which is collected and burnt by women. In addition, animal carbon leaves the grassland ecosystems through the selling of milk products by women. The burning of dung reduces the use of fossil fuels and wood in alpine areas, but causes severe indoor air pollution in homes and greatly increases health risks, mainly among women. Women should receive more education on and made aware of these dangers. Because of their heavy work load and busy time schedule, however, Tibetan women have little time for other activities. Consequently, their education is at an extremely poor level and their health issues are often neglected. Steps should be taken to improve the status of women in the community, involve them more in decision-making, promote their education and health standards, and encourage more gender equality in agricultural labour tasks. These changes for women have been implemented in other pastoral societies and have proven to be successful.

KEYWORDS: Carbon management, nomadic women, female labour, climate change, alpine grassland.

Introduction

From the pre-industrial period to 2010, the atmospheric concentration of CO₂ has increased by thirty-nine per cent, from 280 ppm to 390 ppm. This

* This literature review is an insight into the current mainstream perspective on livestock keeping and climate change in the grasslands of Tibet. Editor's Note.

enrichment in atmospheric CO₂ concentration, along with other greenhouse gases, including methane (CH₄) and nitrous oxide (N₂O), ‘may accentuate radiative forcing and alter the Earth’s mean temperature and precipitation’ (Lal undated). To minimise the risks of global warming, it was recommended at the Copenhagen Accord in 2009 that atmospheric CO₂ concentrations should be contained below 441 ppm by 2100 (Ramanathan and Xu 2010) and that this should be accomplished ‘by reducing CO₂, CH₄ and N₂O emissions and by offsetting emissions through sequestration of carbon in soils and other terrestrial and inland aquatic ecosystems’ (Lal undated).

Of the five global C pools, the soil C pool, with an estimated 2,500 Petagrams (Pg) C (Batjes, 1996), ranks the third largest (the oceanic C pool contains an estimated 38,000 Pg and the geological C pool an estimated 4,130 Pg: see Lal undated). As rangelands produce a large proportion of total land carbon and sequester large quantities of carbon above and below ground, the immense rangelands on the Tibetan plateau ‘could have widespread effects on regional climate and global carbon cycles’; in fact, ‘alpine meadow and alpine steppe range, found primarily on the Tibetan plateau, comprise forty percent of all carbon stored on China’s rangelands, indicating that these ecosystems have a significant and long-lived effect on global carbon cycles’ (Miller, 2003). This can be explained, at least in part, by the colder air temperatures on the plateau, which slow organic decomposition rates and increase the mean retention time of the carbon.

The 390 ppm of atmospheric CO₂ has a total mass of 3,030 Pg or 825 Pg of carbon. Anthropogenic emissions, through activities such as animal husbandry and burning of biomass, total 9.9 Pg C per year, of which 4.2 Pg is absorbed by the atmosphere. Consequently, human and livestock activities are important components of CO₂ emission in the carbon cycle (IPCC 2007, WMO 2010).

In grassland-livestock production and management systems in the Tibetan alpine, the roles of women and men differ substantially, as is the case in many mountain areas (Khadka et al. 2014, Verma et al. 2014) and other pastoral communities (Radel and Coppock 2013) and, consequently, their contribution to carbon balance can differ greatly (Cecelski 2000, IFAD 2004, OECD 2008). Due to traditions and religious beliefs in Tibet, women undertake most of the heavy labour associated with agriculture and livestock production (Dong et al. 2003) while men handle most of the decision-making. As a result, the physical actions of women are integrally involved in carbon balance through their roles in livestock husbandry and fuel management, much more so than men. In essence, their daily activities are the key to the carbon cycle in alpine grassland ecosystems. The importance of women as a labour force has grown over the years on the Tibetan plateau. From 1990 to 2009, the female population increased from 0.9 to 1.2 million in rural and pastoral areas, with about 0.45 to 0.58 million women engaged in agriculture and animal husbandry, mostly in alpine meadow ecosystems.

Although a similar increase in the number of men was reported during this period, a much smaller proportion joined the animal husbandry labour force.

In this review paper we 1) describe the role of the female in carbon cycling in the alpine grasslands ecosystem; and 2) provide information for the need to improve the education, health and social status of women, and to encourage more gender equality in the alpine region.

Female and male labour in rural areas of the Tibetan Plateau

Women undertake almost all of the housework and most of the labour needed for agricultural and pastoral production in the alpine grassland ecosystem (Li and Yang 2005). They are responsible for activities such as milking livestock, making cheese and ghee, drying cottage cheese, frying barley, producing mill-fired power, collecting and drying manure, stacking and storing dung-fuel and drying leather. Their typical day consists of at least ten hours of continuous



Figure 1. Yaks grazing on the Tibetan Plateau with the Himalayas in the background. Photograph: A. Allan Degen.

work, especially during the summer when they start milking animals at 04:00. Milking is usually followed by cleaning livestock sheds, drying animal dung, preparing breakfast, processing milk products and then preparing lunch. In the afternoon, women generally collect animal dung, and then milk the animals until about 17:00, at which time they prepare dinner (Lu undated).

Men have a higher status in the family, and are more involved in making family decisions. In addition, they slaughter animals and may do some hunting, but this latter activity is rare today. Many men become monks in the Gelug sect of Tibetan Buddhism, and consequently cannot marry, have children or participate in productive labour. This religious practice has serious social impacts on the Tibetan population, resulting in labour shortages and women having to play a major role in their family and society. In the traditional family, women have a lower degree of social participation and have a poorer level of education than men (Bowes undated).

There are two main ways in which women influence carbon balance in alpine grassland ecosystems. The first is through their role in animal production. By consumption of livestock products and sales to areas outside the grassland ecosystem, livestock products become part of the carbon output in the carbon cycle. The second is by the collection of livestock dung to be used as fuel. This is an important



Figure 2. Tibetan woman milking a yak on the Tibetan Plateau. Photograph: A. Allan Degen

source of energy in the cold alpine areas, which not only reduces fossil-fuel imports into the grassland ecosystem and the use of firewood, but also accelerates the decomposition of livestock carbon into the atmosphere or ash into the soil.

Carbon management by women through animal products in alpine areas

In the alpine area of the Qinghai-Tibetan Plateau, most dairy products are produced from livestock grazing grasslands (Figure 1; La 1995, Dong et al. 2003). With the increasing number of livestock and with the introduction of intensive production systems, milk production has increased gradually (TARBS 2010). Hand-milking by women is still commonly practised, however, and is more practical than machine-milking in this low-cost labour region, mainly due to the poor infrastructure on the summer pastures where milking normally occurs (Figure 2). Three milking regimes exist in different localities: once-daily in the mountain areas of the northern Plateau, twice-daily on the grasslands of the central Plateau and thrice-daily along the valleys of the eastern Plateau (Dong et al. 2003). Fresh milk is processed immediately into a variety of indigenous products capable of being stored for long periods. Most milk products are consumed locally, although some are sold outside the ecosystem. All these tasks are the responsibility of women in alpine areas.

Although the amount of carbon from animal products increased compared to the 1990s, total carbon leaving the alpine region actually declined due to the reduced sale of milk and its products (TARBS 2010). The population increase led to an increase in the consumption of milk products, while the amount of yak milk, as a commodity, did not increase proportionately. In addition, more milk products are being sent to temples, resulting in a further reduction in the sale of carbon from milk products outside the alpine region.

In alpine grassland ecosystems with no animals, carbon is fixed from the atmosphere through photosynthesis and accumulates in the grassland vegetation and soils. While part of the carbon eventually returns to the atmosphere via geochemical cycles, the cold hypoxic environment reduces its ability to decompose. This results in a rapid, short-term accumulation of carbon, making the alpine grassland ecosystem a positive feedback mechanism for carbon sequestration. Continued plant photosynthesis causes further accumulation of carbon in grassland ecosystems.

Livestock consumption of plant carbon alters the carbon flow and carbon accumulates at a higher trophic level. Animal carbon can re-enter the carbon cycle via two pathways. The first is through the decomposition of the body directly into the carbon cycle. The second is through its products such as meat,



Figure 3. Yaks and sheep grazing on the Qinghai-Tibetan Plateau. Photograph: A. Allan Degen.

milk and leather. Women play a role in the latter through the production of dairy products, an output from plant photosynthetic carbon through the ‘plant-livestock-atmospheric’ system. The output of carbon products can eliminate carbon redundancy by the accumulation of excessive animal carbon products in the alpine grassland carbon cycle, an important part of a negative feedback mechanism. Moderate animal carbon output is necessary to sustain the normal carbon cycle of grassland ecosystems.

From the 1970s to the present, yields of animal products increased throughout the alpine region. The increase in milk products, and hence carbon, was a result of increased livestock consuming more grass and, therefore, more carbon, which reduced the grassland’s regenerative capacity and, inevitably, resulted in grassland degradation. In essence, heavy grazing reduced the net ecosystem exchange (NEE), that is, the net effect of C fixation by plants, heterotrophic and autotrophic respiration and soil C sequestration, resulting in reduced plant biomass (Zhu et al. 2015). Consequently, nutrition levels for livestock have declined, resulting in reduced quantities of high-quality milk being produced per animal. For example, on the Tibetan steppe region of Tianzhu (Gansu Province), a woman milks an average of four yaks daily and each yak produces only 1.5–2 kg of milk per day, which is considerably less than what was produced twenty years ago (Long et al. 2008, Shang et al. 2014).

Zhu et al. (2015) concluded that ‘reducing stocking rates on heavily grazed grasslands of Northern China to moderate grazing levels would enhance NEE, and benefit biomass and animal production’.

Most women in the alpine grassland areas harvest traditional Tibetan medicinal plants (Fang et al. 2012) and this also influences the carbon cycle. The original level of harvesting Tibetan herbs had little effect on the grassland carbon cycle, but the increased collection today can undermine the normal carbon fixation capacity of grassland vegetation. The participation of women in harvesting plants is a significant factor affecting the normal carbon cycle of the alpine grassland ecosystem.

Carbon management by women through using dung as fuel in alpine areas

Globally, the supply of energy in agricultural and livestock systems relies mainly on fossil fuels and firewood. In alpine grassland ecosystems, however, livestock dung is the main fuel used to supply household energy and heat, and hence plays an important role in the livelihoods of the households in these systems (Xiao et al. 2015). This is especially true for the alpine region of the



Figure 4. Tibetan woman arranging dried yak dung on the Tibetan Plateau. Photograph: A. Allan Degen.

Table 1. The amount of yak dung burnt per person and the equivalent quantities of local shrubs (area), coal and emission of CO₂ at different altitudes in alpine meadow ecosystems in China (adapted from Yu, 2010).

Item (per person)	Altitude			
	2500 m	3000 m	3700 m	4700 m
Burning yak dung (kg)	590	2182	9233	3595
Area of local shrub (m ²)	332	1229	5200	2025
Coal quantity (kg)	331	1226	5188	2020
CO ₂ (kg)	847	3133	13257	5162

Tibetan plateau, where yak dung accounts for 91.4 per cent of the entire fuel use (Sharma 2010). The labour involved with livestock dung use as fuel is mainly that of women (Figure 4). In addition, women sell dung at the market, which can replace coal and the need to import fossil fuels into the alpine grassland ecosystem.

Dung-fuel reduces the number of native shrubs that are harvested and lowers the importation of fossil fuels. Yu (2010) reported that in the alpine region of China at elevations from 2,500 to 4,700 metres, households burnt from 590 to 9,200 kilograms of dung-fuel per person per year. This is roughly equivalent to reducing the burning of coal by approximately 331 to 5188 kilograms (Table 1). If coal, however, were used and imported from outside the alpine region, the carbon sink in the alpine region would increase as dung would be used to a lesser extent.

Most Tibetan families have little choice but to use only yak dung for cooking and heating, as their limited income does not allow them to purchase fossil fuels. Families live in either tents or stone homes and, for economic reasons, mainly use simple stoves without chimneys (Xiao et al. 2015). Because of the low air temperatures, they heat for an average of sixteen hours per day (Chen et al. 2011) and, as a result, indoor emissions of black carbon and fine particulate matter rank among the highest in the world. Indoor air pollution has become extreme (Holthaus 2015, Watts 2015), increasing the risk of diseases such as cancer, cardiovascular diseases and respiratory disorders (Pope and Dockery 2006, Holthaus 2015). Women are most vulnerable to these health hazards as they do the cooking and spend the most time near the burning dung.

It has been calculated that approximately 0.4 to 1.7 Gg/year of black carbon is emitted by burning yak dung in Tibet (Xiao et al. 2015); black carbon is one of the main causes of both global warming and the melting of snow and ice in the Himalayans (Menon et al. 2002, 2010). Furthermore, it was reported that the mean indoor concentration of fine particulate matter (PM_{2.5}; aerodynamic

diameter of 2.5 μm or less) in households using a simple stove was 956 $\mu\text{g}/\text{m}^3$, that is, considerably higher than the mean twenty-four-hour average of 25 $\mu\text{g}/\text{m}^3$ recommended by the WHO Air Quality Guidelines (Xiao et al. 2015). It was also considerably higher than the air in kitchens in other countries that use biomass as fuel. These countries, such as India and Mexico, are at lower altitudes and have higher air temperatures, and heat less than the homes on the Tibetan plateau (Xiao et al. 2015).

By collecting yak dung, women reduce its residence time on the grasslands. The decomposition rate of yak dung is very slow in cold and highland areas. It takes at least two years because insects are few and freezing retards decomposition. Collecting dung from grasslands can promote normal vegetation growth as the accumulation of yak dung blocks vegetation regeneration and may affect nutrients returning to the soil. A small amount of dung remains on the grasslands which enables normal cycling of nutrients and elements for grass growth. Good growth and regeneration of grassland vegetation is an important guarantee of a balanced carbon cycle in grassland ecosystems.

Gender responsibilities and inequalities

In the pastoral regions of the Tibetan Plateau, labour for livestock production is very arduous. Most Tibetan women, especially young ones, are fully involved in agricultural labour and housework, and, consequently, participate physically in carbon management to a greater extent than men. In spite of their important role in the economy of the household, however, women have a lower status in the family and society than men do, as is the case in many pastoral societies (Radel and Coppock 2013, Ulambayar and Fernández-Giménez 2013), including those in the mountains (Khadka et al. 2014, Molden et al. 2014). In addition, women have little or no education and their health care is basically neglected (Fan 2010, Yang 2010, Li et al. 2012, Bowles undated).

Improving the educational standards of women would make them more aware of the hazards of indoor pollution and the dangers to their health, and would also better their understanding of the importance of carbon cycling. They could then modify husbandry practices to improve carbon management and biomass production. In addition, involving women more in decision-making would enhance their status within both their working and living conditions, and would acknowledge and enhance their contribution to livestock production (Fan 2010, Li et al. 2012).

Women in other pastoral societies have demonstrated leadership qualities and decision-making abilities when given the opportunity (Radel and Coppock 2013). Ulambayar and Fernández-Giménez state:

In many cultural settings, gender has been one of the factors that have facilitated collective action. Women's participation increases the diversity of views and helps to address specific needs of different community members, which, in turn, strengthens collective decision-making and governance processes within the community organisations. (2013)

They reported that in Mongolian pastoral societies, which are based on livestock production systems, women display better trust-building among community members, while showing equal leadership and rangeland management abilities to those of their male counterparts. They recommended that women should be given increased leadership roles in their communities. Coppock et al., reporting on women's empowerment programs in Ethiopia and Kenya among pastoral societies, concluded:

Men have typically dominated the discourse with development agencies, and women's voices have been muffled. Seeing what empowered pastoral women can do, however, alters this approach. If change agents make sure there are strong pastoral women at the table when projects are conceived and planned, this adds a vital new dimension that more broadly includes the welfare of entire households as well as prospects for diversified livelihoods. Women's empowerment should be a major focus of pastoral development because of the positive synergisms that women can create for their communities. (2013)

For changes in gender roles to occur in the Tibetan Plateau, the government should play a key role in addressing the social problems of women (Halbrendt et al. 2014). Due to the remoteness of the alpine areas, however, it is difficult for government and agencies to effectively influence the lives of women, while local governments have not been willing to be involved. Due to the high cost and sparse numbers of suitable and willing people, the government should recruit social organisations to undertake this capacity-building of women, while providing support to ensure effective implementation. In the alpine region, capacity-building should focus on the long-term interests, involving both women's work and education (Yang 2010, Molden et al. 2014).

Fully recognising and promoting the important role of women in ecosystem-management is an important pathway to strengthen the status of women in society. The government should better acknowledge this important role of women and should provide them with more support for mainstream activities in alpine ecosystems. Female roles should be given greater emphasis in government policy making and should be provided with more support for social development. Through technology and the media, the status of women should be promoted and men should be made fully aware of the important role of women in the ecosystem. Strengthening the education of women in alpine regions would enhance the self-image of women. In addition, proper education

for women would make them more aware of the dangers of indoor pollution and would also improve and promote the sustainable management of ecosystems. Strengthening of education should reduce the marginalisation of women in the politics of the alpine region, but this requires a long-term commitment (Wang 2011).

Improvements in the medical infrastructure to reduce the high rate of female disease and mortality in alpine regions are fundamental in promoting and improving female health (Nan 1996). In alpine regions, in addition to improving medical facilities for women's health care, medical teams are needed with training and skills in women's health. In poor remote areas, mobile medical services should be developed which provide regular medical treatment. The mobile medical teams should pay special attention to women's health issues to improve the ability of women for self-awareness and self-treatment.

Improvements in the social status of women would result in greater participation in social and political decision-making, including ecosystem-management. Historical records show that Tibetan women occupied a dominant position in the management and governance of the alpine region in the past and were capable of making decisions (Wang 2011, Lokyitsang 2014). As well as participation at the village, township and county levels, participation by women in higher administrative organisations could direct policy. Women should be given more opportunities for involvement in social development, as well as policy making for ecological management. The important female role in carbon management should be given greater prominence in social administrative decision-making.

Addressing and protecting women's current and future needs and interests would improve the status of women in grassland ecosystems and livestock management. This should include mainstreaming current gender differences in livestock production and animal-dung management. Women should receive more credit for their roles in livestock production and animal-dung management. Such recognition could promote women's economic and social empowerment, particularly for vulnerable women or those living in highland areas. This empowerment could contribute significantly to meeting commitments agreed in government conventions, as well as addressing development goals of women as social protection for women's labour and contributions (Agoramoorthy and Hsu 2012). Promoting carbon management based on gender could reduce vulnerability and increase opportunities of women, including providing for their families. This is particularly relevant in sub-alpine areas of the Tibetan plateau, such as Sunan County and Tianzhu County. Women in the alpine area have established the management of alpine carbon cycles and grasslands through their actions. Governments should better acknowledge the key role of women in maintaining grasslands through their sustainable landscape management and livestock husbandry systems.

Acknowledgements

We thank anonymous reviewers for the comments. We also thank the Seed Grants of Himalayan University Consortium (HUC) (Collaborative research of innovating social-carbon-stoichiometry method to comparing the different indigenous peoples' contribution for mitigating the global warming in Himalayan mountain region), and Program for New Century Excellent Talents in University (NCET-13-0261), for financial support.

Bibliography

- Batjes, N.H. 1996. 'Total C and N in soils of the world'. *European Journal of Soil Science* **47**: 151–163. <http://dx.doi.org/10.1111/j.1365-2389.1996.tb01386.x>
- Bowes, J. [undated]. *Tibet and Gender: Tibetan Women's Initiatives at Machik*. Accessible online at: http://www.machik.org/index.php?option=com_content&task=view&id=132&Itemid=73 (accessed 23 October 2015).
- Cecelski, E. 2000. *The Role of Women in Sustainable Energy Development*. National Renewable Energy Laboratory. Golden, CO. <http://dx.doi.org/10.2172/758755>
- Chen, P., C. Li, S. Kang, Q. Zhang, J. Guo, J. Mi, P. Basang and Q. Luosang. 2011. 'Indoor air pollution in the Nam Co and Ando regions in the Tibetan Plateau' [in Chinese]. *Huanjing Kexue* **32**: 1231–1236.
- Coppock, D.L., S. Tezera, S. Desta, M. Mutinda, S. Muthoka, G. Gebru, A. Aboud and A. Yonas. 2013. 'Cross-border interaction spurs innovation and hope among pastoral and agro-pastoral women of Ethiopia and Kenya'. *Rangelands* **35**(6): 22–28. <http://dx.doi.org/10.2111/RANGELANDS-D-13-00039.1>
- Dong, S.K., R.J. Long and M.Y. Kang. 2003. 'Milking and milk processing: traditional technologies in the yak farming system of the Qinghai-Tibetan Plateau, China'. *International Journal of Dairy Technology* **56**(2): 86–95. <http://dx.doi.org/10.1046/j.1471-0307.2003.00088.x>
- Fan, X.M. 2010. 'The discussion of relationship between natural resource and population growth in Tibet' [in Chinese]. *Journal of China Youth University for Political Sciences* **4**:119–123.
- Fang, Y.P., D.H. Qin, M.Z. Deng and Z.Q. Ge. 2012. 'Change and affecting element of grassland ecosystem in the source regions of the Yangtze and Yellow rivers based on sociological perspective' [in Chinese]. *Arid Land Geography* **35**(1): 73–81.
- Halbrendt, J., A.H. Kimura, S.A. Gray, T. Radovich, B. Reed and B.B. Tamang. 2014. 'Implications of conservation agriculture for men's and women's workloads among marginalized farmers in the central middle hills of Nepal'. *Mountain Research and Development* **34**(3): 214–222. <http://dx.doi.org/10.1659/MRD-JOURNAL-D-13-00083.1>

- Holthaus, E. 2015. *Yak Dung Is Making Climate Change Worse and There's No Easy Solution*. Slate.com. Accessible online at: http://www.slate.com/articles/technology/future_tense/2014/12/yak_dung_is_making_climate_change_worse_and_new_cookstoves_don_t_help.html (accessed 23 October 2015).
- IFAD [International Fund for Agricultural Development]. 2004. *Enhancing the Role of Indigenous Women in Sustainable Development*. Third Session of the Permanent Forum on Indigenous Issues. Accessible online at: <http://www.ifad.org/english/indigenous/pub/documents/indigenouswomenReport.pdf> (accessed 23 October 2015).
- IPCC [Intergovernmental Panel on Climate Change]. 2007. *Climate Change 2007. The Fourth Assessment Report: The Physical Science Basis*. Cambridge: Cambridge University Press.
- Khadka, M., S. Karki, B.S. Kharky, R. Kotru and B. Darjee. 2014. 'Gender equality challenges to the REDD+ initiative in Nepal. *Mountain Research and Development* 34(3): 197–300. <http://dx.doi.org/10.1659/MRD-JOURNAL-D-13-00081.1>
- La, M.C. 1995. 'Tibetan women's status and function in social and economic life in Qinghai province' [in Chinese]. *Journal of Qinghai College for Nationalities (Social Science Edition)* 4: 64–68.
- Lal, R. [undated]. *Soil Carbon Sequestration: SOLAW Background Thematic Report – TR04B*. Rome: FAO. Accessible online at: http://www.fao.org/fileadmin/templates/solaw/files/thematic_reports/TR_04b_web.pdf (accessed 23 October 2015).
- Li, J. and X.A. Yang. 2005. 'Gender role of female and their social level change of Tibetan population in Gannan' [in Chinese]. *Lanzhou Xuekan* 6:110–113.
- Li, X.M., L. Chen and W.R. Ding. 2012. 'Different methods and population development forecast: a case of status of the Tibet Autonomous region' [in Chinese]. *Northwest Population* 33(4): 58–62.
- Lokyitsang, D. 2014. *Gender Violence, Leadership, and the Modern Tibetan Women*. The Tibetan Political Review. Accessible online at: <https://sites.google.com/site/tibetanpoliticalreview/articles/genderviolenceleadershipandthemoderntibetan-woman> (accessed 23 October 2015).
- Long, R.J., L.M. Ding, Z.H. Shang and X.S. Guo. 2008. 'The yak grazing system on the Qinghai-Tibetan plateau and its status'. *The Rangeland Journal* 30(2): 241–246. <http://dx.doi.org/10.1071/RJ08012>
- Lu, M. [undated]. 'Family and women among nomads of northern Tibet'. Accessible online at: www.cwru.edu/affil/tibet/booksAndPapers/Gelek/Mei.pdf (accessed 24 October 2015).
- Ma, R. 2008. Structure and change of population in Tibet-the analysis of population census data in 2000 [in Chinese]. *Chinese Tibet Science* 3:167–182.
- Menon, S., J. Hansen, L. Nazarenko and Y.F. Luo 2002. 'Climate effects of black carbon aerosols in China and India'. *Science* 297: 2250–2253. <http://dx.doi.org/10.1126/science.1075159>

- Menon, S., D. Koch, G. Beig, S. Sahu, J. Fasullo and D. Orlikowski. 2010. 'Black carbon aerosols and the third polar ice cap'. *Atmospheric Chemistry and Physics* **10**: 4559–4571. <http://dx.doi.org/10.5194/acp-10-4559-2010>
- Miller, D. 2003. *Tibet: Environmental Analysis*. Background paper, in preparation for USAID's program. Accessible online at: <http://www.case.edu/affil/tibet/documents/MillerUSAIDTibetenvironmentalanalysis.pdf> (accessed 23 October 2015).
- Molden, D., R. Verma and E. Sharma. 2014. 'Gender equality as a key strategy for achieving equitable and sustainable development in mountains'. *Mountain Research and Development* **34**(3): 297–300. <http://dx.doi.org/10.1659/MRD-JOURNAL-D-14-00064>
- Nan, W.Y. 1996. 'Status analysis of Tibetan women population' [in Chinese]. *Qinghai National Research (Social Science Version)* **4**: 17–25.
- OECD [Organisation for Economic Co-operation and Development]. 2008. *Gender and Sustainable Development – Maximising the Economic, Social and Environmental Role of Women*. Accessible online at <http://www.oecd.org/social/40881538.pdf> (accessed 23 October 2015).
- Pope, C.A. and D.W. Dockery. 2006. 'Health effects of fine particulate air pollution: lines that connect'. *Journal of Air Waste Management* **56**: 709–742. <http://dx.doi.org/10.1080/10473289.2006.10464485>
- Radel, C. and D.L. Coppock. 2013. 'The world's gender gap in agriculture and natural resources: evidence and explanations'. *Rangelands* **35**(6): 7–14. <http://dx.doi.org/10.2111/RANGELANDS-D-13-00036.1>
- Ramanathan, V. and Y. Xu 2010. 'The Copenhagen Accord for limiting global warming: Criteria, constraints and available avenues'. *Proceedings of the National Academy of Sciences of the United States of America* **107**(18). <http://dx.doi.org/10.1073/pnas.1002293107>
- Shang, Z.H., M.J. Gibb, F. Leiber, M. Ismail, L.M. Ding, X.S. Guo and R.J. Long. 2014. 'The sustainable development of grassland-livestock systems on the Tibetan plateau: problems, strategies and prospects'. *The Rangeland Journal* **36**(3): 267–296. <http://dx.doi.org/10.1071/RJ14008>
- Sharma, B. 2010. *Challenges and Opportunities for Sustainable Energy Solutions in Rangelands – Experiences and Lessons from the Hindu-Kush Himalayas*. Kathmandu: ICIMOD.
- TARBS [Tibet Autonomous Region Bureau of Statistics]. 2010. Tibet General Team of Investigation under the NBS (TGTI of NBS) [in Chinese]. *Tibet Statistical Year Book 2010*. Beijing: China Statistics Press.
- Verma, R., D. Molden, H. Hurni, A.B. Zimmermann and S. Wymann von Dach. 2014. 'Special issue: Gender and sustainable development in mountains – Transformative innovations, tenacious resistances'. *Mountain Research and Development* **34**(3): 185–187. <http://dx.doi.org/10.1659/mrd.3403>
- Ulbabayar, T and M.E. Fernández-Giménez. 2013. 'Following the footsteps of the Mongol queens: why Mongolian pastoral women should be empowered'. *Rangelands* **35**(6): 29–35. <http://dx.doi.org/10.2111/RANGELANDS-D-13-00035.1>

- Wang, T.Y. 2011. The roles and status of Tibetan women [in Chinese]. *Journal of Tibet University* **26**(1): 133–139.
- Watts, A. 2015. ‘Breaking Science News: Yak Dung Burning Pollutes Indoor Air of Tibetan Households’. Watt’s Up With That.com. Accessible online at: <http://wattsupwiththat.com/2015/01/16/breaking-science-news-yak-dung-burning-pollutes-indoor-air-of-tibetan-households/> (accessed 23 October 2015).
- WMO [World Meteorological Organisation]. 2010. *Greenhouse Gas Bulletin: The State of the Greenhouse Gases in the Atmosphere until December 2009*. Geneva: World Meteorological Organisation.
- Xiao, Q., E. Saikawa, R.J. Yokelson, P. Chen, C. Li and S. Kang. 2015. ‘Indoor air pollution from burning yak dung as a fuel in Tibet’. *Atmospheric Environment* **102**: 406–412. <http://dx.doi.org/10.1016/j.atmosenv.2014.11.060>
- Yang, R.M. 2010. ‘Population quality and sustainable development of Tibetan women’ [in Chinese]. *Journal of Tibet University (Natural Science Version)* **25**(1): 64–67, 102.
- Yu, X.J. 2010. *The Role and Mechanism of Yak Dung on Maintenance for Qinghai-Tibet Plateau Alpine Grassland Health* [in Chinese]. PhD Thesis. Gansu Agricultural University, Gansu.
- Zhu, L., D.A. Johnson, W. Wang, L. Ma and Y. Rong. 2015. ‘Grazing effects on carbon fluxes in a Northern China grassland’. *Journal of Arid Environments* **114**: 41–48. <http://dx.doi.org/10.1016/j.jaridenv.2014.11.004>

Zhanhuan Shang is professor at Lanzhou University in China. He does research on rangeland ecology and sustainable management.

Email: shangzh@lzu.edu.cn

Andrew White is a researcher at the University of Adelaide in Australia. He does research on rangeland science.

Email: ian.andrew.white@gmail.com

A. Allan Degen is a professor at Ben-Gurion University of the Negev. He does research on intensive and extensive livestock production and livelihood strategies.

Email: degen@bgu.ac.il

Ruijun Long is a professor at Lanzhou University in China. He does research on ecosystems of rangeland and pastoral development.

Email: longrj@lzu.edu.cn