Interface Focus

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Research

Cite this article: Campbell B, Sallis P. 2013 Low-carbon yak cheese: transition to biogas in a Himalayan socio-technical niche. Interface Focus 3: 20120052.
http://dx.doi.org/10.1098/rsfs.2012.0052

One contribution of 9 to a Theme Issue 'Biofuels, science and society'.

Subject Areas:
biotechnology, environmental science

Keywords:
biogas, low carbon, yak cheese

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Low-carbon yak cheese: transition to biogas in a Himalayan socio-technical niche

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This study looks at how potential for resilient low-carbon solutions can be understood and enhanced in the diverse environmental, economic and socio-political contexts in which actual scenarios of energy needs and diverse development pathways take shape. It discusses socio-technical transition approaches to assist implementation of a biogas digester system. This will replace fuelwood use in the high forests of Central Nepal, where yak cheese production provides livelihood income but is under threat from the Langtang National Park, which is concerned to protect biodiversity. Alternatives for digester design are discussed, and the consultative issues for deliberative processes among stakeholders' varied agendas raised.

1. Introduction

Reducing greenhouse gas (GHG) emissions has become a generally recognized imperative for the global economy [1], while addressing the rights to development of the global poor in achieving Millennium Development Goals entitles them to opportunities for cleaner energy sources. How do these lofty intentions translate into actions on the ground? The turn from dependence on fossil fuels and biomass has focused attention on the possibilities for bioenergy to provide alternative supplies to people in the developing world. However, different kinds of bioenergy and different socio-economic contexts of development and poverty present a complex scenario that calls out for systematic comparative studies of low-carbon energy in development. Several commentators [2] highlight the need for evidence 'on the ground' of what are the dynamics and factors of energy applications in the lives of the poor in the developing world. How can potential for resilient low-carbon solutions be understood and enhanced in the diverse environmental, economic and socio-political contexts in which actual scenarios of energy needs and diverse development pathways take shape. This is an interdisciplinary contribution that combines expertise on local socio-economic processes and appropriate anaerobic digester solutions, to think about solving a particular problem in a concrete place and to raise issues in debates about socio-technical systems transition.

The study looks at an example of energy in development in Nepal, where approximately 90 per cent of energy needs are still met by biomass [3]. The prospect of keeping carbon locked up in the forests converges with the agenda of biodiversity conservation [4] and reducing emissions from deforestation and forest degradation [5]. In the field site, the forests have been used for transhumant subsistence (with sheep and goats, water buffaloes, yaks and cows) by local people from the Tamang-speaking communities of Nepal's indigenous peoples. Langtang National Park was created in 1976, straddling Rasuwa and Sindhu Palchok Districts. A 'yak cheese' factory predates the establishment of the national park, and is under pressure to stop using fuelwood for its operation. The state-run cheese factory brings very significant income to an otherwise underdeveloped district. Clean energy solutions potentially offer new frameworks for collaboration in the often conflictual relationship between local livelihoods and biodiversity protection. With an anthropologist and an

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engineer working together, the pathways for technological, ecological, social and institutional transition in a Himalayan landscape can be opened up. There is no simple, self-evident solution at hand. Technological, labour and land use choices will need to be assessed for long-term suitability. The intention is to facilitate information about options for the benefit of different actors to express their preferences and concerns about feasibility and outcomes of energy decision-making for ecological and livelihood wellbeing. While the possibility could exist for a technological resolution of institutional competition over the yak cheese factory, a historical perspective on knowledge and power in the governance of the Himalayan environment [6–8] suggests there is more at stake than an issue delimited to technological concerns, and matters of socio-technical regime legitimacy come to the fore, underpinning rights to low-carbon livelihoods.

2. Energizing sustainability

Sustainability has entered a third generation (according to Adam's & Jeanrenaud's [9] report for the IUCN), in which biodiversity concerns can no longer be treated apart from the livelihood interests of the poor, and without regard for the rights of indigenous people where protected areas have been created. Vulnerability to the effects of climate change make social justice and livelihood rights an intrinsic dimension for sustainable transitions to low carbon economic systems [9, p.48]. The possibilities for delivering clean energy to serve the domestic and enterprise needs of communities not connected to modern energy systems have been a focus of the UK's Low Carbon Energy for Development Network (LCEDN) since 2012 (LCEDN is sponsored by the Department of Energy and Climate Change; the Department for International Development (DfID) and the Engineering and Physical Sciences Research Council). The LCEDN has explicitly promoted collaboration between social scientists of development and engineers of renewable technologies in addressing the problems of affordable energy access that will not exacerbate carbon emissions. As debated at the LCEDN conference at Sussex University (10 and 11 September 2012), energy access may be met more efficiently with LPG in many parts of the global south, whereas some supposedly 'clean' biofuels may have questionable low-carbon status if transportation is taken into account, leaving aside the ethics and environmental impact of the palm oil industry [10]. 'Clean energy for the poor' needs to be looked at as an objective that requires some developmental 'disambiguation' to use Pottier's [11] phrase. Does this mean the poor can be offered only low-carbon energy while the rich consumer nations continue to pollute? Rather than get stuck in abstract generalities implying good and bad, this study looks at a case context of institutional power and transition preferences affecting a given niche, in which sustainable outcomes are deliberated and contested among different perspectives.

'Sustainable energy for all' is the UN's proposition for 2012 [12]. It promotes the idea of developing countries 'leap-frogging' to clean energy systems. While in many cases there can be argued to be trade-offs between forms of energy access and benefits to the poor, the case under discussion in this study indicates that low-carbon energy can be the cheapest form available. It can be argued there is a continuity of logic and habitual fit between the indigenous Himalayan practices of seasonal transhumant livestock keeping, and the functioning and maintenance requirements of a biogas installation running on cattle dung, which could prove to be replicable at a sustainable level. There are some kinds of transition technologies that require wholesale behaviour change, whereas others could have more affinity with materials and principles of self-reliance linked to science of place in niches that enable pro-poor and pro-biodiversity examples of metabolic cycles [13,14]. The cultural basis for sustainable transition that would suit forest-dependent livelihoods is on the face of it promising.

3. Methods of collaboration

The paper has been written on the back of a field collaboration between B.C. and P.S., involving a two-week visit to Nepal in September 2011. The first idea for the scoping research trip had come from a conversation in April 2011 in Bharku village, Rasuwa District. B.C. met with lodge keepers from Shing Gombo who explained the worries over talk of the Langtang National Park withdrawing licences to fuelwood for the cheese factory. With a background in research on Nepal's protected areas and forest communities, B.C. made the energy connection. The Durham Energy Institute's interdisciplinary networks put B.C. in touch with P.S. once a small grant for the field trip had been awarded. P.S. attended Durham Energy Institute's Low Carbon Energy for Development workshop held on 5 July 2011, which brought panoramic interdisciplinary and institutional perspectives to inspire research on the theme. B.C. then visited Paul's Newcastle laboratory to see a vast array of tubes and containers of digestate, in different stages of anaerobic production, and learnt of Paul's wide international network of students. The pair discussed previous field experiences, how to organize their time, prepare for contacts to interview and decide on light equipment to bring in the two months before departure. A digital video camera was packed along with two GPS units.

P.S. searched and contacted renewable energy sector researchers and NGO offices in Kathmandu. Criss-crossing the valley between Lainchaur and Sanepa, we gathered background information on the policy and project context. The Parks People Programme of UNDP had come to an end, but after the Netherlands had supported biogas promotion, WWF had taken up diffusion of biogas units in the buffer zones of Nepal's lowland protected areas (Biogas Sector Project [15]). We discussed technical challenges and comparable projects to learn about, and gathered opinions of the feasibility of our plan in the light of project workers' knowledge of the relative social and economic development characteristics of the area of study.

In the discussions held at NGO and government offices, the combination of engineering and anthropological expertise was valuable in layering the different parallel strands of enquiry, and in deepening the conjoined knowledge in order to draw the conversation with Nepali personnel into contiguous topics of interest for interdisciplinary attention. Despite repeated attempts, it was not possible to meet with DfID personnel working on renewable energy and forest livelihoods. B.C. and P.S. met with the warden of Langtang National Park at the Dhunche headquarters, and discovered some buffer zone personnel from Mustang with experience of biogas.

On the basis of previous fieldwork acquaintance, the research team was able to make contact with families from the area of study, who were living on the outskirts of Kathmandu. One couple had been raised in the yak–cow dairying encampments of adjacent villages, and were able to advise exactly where we could expect to find the herds at the time of our arrival, and which of the seasonal cheese-making units would be operating. Talking with them about cattle movements through the annual cycle, and considering their own passage into more urban and educated lifestyles in the course of their family life cycle, pointed towards a way for thinking about research into the socio-technical system in transition as made possible by a series of moving points.

Travelling by bus, traversing monsoon landslides and walking to a reception by Tamang villagers alerted by phone of our arrival, we agreed on taking three porter-guides, known from B.C.'s previous fieldtrips, who were all of the same language group as the herders we were about to meet, and who also had direct experience of raising yak–cow hybrids. Their company and commentaries on each stage and encounter of the field trip were invaluable, and provided a sounding board for our information-gathering practices and reflections on the trip. At one vital moment, one of the guides told me a man descending rapidly downhill was the manager of the cheese factory, and I was able to exchange contacts and learn who to ask for when we got there. This was a version of the 'group trek' method (*samuhik bhraman* in Nepali) described by Mathema & Galt [16] for rapid research purposes on farming systems across contiguous village territories, gaining insights on local preferences and agendas for development. A side trip was made by B.C. (after P.S. had to return to Kathmandu for an earlier flight) that took in the neighbouring Dhunche dairying entourage, and led to further interviews about the economics of livestock keeping and the outflow of domestic labour to overseas employment. Data gathering was conducted by observation, filming and informal interviews in Nepali, Tamang and English as appropriate.

As a form of interdisciplinarity, this was a 'problem-oriented' collaboration

> The interesting feature of this sort of collaboration is that the object of study exists simultaneously on two planes: as the theoretical object constituted within each of the participating disciplines and as the object of the informal (everyday or 'natural') language that specialists employ as their koine. [17, p. 989]

Follow-up research and a programme of work will seek to include other disciplines and broaden the problem orientation set in motion through the scoping field trip.

4. Interdisciplinary inputs

The authors here are working for the first time on a joint article, with an explicitly twin-track view of the problem orientation. During future phases of this project, in trialling biogas digesters, training personnel and negotiating their operationalization, we expect to develop writing iterations that will involve more crossover perspectives as the project itself gains momentum and hybrid knowledge practices emerge in the shape of ethno-engineering. There are steps already taken by others in this direction that deserve some brief attention.

In his illuminating essays on the experience of bringing electricity supply to Nepalese communities from the 1980s, Gyawali [18] frequently reflects on the value of anthropological approaches to energy provision. He describes working on the electrification of Lalitpur in 1981, the plan for which had unwittingly left all the political leaders' houses in the area without supply. The politicians took this as a deliberate act of provocation. In fact, it was the outlying location of their residences, compared with the dense peri-urban settlements where provision had been concentrated for the majority of electricity users, that had excluded them as it had been impossible to achieve universal connection.

> Engineering schools do not teach these things. One had to learn on the field that good engineering logic was not necessarily the logic of local politics. [18, p. 2]

The calculation and design for efficient energy provision in circumstances of limited resources will not necessarily deliver social justice or political acceptability. Here is an example of engineering issues being handled with no regard to social context. Gyawali's central argument is that in issues of science and technology in the public sphere of development, it is necessary to bring into view the choices and alternatives, and not to be satisfied by reducing options merely to those favoured by market individualists and state hierarchists. Being a critic of energy and water management policies trapped within a 'construction-paradigm' in the 1990s, he followed the 'cultural theory' approach of anthropologists Douglas [19] and Thompson *et al.* [20] that distinguishes different structural positions towards environmental and social change, the role of markets and effectiveness of intervention. Gyawali has pursued in the context of Nepal, and South Asia more generally, a socially informed interdisciplinary approach to delineate the constituencies of energy policy such as megadam support, and the potential for enormously more cost-effective means of energy provision and 'sustainable development of the poor, by the poor' [18, p. 9]. Much has been achieved through community-based user groups for extending grid connection. Critical decisions for future benefit require opening up rather than closing down alternatives for public deliberation.

Comparing the experiences of organizational capacity in Nepal, Peru and Kenya, Yadoo [21] comments on the institutionally favourable context for community electricity users' groups in Nepal. This can be linked to the wider effects of empowerment of villagers through the community forestry programme, based on letting local groups decide their own terms for self-organization.[1] Acknowledging the effectiveness of local resource management capacities connects with a strand of field-based knowledge pertinent to the energy transitions propensity for learning from others' knowledge advocated by Adams & Jeanrenaud

> We must break down the barriers between disciplines, the tawdry trade in academic prestige and the sterile politics of establishment thinkers and their routine-bound ideas. We must embrace informal as well as formal learning, oral as well as written knowledge, poetry as well as mathematics, natural history as well as economics, ethics as well as engineering. [9, p. 78]

5. Cultures of poverty

Energy poverty is defined in the UK in terms of households that spend more than 10 per cent of income on energy. In rural Nepal, most energy for cooking and heating is still collected from forests or agricultural residues, and access to forests in the mid-hills of Nepal has for the past decades been quite successfully managed through community forestry groups. These areas of forest face a decent prospect of sustainable renewal owing to user group regulation of members' use rights. The livelihood justice of recognizing use rights in a resource that it is in the common interest to protect (for men and women, and to a large extent including low-caste membership too) has been a major underlying reason for the international renown of Nepal's community forestry [8,22,23].

From an anthropology of development perspective, the challenge of bringing low-carbon energy to the poor involves understanding the dynamics and characteristics of poverty in historical structures of inequality. In a country such as Nepal, there are factors of ethnic–cultural difference and community-adapted knowledge and skill sets that make Euro-American notions of poverty as lack of modern technological inputs too simplistic.

Leaving the mid-hills areas of rural Nepal to consider the less densely populated mountain areas, there is a cultural shift that accompanies the ecological transition into temperate and sub-alpine zones of overlap. Here, the transhumant agro-pastoral way of life mixes some crop growing with livestock management. Most of the communities practising this subsistence regime are the 'janajati' or indigenous ethnic groups of Nepal. Most of these groups do not speak Nepali as their mother tongue, and have a strong sense of belonging to a different social world than the mid-hills and lowland cultural mainstream of the country. They tend to have only weak forms of social hierarchy, and the exclusionary practices of caste are not prevalent, beyond some instances of privileged land title and ritualized interactions with service castes of blacksmiths and tailors.

In the eyes of people located within the literate, irrigated rice-growing Nepalese mainstream, the indigenous language speakers living uphill on less productive soils are seen as poor and backward. From higher up looking down, a system difference appears, and the view can be one of being deprived of legitimate development needs, excluded from political participation and not being treated as equal citizens. This raises a major issue for the application of socio-technical systems' multi-level perspectives [24]. Can sub-dominant systems preferring alternative norms, practices and techno-environmental values be recognized as subaltern regimes? Who manages to define the status of regime in contrast to niche? These are questions to hold in mind when learning more about the case.

It is in such locations that the state has created several national parks and intentionally disrupted the traditional access to forest resources to prevent loss of habitat. To the educated officials of the protected areas, who consider themselves as missionaries of progress in remote backwaters, the transhumant herders represent a primitive (*jangali* in Nepali) way of life, incongruous with their image of a modernizing state that supports, and benefits from, global conservation agendas. Making a living from subsistence livelihoods in protected areas is perceived by them as anomalous [25]. There has been a more empowering dimension countering this institutional tendency in the shape of participatory conservation within buffer zone policy since 1996. In this framework, consensual environmental protection is fostered by pro-poor livelihood measures to wean local communities off traditional levels of harvesting from forests (fuelwood and non-timber forest products). These have included domestic biogas provision to the buffer zone communities of the protected areas in Nepal's *terai* lowlands. By giving rights to the poor in places where the forest makes everyday small differences to people's subsistence welfare the perception of conservation has benefited, by not simply being seen as designed to protect the non-human environment to the detriment of resident humans. One study funded by DfID [26] even concluded that during the 10 years of conflict in Nepal (1996–2006) the pro-poor aspects of socially inclusive participatory conservation programmes had been more effectively implemented than might have otherwise been the case. It is within these parameters of changing relations between villagers and state, and the improvements in livelihood justice relating to forest management, that transition in the rights and incentives to promote low-carbon energy practices for the poor need to be embedded.

The transition pathways most suited to rural Nepal will have to work with the most adaptable elements of 'incumbent' socio-ecological regimes, and identify the points of friction and recalcitrance to low-carbon transition within existing socio-technical regimes, and the room for manoeuvre within niches [27]. To this end, the historical changes, energy dimensions and socio-economic consequences of transhumance practices affecting the yak cheese factory need to be considered before we turn to look at the contemporary dynamics of poverty, markets and ecological livelihood practice in Nepal's mountains.

5.1. Livelihoods at altitude

The issue of communities' livelihood adaptations in the mountains with their diverse ecological characteristics became the focus of numerous studies after foreign researchers were permitted into the Nepal Himalayas following the fall of the Rana regime in 1950. By the 1970s, there was a significant body of ethnographic cases with which to compare these adaptations and theorize the connections between livelihood adaptations and ethnic groups at different altitudes. The interdependence of local subsistence modes and exchange relations with other communities became an obvious point of comparison. The pioneer of Himalayan anthropology Christoph von Fürer-Haimendorf traversed Nepal from east to west and wrote up his findings in the 1975 book *Himalayan Traders*. He argued that those communities living at altitudes of over 10 000 ft could not generate sufficient local production to support themselves even though they made the best of transhumant movements between higher and lower seasonal pastures. In addition, they needed to trade. Many of the groups Fürer-Haimendorf conducted fieldwork with had traditional trading partners on the Tibetan side of the mountains from whom they could obtain salt, which was in demand by the rice-growing communities of lowland Nepal. The circuits of trade enabled by carrying these goods by beasts of burden (yaks, yak–cow hybrids, mules and goats) had been interrupted by the Chinese occupation of Tibet when most of this trade had come to an end. Tourism then filled a gap in the economy of these mountain communities.

Transhumance works as an adaptation to variation in seasonal and spatial availability of photosynthesized energy in mountain ecological communities. Different kinds of livestock thrive on movement between ecological niches with varying forage patterns [14]. Apart from affording meat, milk, hides and horns, the animals traversing mountainsides were welcomed by farmers for the manure deposited on their fields. By the 1970s, there was enough comparative research on studies of Nepal's different ethnic communities, their subsistence and their histories for the French anthropologist Sagant [28] to argue that there were effectively two types of technological adaptation in Nepal established since the unification of the country by the Gorkha dynasty at the end of the eighteenth century: a lowland rice-growing adaptation and a highland livestock–forest adaptation. The crops, animals, materials and knowledge for these production niche-regimes did not vary significantly across ethnic groups. There was effectively a socio-technical lock-in by this time, but their articulation was weekly governed (the state taxed through corvée labour), with independent changes of socio-technical practices in response to new circumstances. As Stevens' [29] work on the Everest area demonstrates, the herds kept by mountain pastoralists are very responsive to market fluctuations. He observed an increase in numbers of male yak–cow crosses being kept owing to their popularity (and transport efficiency) with tourist trekking groups.

In the mountains of central Nepal, it was not just villagers' herds using the forests and high pastures. There were in addition state dairy herds from the royal household. In the old Nuwakot district (divided into Nuwakot, Dhading and Rasuwa after 1970) royal herds of cattle and water buffalo moved through the area every year. Local villagers were forced to assist in corvée labour gangs to carry all the equipment for butter production, and provide timber for the construction of shelters [30]. The winter pasture was at Shikar Besi. In the mid 1950s, a Swiss and Food and Agricultural Organization project introduced Alpine cheese-making techniques at a dairy in the high Langtang valley for the numerous yak–cow milk animals there. The yak cheese operation had been successfully transferred to the Dairy Development Corporation by the 1960s. The popularity of the 'yak cheese' spread among the growing numbers of tourists in Nepal, and cheese factories were opened in many districts making European style cheeses, butter and Nepali *durka* (a hard cheese stick popular among office workers for sucking in the corner of the mouth like a boiled sweet).

Extending the national development regime of modernization into areas of poverty, in 1970 a new cheese factory was opened by the Dairy Development Corporation to the south of Langtang at Chandanbari (Shing Gombo in local Tamang language). Loans from the Agricultural Development Bank encouraged Tamang herders from Shyabru and Dhunche village development committees (VDCs, formerly *panchayats*) to invest in breeding and dairying yak–cow hybrids (*chauri*) to supply the cheese factory. In 1976, the Langtang National Park was established, after which herds were permitted only within VDC territories where herd owners held landed property [31]. The long-distance transhumance of cattle, sheep and goats disappeared, and livestock had to make do with their immediate vertical ranges. Together with the ban on barter and trade in forest products, this marked the ending of a distinct socio-ecological regime that had linked together complementary ecological niches in mutually advantageous ways, with little integration by governance [32].

Currently, the herds from six different villages (Thulo Bharku, Sano Bharku, Thulo Shyabru, Brabal, Dhunche, Galje) of three VDCs (Shyabru, Dhunche, Yarsa) supply fresh milk to make cheese that is stored at Chandanbari, before being portered down to the road head and on to Kathmandu. The organization of dairy production synchronizes with the transhumant movement of the herds. The herds progressively gain height as the pastures are seasonally grazed from lower levels in May, and up to nearly 4000 m in July, returning downhill in October. The milk is collected at temporary processing centres (*sagha*) where it is pasteurized, and turned to fresh cheeses the same day before being carried to the cheese factory depot at Chandanbari. The output from this operation was approximately 21 000 kg of cheese in 2011. The DDC in 2011 paid approximately 8.5 million rupees (approx. 120 rupees to the pound) to the herders for their milk over six months of production (Giri Bajracharya interview in DDC office, Kathmandu, 11 April 2012).

Despite attempts made by the national park to limit herd sizes by licencing pastures, and charging fees for timber used in dairy operations, the relative profitability of *chauri* keeping and rearing when compared with income from seasonal labour or even government salaries has meant that this high-altitude livelihood option is still preferred by many households. A good *chauri* heifer is worth up to 25 000 rupees, a milking *chauri* up to 40 000 rupees. One male yak costs 45–60 000 rupees and can serve 50 or more cows for breeding purposes.[2] On the field trip in September 2011, we found people from outlying VDCs such as Yersa and Galje carrying milk on 6 h round trips for delivery to the Dhunche seasonal cheese-making unit (*sagha*). We were informed this is the biggest single cheese production unit in all Nepal, processing up to 900 l of milk per day at the height of production. The Tamang-speaking herders of this area see the cheese factory as providing vital livelihood support. It provides a modern economic outlet for sustaining a strong indigenous commitment to ecologically extensive livelihoods that distribute production over time and space, and make use of the opportunities between the Tibetan lands to the north and the Nepali-speaking hills of rice growers to the south. In their own idiom, they inhabit the land between the juniper up above, and the palm tree down below.

The national park authorities are concerned at the number of 1100 *chauri* in the national park, and consider the use of fuelwood for the cheese factory unsustainable [34]. At one site (Kondongjet), a military patrol deemed in 2009 that green wood had been cut for fuel supply by the cheese factory workers, thereafter drawing the national park into maintaining a stronger position on the urgency to find alternative fuel systems. There are also arguments about livestock damage to the bamboo feeding grounds of the red panda [35]. The cheese factory pays the park 30 000 rupees (*ca* £250) per year for fuelwood, and has given 200 000 rupees (*ca* £1700) for costs of fencing and reforestation around the main site of Chandanbari.

Fürer-Haimendorf [36] commented on the loss of control of forest rights by the Sherpas of Solu-Khumbu. He regretted that after nationalization of the forests in 1957, Sherpas had to walk up to four days to get permission to use forest timber, when they had previously operated a local forest regulation institution with a guard known as *shing ki nawa*. This account has been subjected to rigorous scrutiny and found to be too simple (there were many different categories of forest that had different kinds of access control, and the guards were often happy with a token offering of local alcohol, cf. Stevens [29]), but the issue Fürer-Haimendorf identified inspired a number of forest researchers to explore indigenous management systems [22,23,37,38] as the basis for Nepal's world-leading community forestry initiatives. Deepak Gyawali also participated in the research on community-based natural resource management, and specifically concluded that 'local ownership of resource management decisions allowed for more sustainable behaviour vis-à-vis resource use' [18, p. 10]. This lesson provides encouragement for extending Nepal's potential for off-grid autonomous energy supplies by empowering decentralized biomass harvesting systems with membership accountability organized among rights-holders. Niche resource management regimes make sense to rural Nepalis.

There are attempts to overcome endemic antagonism between the national park and the herders. A local youth group, the Langtang area conservation concern society (LACCOS), supports the institution of the park and advocates the cheese factory should adopt alternative energy sources. A LACCOS report on the effects of the cheese production lists examples of micro-hydro provision in the Upper Langtang Valley that have already served smaller scale dairying operations. The situation of competing interests, perspectives and agendas concerning low-carbon energy pathways makes the approach set out by Byrne *et al.* [39] highly relevant. This consists in identifying the incumbent regimes and technical lock-ins as socio-technical systems in order to understand the alternatives that would achieve transformation in the sets of relationships in which technologies are embedded. The pathways approach emphasizes deliberative processes and listening to the voices of marginal stakeholders affected by technical options and changes to socio-technical regimes. Adams & Jeanrenaud offer similar counsel

> a transition to sustainability must involve listening to voices (many of them voices of the poor in the developing world, others voices of environmental and social groups in the North) saying 'wait, the future can be different. [9, p. 45]

The case of the cheese factory connects to spreading awareness of the need for social and natural science interdisciplinarity, and for collaboration between academics, institutional actors, NGOs, private sector and local people and their representatives in shaping alternative pathways for sustainable energy solutions. The key message emerging from observation of positive interactions over niches of low-carbon development in sub-Saharan Africa as well as the Indian sub-continent is that facilitation of local actors to experiment with what works for them in their own places is vital. Centres of innovation distributed away from metropolitan concentrations and perspectives are more likely to spread field-based knowledge and user uptake, rather than follow technical performance measured to laboratory conditions [40].

Section 6 describes the current energy use system of cheese-making, and discusses some alternatives.

6. Transitioning processes from fuelwood to biogas

The use of renewable energy for pasteurizing milk offers a potential solution for rural cheese production units operating in Rasuwa, Nepal. Historically, the energy demand for pasteurizing milk prior to cheese manufacture in these areas has been satisfied by the plentiful supply of wood from natural forests.

Options are limited for small cheese production units (*sagha*) needing to make a rapid transition to renewable energy use. Geographically, Rasuwa district has the potential for both solar- and hydro-power to be applied. However, difficulties arising from the extremely remote location of the pastures are exacerbated by the transhumant management practices that lead to short periods of cheese production (*ca* four to six weeks) at any single location. This requires a renewable energy technology that is either cheap enough to be replicated at each *sagha* location (typically three to five separate locations cover the annual range of elevations), or one that can be decommissioned every six weeks, transported vertically some 500–1000 m, and reinstated at the new site with a minimum of effort. Furthermore, the cost of any technology must be appropriate to the low financial returns of the herders and cheese manufacturers in the rural economy. Consequently, providing fixed installations of hydro- or wind power at each *sagha* location is likely to be prohibitive, and the transportation of a single unit between the different *sagha* locations is unrealistic owing to the physical mass of the equipment. Solar water heaters may be appropriate as a supporting technology; however, the variability and regularity of cloud cover at elevations above 2500 m limits their use as a primary source of energy, especially when milk production occurs without cessation from start to end of the grazing season (*ca* six months). Additional drawbacks in applying highly engineered technologies, such as wind and hydro power, in remote and rural locations are the lack of skilled labour locally for installation and servicing of the equipment, bringing both high maintenance costs and unacceptable downtime periods. Equally, the more compatible the sustainable energy technology is towards existing process and maintenance skills associated with the core business of cheese manufacture, the more likely it will integrate successfully with the business.

Despite comparing favourably on most of the points above, biogas energy has not been implemented widely in hilly and mountainous districts of Nepal, despite the great success in biogas digester installation in lowland areas through the activity of subsidy schemes such as the Biogas Support Programme Nepal. Furthermore, the majority of biogas plants supply households, a small number serving institutions such as schools, because the prevalent design, the fixed dome digester, is well suited to applications where the digester volume is between 2 and 10 m^3, on account of the established construction techniques and inherent simplicity. These digesters are not usually used for commercial or industrial applications. The fixed dome digester, also known as Chinese dome digester on account of the large numbers of digesters (26.5 million [41] installed in China to a standard fixed-dome design), has also gained popularity in Nepal and India, where it is now favoured over floating drum type digesters (Khadi and Villages Industries Commission model) on account of cost [42], despite the latter having a more efficient biogas output, lower methane emission to atmosphere and greater retention of functionality with time [43].

Although it has been shown that the switch from cooking with fossil fuels to biogas, produced by a household digester, can bring about a net reduction in GHG emissions [44], the dome digester design still emits substantial quantities of methane (some 12% of the total methane produced) directly to the atmosphere, causing significant GHG emission. This is due to its simple but inherently inefficient design. Specifically, a large quantity of the actively digesting material (digestate) is forced each day from the digestion chamber

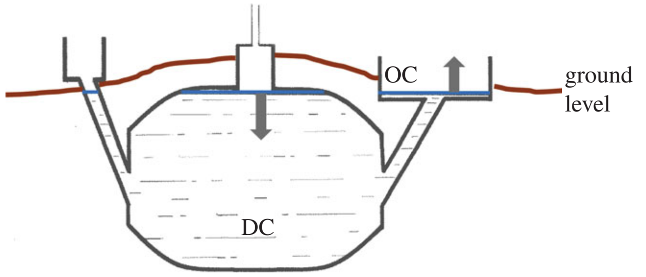

Figure 1. Elevation view of a dome digester installed below ground level. Biogas production in the digestion chamber (DC) forces digestate into the outlet chamber (OC). Arrows indicate the direction of movement of the digestate : biogas and digestate : air interfaces. Not to scale.

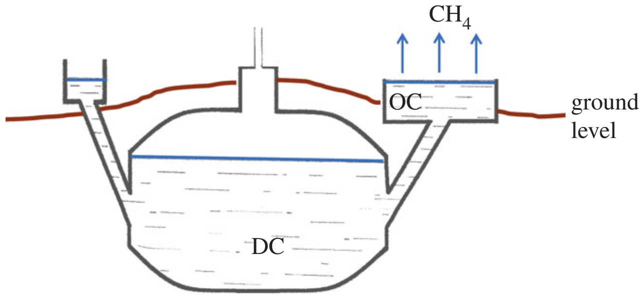

Figure 2. Dome digester from figure 1 at the end of a daily cycle of biogas production, showing a large volume of biogas inside the digestion chamber (DC) and a large volume of digestate displaced into the outlet chamber (OC). Arrows indicate major methane emissions to atmosphere. Not to scale.

(DC) into the outlet chamber (OC) where it is open to the environment, allowing any biogas generated by the mass of digestate in the OC to be lost to atmosphere. Concrete covers installed over the OC do not contain these emissions, as they must allow free movement of biogas/air to avoid restricting the flow digestate into the OC. Furthermore, the biogas contained in the OC, if covered by a concrete slab, has the potential to form an explosive mixture (5–15% methane in air) at some point each day, although this is not reported to pose a high risk in practice, probably due to the lack of ignition sources. The process of digester operation that leads to biogas emissions is shown schematically in figures 1 and 2.

If it is assumed that the digestate is not cooled substantially when displaced from the DC to the OC, and that the reactor is not operating in plug flow mode, then the OC contents will continue to emit biogas to atmosphere at the same rate that biogas is generated internally in the DC. Assuming the rate of displacement of digestate to the OC is proportional to the rate of biogas production inside the DC, allowing for a small amount of biogas compression caused by the hydraulic head between the DC and OC digestate levels (typically 0.3–0.8 m), and that the digester is operating at a specific biogas production rate of 25 per cent vvd (0.25 m^3 biogas per 1 m^3 reactor working volume per day), then summing the product of digestate volume and residence time within the OC over a 24 h period, a 12 per cent loss of biogas to atmosphere can be calculated. For a digester designed to produce 2 m^3 of biogas per day, i.e. 8 m^3 internal digestate volume, then this loss would amount to 240 l of biogas per day. At 60 per cent methane composition, this would mean an annual loss to atmosphere of 52 m^3 of methane (i.e. 37.5 kg of CH_4), which agrees closely with biogas emission measurements of 203–280 l of biogas (46–60 kg CH_4) made on operational digesters [45]. The implication is that significant GHG emissions are generated by dome digesters, and that they are operating at only 88 per cent of their achievable efficiency. In addition, dome digesters must be installed underground to provide structural integrity from the mass of soil cover, requiring excavations over 2 m deep. This may not always be possible in hilly areas where *sagha* are located, as soil depth may be much thinner over the underlying bedrock. Therefore, alternative designs may be more appropriate for biogas generation.

Considering their simplicity and cost, tubular digesters have not reached the same level of popularity as dome digesters, their vulnerability to damage by cattle and children often being cited as the reason (though inflexibility within governmental policy has probably led to installation programmes being bound to their original choice of design, the dome digester). Although simple, the design of the tubular digester has been studied in recent times in some detail [46], and examples are cited operating up to 4200 m elevation [47], which exceeds the altitudes cited by Acharya *et al*. [48] for dome digesters in Langtang, Nepal (3800 m), and Leh–Ladakh, India (3500 m). High-altitude digesters do not appear to suffer adverse effects from low ambient pressure [47,49], although the lower temperatures associated with high altitudes can reduce reactor biogas production rate and composition significantly, biogas productivity at 11°C dropping to around 15–30% of the rate observed at 35°C [49]. However, greenhouse heating (use of clear plastic covers), and insulation can increase digester temperature by 5°C, which can improve the performance of digesters operating at low ambient temperatures [50].

Because the type of biomass feedstock can influence digester performance at altitude, significant differences in methane composition and biogas production being observed between digesters fed on cow and llama dung [49], the use of biogas plants for energy supply in the mountain cheese industry of Nepal would need to assess available feedstocks for their methane yields. The most widely available material is dung from the hybrid yak–cow crosses (*chauri*), possibly supplemented with weed vegetation leaf biomass which is abundant on the forest floor. Indeed, by using gathered weed foliage, not only would the supply of feedstock be supplemented, but management of the most invasive forest weed species could be achieved as well. Weed leaf foliage has been shown to be a viable feedstock for community-sized digesters, even when used exclusively as the sole feedstock input [51]. Furthermore, because the cheese production process generates large volumes of whey, which have low economic value but high organic matter content, this material could be readily used to supplement dung resources and improve biogas yields [52]. Dung collection also offers an opportunity to re-use the labour force currently linked to fuelwood harvesting, thus averting imminent redundancy should fuelwood harvesting be banned.[3]

From considerations mentioned earlier, we envisage the most appropriate biogas system for transient operation at multiple *sagha* stations would be a plastic tubular digester with insulation (e.g. dry fodder crop) and solar heating (plastic sheeting greenhouse). Because fuelwood utilization for water heating (pasteurization) currently spans the full working day, mainly as a result of milk churns being delivered by herders throughout the entire morning period, the

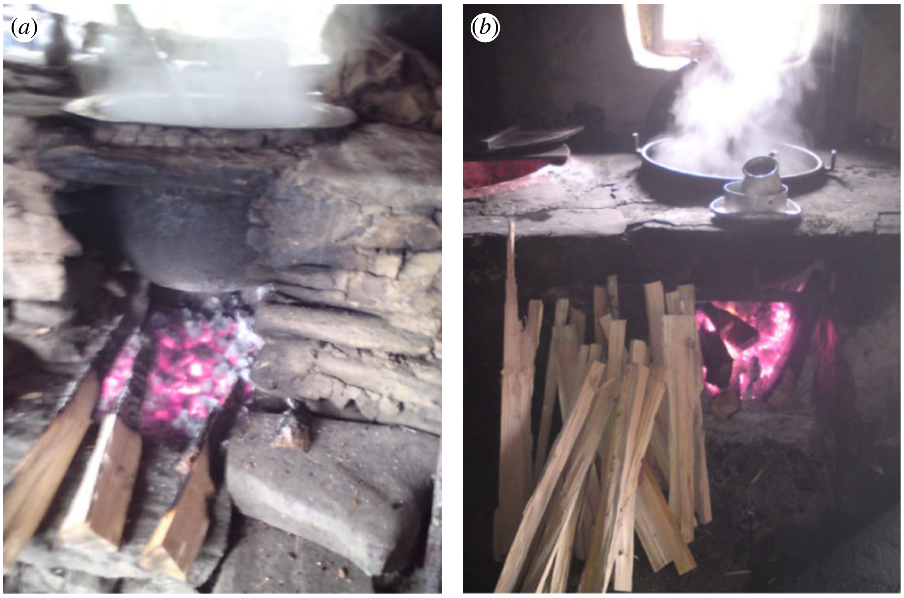

Figure 3. Heating water (and milk churn) in open-fired chulo. Two different examples are (*a*) Parakharka *sagha* and (*b*) Chandanbari cheese factory.

biogas-holding capacity for each *sagha* is likely to be satisfied by the biogas-holding capacity directly within the tubular digester itself, although an external polythene bladder gas holder could be used to store the entire daily biogas output should pasteurization activities be intensified in the future to a period spanning just 1 or 2 h.

7. Energy demand

The present method for heating water and milk during cheese manufacture involves the burning of fuelwood in an open fire below a copper cauldron/kettle (*tama*) mounted in a stove/boiler system (*chulo*). The open–fronted, stone-built *chulo* allows substantial heat loss (figure 3), increasing the level of wood fuel consumption. Furthermore, the practice of stoking the fire with wood at the end of the working day so that the water remains near to operational temperature (greater than 65°C) at the start of the next day, is wasteful of energy owing to continued heat loss throughout the night.

Energy calculations, based on the fuelwood utilization observed at Chandanbari cheese factory and two rural *sagha* in 2011, show that between 0.5 and 0.9 kg of fuelwood is used to process (pasteurize and coagulate) each litre of raw milk. Assuming typical milk processing requirements of between 200 and 400 $l\,d^{-1}$, although higher processing volumes (900 $l\,d^{-1}$) were observed at Dunche *sagha*, and the most efficient fuelwood utilization rate (0.5 $kg\,l^{-1}$), the daily energy budget is 1500 $MJ\,d^{-1}$. However, if the thermal energy budget is calculated from first principles, assuming all milk and water is heated from ambient temperature to working temperature of 65°C and *ca* 100°C for pasteurizing and final sanitizing purposes, respectively, and typical heat losses from the uninsulated *tama* are assumed over the observed processing period (*ca* 6 h), then a daily energy budget of 180 $MJ\,d^{-1}$ is found. This indicates that current equipment and practices are highly inefficient in the use of fuelwood energy, a factor which is offset by the convenience, low cost and simplicity of the *chulo*-based batch pasteurization process (40 l milk churns are simply immersed in the *tama* 'waterbath' for *ca* 40 min in order to achieve '30 min at 65°C' contact time required for pasteurization). Although continuous *high-temperature, short-time* pasteurization, as practised in large modern dairies, is unrealistic in the *sagha* setting, some improvement to the energy budget could be achieved if heat was regenerated between batches by using a simple heat exchanger (e.g. a tubular heat exchanger). Indeed, the importance of heat recovery even in rural cheese production facilities has been long recognized [53]; Arias *et al.* [53] proposed that pasteurization energy could be provided by biogas digesters operating on cattle dung, although no energy budget was mentioned.

Taking the best case mentioned earlier, and assuming yak dung to have a biogas yield similar to fresh cow dung (0.04 $m^3\,kg^{-1}$) [54], the daily energy budget of 180 $MJ\,d^{-1}$ could be achieved from the digestion of 190 kg fresh dung, yielding 7.7 m^3 biogas. At typical volumetric biogas productivities of 25 per cent vvd (0.25 m^3 biogas per 1 m^3 reactor working volume per day), a digester with a digestion tank working volume of about 30 m^3 would be required. The specific design of such a biogas digester would need to consider site-specific factors; however, from experiences gained in the Peruvian Andes at elevations of 2800–3900 m, digesters up to 7.5 m^3 working volume with greenhouse type covers and hydraulic residence times between 60 and 90 days have been shown to be operationally stable [55], such a design scenario appears feasible in the context of rural cheese manufacturing in Rasuwa, Nepal. Therefore, even without the energy savings possible from heat regeneration within the pasteurization process, four parallel 7.5 m^3 digesters, each receiving a daily feedstock of 50 kg of fresh dung (assumed to be 6.5 kg of volatile solids content), would be able to meet the heat energy requirement for milk processing, cleaning and sanitizing in the *sagha*.

8. Poverty and migration

There is one further overriding factor in considering the prospects for low-carbon energy systems for development projects in rural Nepal, namely the outflow of labour. In some districts, this was already a known process with

Gurkha recruitment, but in Rasuwa District there had been little outmigration apart from seasonal work, and some cases of people going to India. It was a combination of the years of insurgency (1996–2006) and the bleak domestic economy as 'push' and the opening of labour markets in Malaysia and the Gulf as 'pull' that led to approximately two-thirds of the male labour force going abroad [56,57]. This leaves the women and the old to keep households going, and the withdrawal of this much labour from the subsistence economy has contributed to people rationalizing their cropping and livestock systems. Keeping a high-altitude herd away from the village house of course relies on others to stay home, or on making flexible domestic resource arrangements with kin and neighbours. Several conversations with herders revealed they were agonizing over how they could keep going with sons and even daughters abroad, and the livestock market being such that as one herding woman told us 'you don't know whether to buy, or to sell'. It did seem in 2011, however, that if some herding households might have to give up owing to labour out-migration, there are others positioned to fill the gap. Indeed, from field enquiries made in April 2012, there are numbers of people in the area wanting to set up small-scale cheese-making units who have been denied licences to operate from the national park because of the perceived impact on the forest of fuelwood use.

After the introduction of the national park regime's regulatory approach to behaviour change, out-migration has caused the next big shift in the socio-technical regime for villagers in Rasuwa. Remittances come in irregular and unreliable times, and so the daily search for fuelwood for cooking and heating goes on, even if there is now electric supply to many roadside villages for lighting. How far up the mountain will the biogas systems travel that have proved successful in the lowlands and mid-hills? Will methanogens be found (with appropriate permissions from the national park) in the sludge of high-altitude lakes that will improve biogas performance across the barrier of sub-tropical and temperate zones? The research pathways point to technical trials and multiple rounds of stakeholder consultation for a transition to biogas acceptable to the national park, the cheese factory and the herders. Our focus is with the cheese factory, but it will be expected that if demonstrated effective and affordable there will be diffusion of the technology at household scales.

Success with this niche innovation could transform the future of high-altitude livelihoods and especially the green credentials of 'eco-tourism' in the area. It is, however, open to question whether this intervention will necessarily benefit the poor. The case of the cheese factory and its suppliers will have to be looked at in terms of the processes of socio-economic differentiation of its connected actors. There are some wealthy owners who play dominant roles and a further number of minor levels down the chain, supplying the core milking herds. They in turn have herd helpers (*gothalo*) drawn in sometimes through indebtedness from outlying villages to look after livestock for long periods, without much by way of remuneration, personal comfort or variety in material consumption on a daily basis. Future socio-economic research will have to monitor these dynamics, and especially look at who is given the task of carrying basket loads of fresh dung for the anaerobic digesters.

Byrne *et al.* [39] challenge the simple assumption that a technological introduction can directly meet the needs of impoverished and socially marginalized communities. In the process of disaggregating contexts beyond the scope of existing policy debates and instruments, they argue 'the broader question of what exactly a construction of technology transfer and development as pro-poor actually looks like also needs to be unpacked' [39, p. 59].

The broader context of poverty of the state and economy in Nepal is such that capacities for indigenous innovation are extremely limited, and it is low budget pathways of applying knowledge and effort at small scales that perhaps stand most chance of diffusion. The authors were repeatedly told there is no money to invest in organized programmes of research to change practices of energy use. The challenge of reorganizing technical habits of generations' standing and shifting the valuation of fresh dung and invasive weeds as digester input could be more influential factors in the appeal of the proposed system than the simple technological factors.[4] Sovacoll *et al*. [59] quote an experienced technician of renewable energy:

> Institutions like the World Bank or USAID think that if you have a good idea or new energy technology, you are 90 percent there, and implementation takes the remaining 10 percent. Experience here suggests it is really the opposite: 10 percent the idea, and 90 percent the training, the consumer awareness, and the promotion. Getting the technology right is completely secondary to effective promotion in gaining social acceptance. [59, p. 1539].

9. Conclusion

At this preliminary stage of the project, the technical performance and GHG emission criteria of different anaerobic digester systems at altitude are in need of trialling. Subsequently, multiple consultations and negotiation will be required for coordinating viable dairy-herding practices by indigenous communities with the requirements of biogas for cheese-making in the Langtang National Park. The major challenge is less likely to be technical, and more about reconfiguring sets of practices and institutional belief systems. To bring both sides of the issue to settle on a new energy regime for the yak cheese operation will require them (the national park officials on one side and the cheese factory and herders on the other) to accept new ways of working for active management of people–biodiversity interactions. A positive circular metabolism of biomass for methane to replace fuelwood is in principle achievable, but the ability to achieve this in a local niche when the two most powerful institutional actors are responding to different directives from the capital presents complications. Global agendas and narratives impinge on the possibilities for sensible accommodation in particular places.

This research has attempted to review the case at hand in the light of some dominant frameworks for analysing sustainable energy transitions. In contrast to a neat hierarchy of niche, regime and landscape in the multi-level perspective of socio-technical systems transition [24], our case offers some indicators of radical niche autonomy within which multiple regimes are vying for authority. Niche-based actors are weighing up subsistence livelihood alternatives within the conflict-ridden power struggles of the state of Nepal, as against opportunities for external migration. Even within the national park, there is not a homogeneous position on prospects for active management of the forest, as the buffer zone agenda for working with local communities' development needs competes with the park's prioritization of wildlife.

Working within the socio-technical transitions framework, Smith & Sterling address [27] the problems of how grand ideas such as sustainability come to take shape on the ground:

> governing transitions is more complex than simply negotiating closure around a particular vision of sustainability. The driving aims, orientations, and modalities of sustainability itself, not just the managerial instrumentalities, are much more plural in practice and are continually open to radical reformulation. Questions over the political conditions for the kinds of consensus and coordination implied by transition management, and how these conditions are to be achieved, have yet to be addressed fully. [18, p. 11]

For their part, Adams & Jeanrenaud [9] engage with the concept of 'conservation in transition'—how biodiversity protection can reposition its goals and horizons to be more socially inclusive and committed to wider dimensions of sustainability. A new regime of systemic low-carbon socio-technical practices and norms would mean that 'conservation must be integrated with concerns about wider ecosystem health and human wellbeing' [9, p. 53].

The room for manoeuvre for development and conservation arms of the state embroils questions of energy transition into ongoing discussions of national governance. Nepal's new constitution may have significant federal dimensions that could bring decision-making closer to those most affected and desirous of transition. The links between energy transitions and climate change adaptation could become more amenable to innovatory practices and deliberative spaces for local communities if decisions could be made in effective niches of transition in the geographies of familiarity that neighbouring districts constitute, rather than referring to office headquarters in the capital (Kathmandu). Empowering communities for development needs to address environmental justice and social change to enable citizenships of active and informed clean energy users, and use participatory methods for engaging with local knowledge of climate change effects to best design and distribute knowledge of innovations for resilient, low-carbon livelihoods.

The unstable recent history of Nepal has positive elements that include a more critical stance towards conventional and complacent norms, and authoritative knowledge [4]. The context of the indigenous movement in Nepal provides an opportune historical niche testing ground for deliberating energy options at altitude: to work with the best and most adaptable elements of 'incumbent' socio-ecological regimes, and identify the points of friction and recalcitrance to low-carbon transition within existing socio-technical regimes [22]. What has emerged from this scoping visit to Nepal is a picture of overlapping scales that blur divisions of socio-technical niche, regime and landscape and bring into view the effects of climate change concerns on protected areas alongside, and butting up against other global agendas such as employment abroad and more indigenous livelihood rights at home. The practical sense challenge of finding common ground between these agendas is a huge but incrementally feasible goal of transition.

This research was made possible by a small grant from the Durham Energy Institute.

Endnotes

[1]An aspect Yadoo does not discuss is the fact that the off-grid electricity system was implemented in Kavre District in the midst of a countrywide insurgency. This was a time when almost all development projects were halted. It was only projects deemed to be serving 'pro-poor' livelihood justice that avoided becoming targets of the Maoist rebels.

[2]McVeigh's [33] study of the Langtang pastoral economy underestimated the extent of its role in supplying male yaks for breeding purposes in village areas to the south. She mentions Boka Jhunda in Dhunche VDC, but Langtang yaks are used for breeding purposes with cattle as far as Ramche VDC and Tangdor in Yersa VDC.

[3]Dung is not currently used apart from at permanent houses and lodges where potato gardens are kept. Baskets in excess of 40 kg are regularly carried by Tamang people. At the tourist lodges human manure could be a significant additional input. During the pilgrimage season of July and August thousands of Nepalis come through the area on foot to Lake Gosainkund.

[4]Common weeds that thrive to the exclusion of more palatable species in the over-fertilized pasture areas include *Sambucus adnata* and *Rumex nepalensis* [58]. At lower altitudes the invidious *Eupatorium adenophorum* dominates on landslides and rough ground.

There is no control of these weeds by active biodiversity management, and the local controlled fire practices were banned by the national park regime in the 1970s, which leads to worse fires when they do break out accidentally.

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