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# Tourism, Social Management of Water and Climate Change in an Area of High Altitude: the Everest Massif in Nepal

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## Introduction

- <sup>1</sup> The effects of climate change on mountain environments have been of interest to researchers since the beginning of the 1990s (Beniston *et al.*, 1997; Becker and Bugmann, 2001). Their interest later extended to tourism in the early 2000s (Perry, 2000; Elsasser et Bürki, 2002; Dubois et Ceron, 2006) and, more specifically, to the issue of water. An essential component of mountain landscapes' attractiveness to tourists (glaciers, snow, springs, streams, waterfalls), water is key to a number of practices (hydrotherapy, skiing, white water sports) liable to be affected by climate change (Abegg *et al.*, 1997). The pressure exerted by tourism on water, in competition with domestic and agricultural use, can be problematic where there is increasing scarcity of the resource due to climate change (Gössling *et al.*, 2012). Until now, research has mainly focused on the effects of climate change on the variability and reduction in snowfall at winter sports resorts in the temperate zone (König and Abegg, 1997; Elsasser and Bürki, 2002; Loubier, 2007; Richard *et al.*, 2010; Gonseth, 2013). However, in mountainous areas of poor countries in the tropical zone, which lack ski resorts and where tourism is practised in an itinerant and diffuse manner, the issue of the availability of water for the needs of tourism is hardly addressed, despite being just as crucial. This is the case in the region of Solukhumbu in Nepal, where the presence of Everest has fostered the development of trekking, a form of itinerant walking tourism practised in remote natural areas (Sacareau, 1997). Located in the eastern part of the Nepalese Himalayas, the Everest massif has high rainfall during the summer monsoon, at around 3,000 mm per year in the mid-hills of upper Solu, to less than 900 mm in the

highland mountains of Khumbu (Smadja *et al.*, 2015). Meltwater from snow and glaciers, combined with monsoon rains, flows into the rivers, whose discharge varies significantly between the winter low-water and summer high-water periods. Stream water is collected by the villagers for domestic and agricultural use. However, the growth of tourism has generated a significant need for water and energy, particularly hydroelectricity. New uses of water are emerging, begging the question of the availability of a resource that is essential to the current functioning of tourism, but which could be impacted by climate change over the long term.

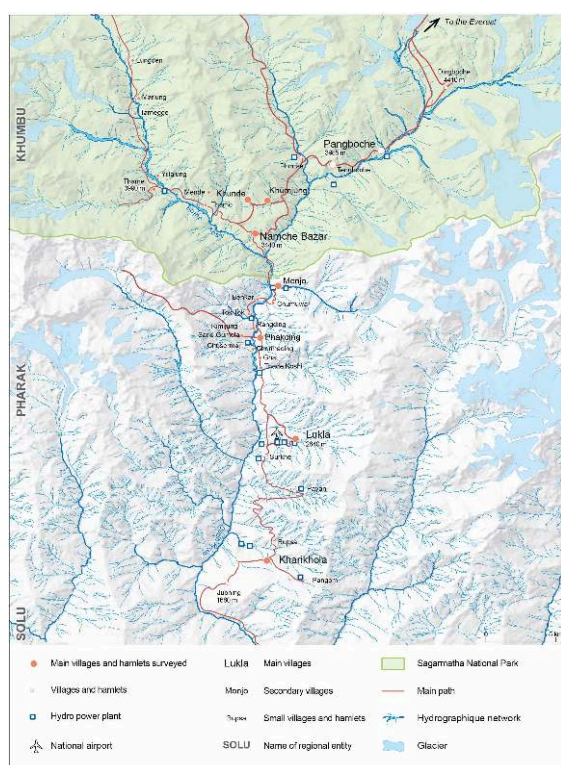
- 2 While this part of the Himalayas has become an open-air laboratory for glacial melt research (Bajracharya and Mool, 2009; Shrestha and Aryal, 2011; Garrard *et al.*, 2016), the relationship between water, tourism and climate change remains a little studied area. The impact of tourism on the environment of Khumbu, particularly the forest, has been the main focus (Byers, 1987; Byers, 1997; Byers, 2005; M.N. Sherpa, 2013). Over the past ten years, however, multidisciplinary French and Nepalese teams have been conducting joint research on this relationship (Wagnon *et al.*, 2008; Aubriot *et al.* 2012; Faulon, 2015; Puschiasis, 2015; Savéan *et al.*, 2015; Smadja *et al.*, 2015; Jacquemet, 2018). Despite eight years of basic research in hydrology and glaciology, much uncertainty remains as to the proven effects of climate change (Savéan, 2014; Eeckman, 2017; Mimeau, 2018). However, surveyed populations report milder winters, less frequent and heavy snowfalls, covering the ground for shorter periods of time, earlier thawing of streams, and unusual precipitation in September and October, when the tourist season begins (Smadja *et al.*, 2015).
- 3 Following on from this work, this article will examine the availability of water for the needs of tourism, on the hypothesis that the supply difficulties observed in the field currently result, not so much from the effects of climate change than from the social management of water. This concept, initially developed by agronomists for the study of irrigated crops (Sabatier and Ruf, 1995), integrates distribution by local companies into the technical methods of using and managing water resources. It proves to be broadly transposable to the water uses that we have been able to identify. This social management of water has been approached through observations and interviews on the “practical distribution of water”, namely, socio-technical systems (Akrich, 1989) in the form of pipes, pumps, cisterns and turbines deployed to collect and use stream water. They encompass modes of collective organization and choices that prove to be good indicators of the socio-spatial inequalities observed in the field concerning access to this resource and its distribution by local stakeholders. We will therefore show that water has become an essential resource to the tourist economy (water and energy supply for tourist accommodation, market gardening for the tourist market). We will then attempt to evaluate the pressure exerted by tourism in the context of ongoing uncertainty about the effects of climate change in the region. Finally, by processing our field surveys, we will be able to identify the nature of the disparities in the populations' access to water, in comparison with an analysis of the water and electricity supply networks' modes of organization and management.

## Fieldwork and methodology

- 4 Our analyses are the result of a five-year multidisciplinary research programme in upper Solukhumbu, involving researchers in social sciences, hydrology and glaciology<sup>1</sup>.

The study site is located between 2,900 and 3,800 metres altitude upstream of the basin of the river Dudh Koshi, which derives its source in the north in the Everest massif. From north to south, it comprises three subsets, Khumbu, Pharak and upper Solu, all within the perimeter of the Sagarmatha National Park and its buffer zone (Figure 1). Its 7,000 inhabitants belong to the Sherpa ethnic group, dominant in Khumbu, with other ethnic groups (Rai, Magar, Tamang and Bahun-Chhetri), more present in Pharak and upper Solu. In addition, there are more than 43,000 tourists accompanied by their guides and porters, distributed across two main tourist seasons: autumn (from October to early December) and spring (from March to early May).

Figure 1: Map of location of surveyed villages



Authors: Olivier Pissot, Véronique André-Lamat, Marie Faulon.  
Produced using: QGIS, Adobe Illustrator.

- 5 The results derive from a systematic field survey, conducted on the basis of a random sample of 366 housing units (including 144 guest houses), and on the work of doctoral and master students supervised under the programme. The surveyed villages were selected based on their tourist numbers. The most popular tourist villages located on the trekking path leading to the Everest base camp (Lukla, Phakding and Monjo in Pharak, Namche, Khunde and Thame in Khumbu) were all surveyed, as well as Kharikhola, a mid-mountain village with fewer tourists in upper Solu, which still relies heavily on agriculture. More isolated surveys were also conducted in hamlets located on high-altitude slopes away from the main road. The questionnaires and interviews conducted among the inhabitants (farmers, landlords, tenants and managers of guest houses and tea shops<sup>2</sup> and shopkeepers) addressed methods of accessing water during and outside the tourist season, electricity consumption, housing amenities and problems identified by users with regard to the availability of water and electricity.

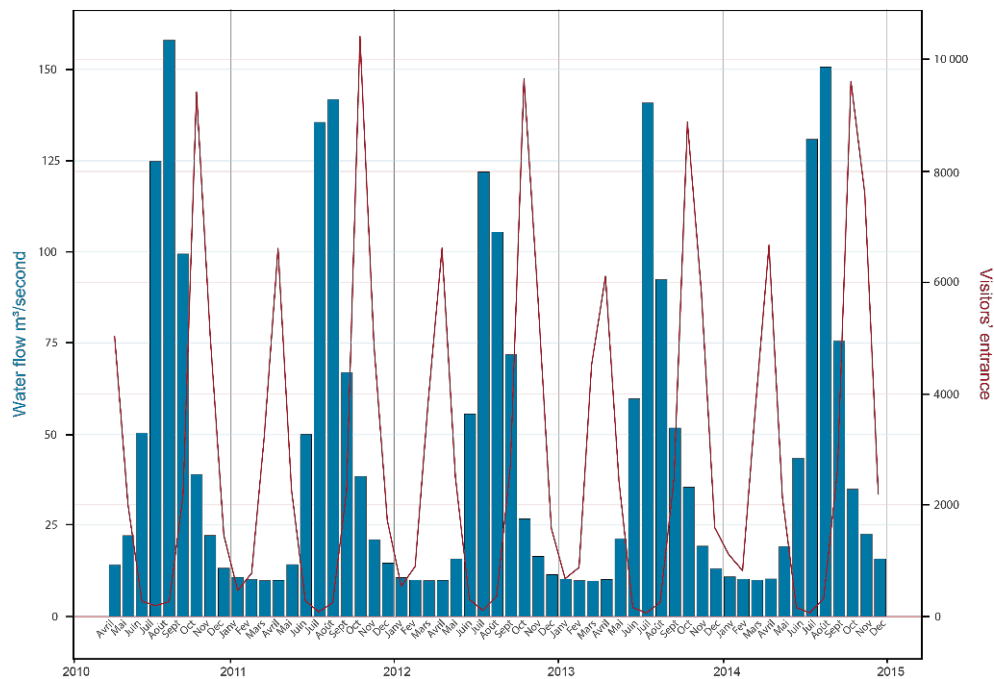
These surveys were supplemented by interviews with water management committees and operators of micro hydro power plants and by conducting transects of the rivers where water-related infrastructure is located.

## Water's role in tourism in Khumbu

### A high-altitude area organized around trekking

- 6 Possessing the highest peaks on the planet, the Everest massif is the world's trekking Mecca, a pursuit that has brought into being numerous guest houses along the path leading from Lukla (2860 m) to the Everest base camp (5364 m). Phakding and the neighbouring villages in Pharak are obligatory stopovers at the start and end of the trek before entering the Sagarmatha National Park and arriving at Namche Bazar, the tourist capital of the land of the Sherpa at 3440 m. The villages of Khumjung and Khunde serve as acclimatization stopovers for trekkers, before their ascent to the Everest base camp and Kala Pattar viewpoint (fig. 1). The tourist season is determined by rainfall patterns. In summer, monsoon rains make paths impassable and clouds obstruct the view of the mountains, while in winter, snowfall can block the trekkers' progress at higher altitudes. Consequently, the trekking season is mainly in autumn and spring (fig. 2).

Figure 2: Diagram of the discharge of the Dudh Koshi at the Phakding meteorological station in relation to tourist attendance of Sagarmatha National Park



Source: ANR Paprika and ANR PRESHINE.

Author: Marie Faulon.

Produced using R and Adobe Illustrator.



## Changing practices creating new water and electricity needs

- 7 The development of trekking and the changing needs of inhabitants and visitors alike have led to an increased need for water among a small population that previously limited it to domestic and agricultural uses (Müller, 2016 ; Aubriot et al. 2019). Tourist pressure on the resource remained moderate when trekkers and their porters camped and simply took water from the streams to drink, wash and prepare food brought with them from Kathmandu (Sacareau, 1997). However, since the 1980s, it has become customary to stay in guest houses, and water is now a commodity (André-Lamat, 2017): from a cup of tea (about 0.50€ in Phakding) to a hot shower (between 3 and 6€ in 2015), everything is expensive and the price increases with the altitude. Building a guest house is therefore a profitable investment, which explains their proliferation along the trekking route where most services for tourists are now concentrated (Nepal, 2005). For example, in Sano Gumela, a village located off the trekking route, the houses are smaller and more dispersed than in Phakding, a village stretched along the main route with around 30 guest houses in 2015 (fig. 3).

Figure 3: The village road of Phakding on the left bank of the Dudh Koshi, opposite the scattered village of Sano Gumela on the right bank



Author of the photos: Marie Faulon.  
Produced using R and Adobe Illustrator.

- 8 The running water consumed by tourists comes from the domestic water network supplying the guest houses. It is therefore consumed in addition to the water consumed by inhabitants. However, given the lack of meters, it is difficult to evaluate it precisely and distinguish it from water used by the individuals who reside in the guest houses. However, according to surveys among tourists conducted in 2014-2015, a tourist would reportedly consume around 40 litres per day, compared with 20 litres per day, per

person in a peasant family (Jacquemet, 2016). In addition to domestic consumption, it is also used for watering field vegetables and in greenhouses, whose numbers have increased in Pharak (54 in 2015 covering almost 6000 m<sup>2</sup>) to provide fresh food for the guest houses' restaurants. Their consumption is difficult to estimate, but a full cycle of tomato production over 12 months covering 200 m<sup>2</sup> of greenhouses reportedly amounts to 16,800 litres or, theoretically 46 litres per day. The surveys, however, show that water supply problems only happen on occasion (Abadia, 2016).<sup>3</sup>

- 9 Water also plays an important role in being used to generate electricity. It has enabled guest house owners to equip themselves with household appliances (electric water heaters, kettles, toasters, ovens, refrigerators and even washing machines), taking the establishments upmarket, which has become essential to attract a more demanding clientele. From kerosene for lamps and wood stoves for heating to the widespread use of electric lighting and digital devices (cameras, telephones, tablets and GPS), the guest houses' energy needs have changed and guests must now pay to recharge batteries<sup>4</sup>. Inhabitants also benefit from access to amenities thanks to hydroelectric power (Puschiasis, 2015; Jacquemet, 2018): 86% of the villagers surveyed had a mobile phone, 74% a television and 25% a computer with internet access. Given this new demand for comfort, it has become necessary to invest in equipment using water and electricity (electric sockets and rooms with private bathrooms with hot water) to improve the quality of the guest houses in a very competitive market. However, when the high season coincides with the low-water period and all the guest houses are simultaneously consuming electricity, power outages occur due to surges on the grid. This raises the question of the effects of global warming –which remain unclear– on discharge of streams, upon which the efficiency of the hydroelectric plants they power depends.

### A plentiful water supply likely to be impacted by climate change

- 10 The data currently available is still too partial to accurately assess the effects of climate change on water supply in the Dudh Koshi river basin. Large margins of error remain, which researchers are, however, trying to reduce (Wagnon *et al.*, 2008; Guinot *et al.*, 2015; Savéan *et al.*, 2015; Eeckman *et al.*, 2017; Mimeau, 2018). While scientific attention is focused on the melting of glaciers, a symbol of climate change, (Bajracharya and Mool, 2009; Shrestha and Aryal, 2011; Garrard *et al.*, 2016), it is not certain, apart from the risks of glacier lake outburst flood (GLOF)<sup>5</sup>, whether it will affect, in the short or medium term, the livelihoods of inhabitants, the majority of whom live at much lower altitudes. Nevertheless, the region's tourism-based economy relies directly on the availability of water in the tributaries of the Dudh Koshi, along which the villages are established. Most of them are supplied only by snow and rainfall (fig. 2). As a result, the seasonal variability of rainfall, which affects crops and energy supply, is of more concern to inhabitants than melting glaciers (P. Y. Sherpa, 2014; Puschiasis, 2015; Smadja *et al.*, 2015). Indeed, it is estimated that rain and snowfall account for 72% of the discharge of the Dudh Koshi compared with 29% from glacial melting (Savéan, 2014). Yet stream discharge relies on this precipitation in the high season in autumn and spring (fig. 2). If a decrease in snow cover were to be confirmed, while its melting partly compensates for the low rainfall in late winter and early spring, the already existing seasonal pressures in supply to villages could increase. However, to the best of our knowledge, these pressures cannot be attributed to climate change alone. They may be explained by the unequal efficiency of water and electricity supply systems and the

inequalities within society itself, which are reflected in the way in which water resources are managed.

## When social water management increases the tourism system's vulnerability to climate change

- 11 Compared with other mountainous regions of Nepal, upper Solukhumbu is privileged with regard to its water and electricity services: all but one of the households surveyed have a continuous electricity supply. Likewise, all houses have an indoor or outdoor water point. However, the supply is insufficient for the needs of some inhabitants, as there are both social and spatial disparities in access to water resources.

### Wide socio-spatial disparities in access to water

- 12 In order to evaluate these disparities empirically in the field, we have statistically processed our surveys using regression trees built under R according to a recursive partitioning principle: it aims to create groups of individuals that are as homogeneous as possible with respect to the variable that the tree is trying to predict (Breiman *et al.*, 1984). The group is asked a set of binary (yes/no) questions relating to explanatory variables defined as relevant. The most relevant explanatory variable for dividing the group into two distinct and homogeneous subgroups is selected, and the process is repeated until the tree reaches its optimal size, namely, when the divisions no longer produce sufficiently homogeneous and distinct groups. The homogeneity of the subgroups is determined by an adjustment to a constant which is, in this case, the mean (written as  $m$ ). The first tree seeks to determine inequalities in levels of household electrical equipment (mobile phones, televisions, radios, toasters, ovens, water heaters, etc.) and the second their level of sanitary equipment (fig. 4). The explanatory variables used here are the location, nature of the housing unit or type of building (lodge, tea-shop or house) which are linked to their economic function (tourism, trade or agriculture), the power plant to which the housing units surveyed are connected, the number of beds available in the guest houses, the ethnic group of the occupants, whether or not the dwelling is owned.



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Produced using Baobard sous R (App UMR Passages) and Adobe Illustrator.

- Journal of Alpine Research | Revue de géographie alpine, 108-1 | 2020

are, firstly, the type of building and, secondly, the location of the village. Only two levels of partitioning are required to form homogeneous groups, suggesting that the starting group is more homogeneous than that of the previous tree. Almost half of the group, or 175 individuals, only have one sanitary facility or none at all, while almost a third of the individuals (111) have almost all of them. Most of the villages in Pharak are distributed between the two intermediate groups and the two groups' close-range averages ( $m = 2.09$  and  $m = 2.62$ ) illustrate little inequality, either between villages or between guest houses and houses. The villages of Khumbu and upper Solu are more evenly divided between the two groups at the extremes: the greater inequalities within the villages are, in this case, linked to the ownership of a guest house.

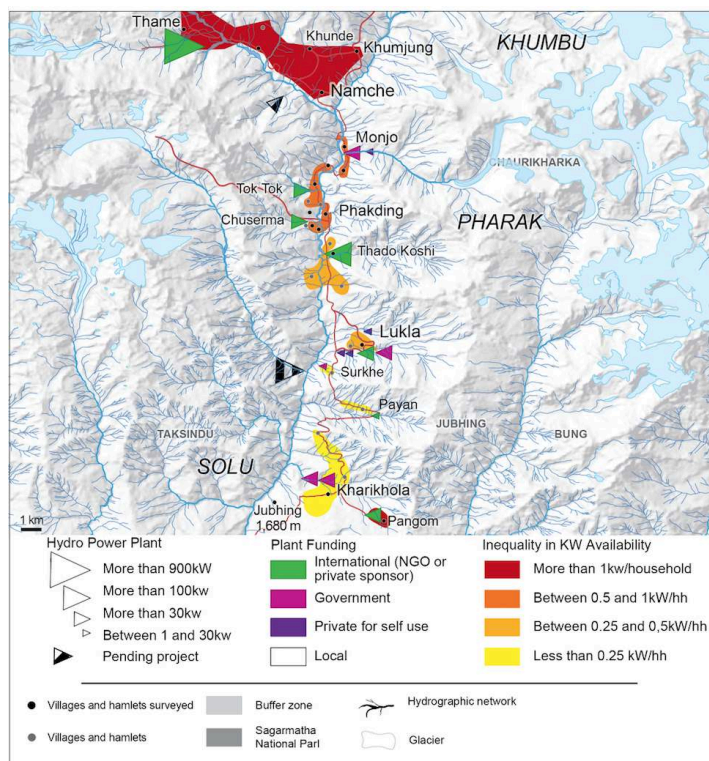
- 15 This analysis shows that the two most significant variables are the geographic location of villages and the economic function of the housing unit. They suggest the existence of spatial disparities in the valley with a strong contrast between top and bottom, and of socio-economic inequalities within the same village, the guest houses being generally better equipped than the farmers' houses. In order to explain them, it is now necessary to look at how the villages are connected to running water and electricity, and how this resource is managed by social stakeholders.

### **Fragmented electricity and water supply systems of unequal efficiency**

- 16 Given the lack of development by the State, villagers in upper Solukhumbu have had to organize individually or collectively, with the help of various donors in order to build their own water and electricity infrastructure. A distinction has to be made here between the electricity and water supply networks since they operate on the basis of differing financing and development principles. However, they are both extremely fragmented.
- 17 The energy supply is reliant on micro hydro, a technology that is relatively manageable for villagers if they secure the necessary financing and technical assistance. The plants are located on small tributaries of the main rivers (Duh Koshi and Bothe Koshi), which are undeveloped due to their entrenchment, turbidity and large variations in discharge. There are significant spatial discontinuities in the power grid (fig. 5). Seventeen plants, ten of which are less than 15 years old, produce between 1 kW and approximately 960 kW for 17 drainage basins of varying sizes. Thame is the oldest and most efficient one, managed by the Khumbu Bijuli Company. Built with the help of Austria and the NGO, EcoHimal, it serves all the houses in the most popular tourist villages in Khumbu (Namche, Khumjung and Kunde), but not the northernmost hamlets of Bothe Koshi. The electricity supply is also very uneven from one house to the next, as the owners of the largest guest houses, which are the best equipped with electrical appliances, monopolize most of the energy supply (Jacquemet, 2018). In Pharak, the situation is more varied. Some of the larger guest house owners have built their own private micro power plants such as Summit Home in Monjo. The others have benefited from international funding (NGOs or former tourists) or government funds. Rivers with the highest discharge are not necessarily the best equipped. Monjo, for example, has a river with greater discharge than those in Pharak, thanks to its vast drainage basin and glacial feed. However, it is not equipped with an efficient power plant. On the contrary, its power plant is among those serving the lowest number of households and has the

lowest power output. Moreover, the power plants supplying certain tourist villages are more powerful, yet their drainage basin is smaller. For example, the Chuserma and Tok Tok power plants, whose installed power capacity is equivalent to that of Kharikhola, have between four and eight times fewer homes to supply than Kharikhola. A great deal more electricity is therefore available to each inhabitant, allowing them to be better equipped. Given the lack of concerted development of hydroelectric power plants throughout the valley (Faulon, 2015), local stakeholders sometimes compete fiercely with each other to attract investors to their villages. This happened between Monjo and Lukla in 2008 (Sherpa, 2013). Having grown wealthy through tourism, the Sherpas have managed to use their global contacts to fund the power plants, thanks to their work in trekking (Jacquemet, 2018) and the support of their diaspora (Puschiasis, 2017). Conversely, the inhabitants of Kharikhola, who work less in tourism, do not have the same access to these networks, resulting in more domestic funding, which is less generous than that of NGOs.

Figure 5: Map of the fragmentation of hydroelectric power areas in Solu Khumbu



Source: ANR PRESINE database.

Authors: Olivier Pissot and Marie Faulon.

Produced using Qgis and Adobe Illustrator.

- 18 The water conveyance systems developed by villagers are far more rudimentary and even more fragmented (André-Lamat, 2017). The water comes either from public fountains or from nearby streams. Generally, it is conveyed into homes through pipes bought and laid freely by individuals. In that case it is every man for himself. In other cases, inhabitants have set up a collective village or neighbourhood network managed by a water committee. The supply problems to which respondents referred are more related to climatic conditions (fluctuations in stream discharge, freezing of pipes) than to consumption by tourists and, above all, poor management (leaky, block or out-of-

place pipes). This leads to a great deal of wastage (permanently running taps, leaks), especially since water is free, apart from the cost of pipes, cisterns or fees paid to water management committees. The inhabitants do not recognize the need to save a water resource that is not currently lacking, except occasionally, when it freezes in winter.

- 19 These technical water conveyance systems illustrate water management systems that are, to various extents, collective. In Sano Gumela (fig. 2), the water supply system is collective; it was partly financed by redistributing National Park entrance fee income to the valley and using inhabitants' personal contributions, especially in the form of working days at the time of its construction. In Phakding (fig. 2), on the contrary, the issue of financing a collective system for the entire village has not been raised. The owners of the large guest houses have installed their own private water supply system, occasionally shared with a few neighbours. On the other hand, on the right bank, where a majority of non-Sherpa tenants are located, a collective water supply system has been organized, as the inhabitants could not afford an individual system. The coexistence of these three systems highlights the divide in this village between the "historic" inhabitants, the Sherpas, who generally own their land and, above all, own the largest guest houses, and the new arrivals who have recently settled and rent small guest houses or businesses and are less well-regarded than the former (Jacquemet, 2018; Sacareau, 2018).

## Conclusion

- 20 In two decades, water has become a key resource for sustaining the local tourism system, in which most inhabitants participate to varying degrees. The pressure exerted on water resources remains moderate, however, as the water taken from streams is currently sufficient for domestic and agricultural needs. The pressure mainly centres on electricity generation due to the mismatch between the tourist season and the streams' hydrological regime, without it being necessary yet to bring the responsibility of climate change into play. Moreover, this pressure should be put into perspective since the technical infrastructure making it possible to utilize water has not been optimized. The lack of planning and territorial governance with respect to the valley has resulted in fragmented technical networks and competition between villages to attract donor and NGO funding, as well as between social groups to own and manage water resources. The heavy interdependence of water and tourism, combined with uncertainty about how stream discharge could be affected by climate change, increase the inhabitants' vulnerability: not only the poorest who still rely on agriculture, but also those who have invested heavily in welcoming tourists and equipping their guest houses with electricity. In the event of a water shortage, in connection with increasing demand in the short term and/or the effects of climate change in the longer term, local stakeholders would have to entirely rethink the tourist area's functioning and management.

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## NOTES

1. ANR-13-SENV-0005-03/ PRESHINE (Pressure on water and soil resources in the Nepalese Himalayas) conducted from 2014 to 2018, follow-up project to ANR 09\_CEP\_0005\_04/ Paprika (Cryosphere responses to anthropogenic pressures in the Hindu Kush Himalayan Region: impact on water resources and socio-economic adaptation in Nepal) conducted from 2010 to 2013.
2. A term used locally by the Nepalese to refer to modest stopping places along the way supplying porters with tea, food and sometimes basic accommodation.
3. The Water Resource Act of 1992 guarantees free water in Nepal, with free access for domestic and agricultural use. A licence is only required when it is used for commercial purposes (bottled mineral water, hydroelectricity) (Faulon, 2015).
4. The mobile network was introduced throughout Khumbu in 2000 and there is now internet coverage along the whole route to the Everest base camp (Jacquemet, 2018).
5. The Dig Tsho GLOF, which occurred in 1985 upstream of the villages of Bothe Koshi, fortunately only affected a few houses, but destroyed roads, bridges, and the region's first hydroelectric power plant.

## ABSTRACTS

This paper deals with the relationship between water, tourism and climate change in the touristy highland region of the Everest in Nepal. Tens of thousands of trekkers visit yearly this valley drained by the Dudh Koshi and its tributaries. We question water availability for tourism needs, assuming that the observed supply difficulties might be caused by the social management of the resource rather than the iffy effects of climate change. We show that the evolution regarding the way people trek brings new needs in water and electricity. It results in a new pressure on water resources since the touristy season and the hydrologic regime are misaligned. However, the pressure must be put into perspective with regard to the way inhabitants organize and plan the infrastructures for collecting and withdrawing water from the rivers. Our analyses show strong inequalities in the access of water at two distinct scales, between villages and within villages, as well as a high territorial fragmentation of water and electricity networks. They bear witness to a complex social management of water and a lack of coordination at the valley scale, which threatens the sustainability of the infrastructures as well as the tourist economy.

## INDEX

**Keywords:** Nepal, Everest, climate change, water, tourism

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