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Journal of Alpine Research | Revue de géographie alpine

103-2 | 2015
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Publisher
Association pour la diffusion de la recherche alpine

Electronic version
URL: http://rga.revues.org/2910
DOI: 10.4000/rga.2910
ISSN: 1760-7426

Electronic reference
Joëlle Smadja, Olivia Aubriot, Ornella Puschiasis, Thierry Duplan, Juliette Grimaldi, Mickaël Hugonnet and Pauline Buchheit, « Climate change and water resources in the Himalayas », *Journal of Alpine Research | Revue de géographie alpine* [Online], 103-2 | 2015, Online since 04 September 2015, connection on 30 September 2016. URL : http://rga.revues.org/2910 ; DOI : 10.4000/rga.2910

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AUTHOR'S NOTE

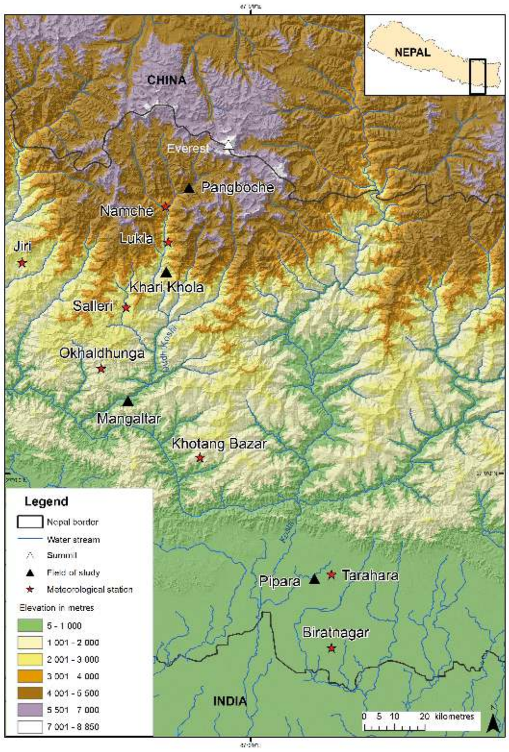
Acknowledgements.
We would particularly like to thank: our colleague Narendra Khanal, Professor at the Department of Geography at Tribhuwan University (Kathmandu, Nepal) who provided help throughout this programme; Harka Bahadur Majhi who accompanied us on most of our field trips, as well as Dawa Nuru Sherpa in the high mountains and Manisha Rai in the low mountains, the three of them playing the role of translator for students; the reviewers who enabled us to improve our text. This paper was finalised after the earthquakes that struck Nepal on 25 April and 12 May 2015 and caused thousands of victims and considerable damage: our special thoughts go to all the Nepalese we have worked with in the field.

Introduction

1 Climate change is expected to have a strong impact on water resources, especially in mountain regions (Buytaert, 2012), and even more so in the Himalayas where the rise in temperature, which is higher than the global average, has a significant effect on the cryosphere (Eriksson *et al.*, 2009; IPCC, 2013). Given this assessment,[1] we started our research via an interdisciplinary programme called Paprika:[2] "CryosPheric responses to Anthropogenic Pressures in the Hindu-Kush-Himalaya regions: impact on water resources and society's adaptation in Nepal", focusing on part of the Koshi basin in eastern Nepal

(Aubriot *et al.*, 2012) (Fig. 1). Our aim was to find out whether populations had noticed any variations in water availability that affected their usual practices and whether they attributed them to climate change.[3]

Figure 1. Location of study sites and meteorological stations selected in the Koshi basin, Nepal



Designed by O. Puschiasis (2015). Sources: data from the Paprika project and ICIMOD. (http://geoportal.icimod.org)

2 Field studies carried out in several places in the Himalayas have provided an affirmative answer to this question.[4] By relaying them and focusing on the most spectacular cases, such as the displacement of villages in Mustang, which led to talk of the "first climate refugees in Nepal"[5], the media and development agencies tend to portray a uniform image of the situation in the Himalayas: a water shortage, today and in the future. This therefore corroborates Crate and Nuttall's assumptions (2009: 9) that "everywhere [...] indigenous and local peoples [...] are already seeing and experiencing the effects of climate change [...] they struggle to apprehend, negotiate, and respond to". As for studies in which measurements and simulations are used, they are less categorical. Authors agree that the climate will vary more in the coming years, but many point out some uncertainties (Hallegatte, 2009: 242; Buytaert, 2012: 385; Bharati *et al.*, 2012: 22) and notable differences between the western and eastern parts of the Himalayan range in the dynamics of glaciers and their contribution to river discharge. In the west of the range and in the high valleys that are sheltered from the monsoon, precipitation that mainly falls in winter recharges glaciers (Bookhagen and Burbank, 2010) whose meltwater in summer is the main source of supply for rivers (ibid.; Rees and Collins, 2006). In the east of the range, glaciers undergo an accumulation due to both monsoon precipitation (Wagnon *et al.*, 2013) and summer melt (Rees and Collins, 2006). Although they have lost mass (Gardelle *et al.*, 2011) and are retreating, they contribute little to annual river

discharge, 75-80 per cent of which is made up of monsoon rainfall (Bookhagen and Burbank, 2010). In the Koshi basin dominated by Everest, the retreat of glaciers, which is emblematic of climate change, should therefore have less significant implications for the population's activities than variations in the rainfall pattern[6] (Wagnon *et al.*, 2008).

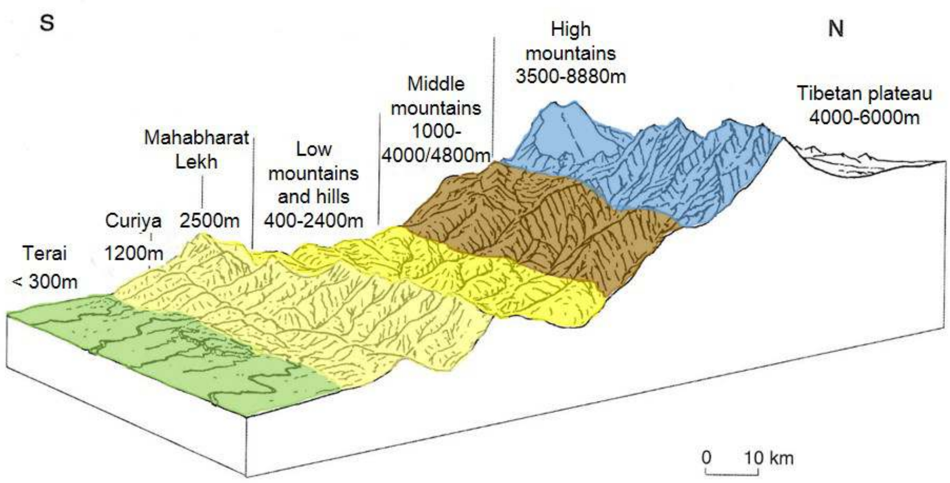
3 In Nepal, a proper assessment of the availability of water for the population, and particularly its link with climatic variations, proves to be a complex task. The Department of Hydrology and Meteorology (DHM) only measures the discharge of main rivers. Yet, due to the high variation in their flow, their dangerousness, and the amount of sediment they carry during the monsoon, they are rarely used by mountain people; they use mountain streams instead. Moreover, in this monsoon region where there are significant climate variations from one year to another and from one region or even one slope to another, meteorological stations, most of which are set up at low altitude, are insufficient in number and not always reliable.[7] Finally, the underground water "reserve" is seldom studied, which several authors have noted (Andermann *et al.*, 2012; Miller *et al.*, 2012).

4 Thus, the need for studies combining observations and enquiries among the population in an attempt to understand local realities, which modelling cannot take into account, no longer has to be proved (Aykut and Dahan, 2011; Jasanoff, 2010). However, the choice of places to study and the way data are acquired and interpreted call for rigour and attention. Other than the disparities between the east and west of the Himalayan range, our position has been to take into consideration the diversity of its milieus from north to south as well as the cultural and socio-economic context of the regions studied. This approach has led us to highlight the geographical units and groups most likely to be affected by climatic variations.[8]

Methodological principles

5 In Nepalese studies, geographical units are commonly classified by distinguishing between the high mountains, the hills and the plains.[9] This division seems inadequate here since the origin and availability of water vary greatly between the high mountains, the middle mountains, the low mountains/hills, and the plains (Smadja, 2009 [2003]) (Fig. 2). Consequently, we selected a village[10] for our case study in each of these four units.

Figure 2. Block diagram from north to south of the Nepalese Himalayas



J. Smadja 2003, adpated from figure in Ramsay, 1986

Studying climate change without speaking about it …

6 Unlike enquiries directly related to how people regard climate change,[11] and following the example of Marino and Schweitzer (2009), we did not broach this question to start with for fear of orienting the discussion towards ideas conveyed by the media, researchers or development organisations, of which there are many in the Everest region. Our enquiries among villagers first focused on water-dependent practices (farming, breeding, the use of water taps, mills, hydroelectric turbines) and on changes in them before finally working round to the subject of the climate and any possible changes in it. What they said must be interpreted in the light of the representations they have of their environment, which are neither neutral nor objective: they are culturally and socially constructed, as recalled by Guneratne (2010), Depeau (2006: 8) and Marry and Arantes (2012: 2).

7 Our method is therefore based on the principle that farmers and breeders are interested in variations in climatic elements that are likely to affect their yields and practices (Vedwan and Rhodes, 2001). However, as a result, not all climatic phenomena were mentioned; the changes referred to were based on what the weather or seasonal conditions should ideally be (Rebetez, 1996; Vedwan and Rhoades, 2001; Harley, 2003; Orlove, 2003; Maddison, 2007); farmers are thought to remember only average trends (West and Vasquez-Leon, 2003) or, on the contrary, extremes (Vedwan and Rhodes, 2001); they retain visual facts in particular (ibid.); their answers differ according to age or gender (Maddison, 2007; Brou and Chaléard, 2007; Aubriot, 2014), the source of knowledge (Sherpa, 2014) or village location (Byg and Salick, 2009). These difficulties prompted us to opt for a qualitative approach based on open or semi-directive enquiries, directly in Nepali or with the help of a translator, among a representative population sample in each village. Socio-economic and agrarian system diagnostics for a period of several decades were carried out over several months of fieldwork. The results obtained, once their limitations are known, can be used to complete quantitative data, without replacing them.

… when the Nepalese speak about climate and its changes

8 Nepalese farmers express the notion of climate using the terms *hāwā pāni* (*hāwā*: air or wind, *pāni*: water or rain) which evoke favourable weather conditions for good harvests, hence for good living conditions: "[...] the different ethnic groups in Nepal feel particularly attached to an environment, their *hāwā pāni* (wind, rain), terms that not only denote the climate, but also what is linked to it: the flora, fauna, type of crop, habitat, etc." (Lecomte-Tilouine, 2009 [2003]: 165). However, they hardly speak of "climate change". Like their Indian counterparts, Nepalese people who are aware of this issue (scientists, village headmen, members of NGOs, journalists, etc.), use the "scholarly" Sanskrit expression *jalavāyu parivartan* (*jala*: water; *vāyu*: air; *parivartan*: change). In both cases, the notion of climate is linked to air and water, "to the wind that brings rains needed for crops at the right time"[12] and, for farmers in the central and eastern Himalayas, mainly to the wet monsoon flow which, if disrupted, jeopardises harvests.

9 As for glaciers and snow, they have taken on a specific value in the Himalayas because they have given their name to the whole mountain range: in Sanskrit, *him* means snow and *alaya*, abode. The Himalayas, the abode of eternal snow (locally associated with glaciers), is also, and above all, the realm of the gods and, for many people, climatic disturbances are a result of the gods' anger. Were glaciers and snow to disappear, were the mountains to turn "black", as many interviewees already regret, the symbolic universe of the Himalayan populations would collapse.

One change among others

10 Lastly, the observations about climate change need to be situated within the framework of a country undergoing major transformations. The last thirty years have seen the spread of new techniques and agricultural practices, of new lifestyles, as well as the development of tourism in high-altitude regions,[13] all of which has contributed to a greater need for water. Hence, the assertion about a water shortage, which can be attributed, for convenience's sake or as a result of the current discourse, to "climate change", must also be analysed in the light of these social, economic and technological changes.

North-South variability at four study sites

11 This part reports the main changes that people mentioned during our interviews, stressing the dominant features and based on what interviewees highlighted.

High mountains

12 In the high mountains (8,850-3,500 m a.s.l.), where glaciers and snow cover the summits, the water used by the population comes partly from their meltwater. More than 200 interviews were carried out in the village of Pangboche (6,000-3,800 m a.s.l., Khumjung VDC [see note 10], Solu-Khumbu district) (Fig. 3) and in some neighbouring villages.[14] At an altitude of 3,850 m, annual precipitation amounts on average to 646 mm and the mean temperature is 5°C (minimum: -0.4°C; maximum: 13.8°C)[15] (Fig. 4). Rain-fed agriculture

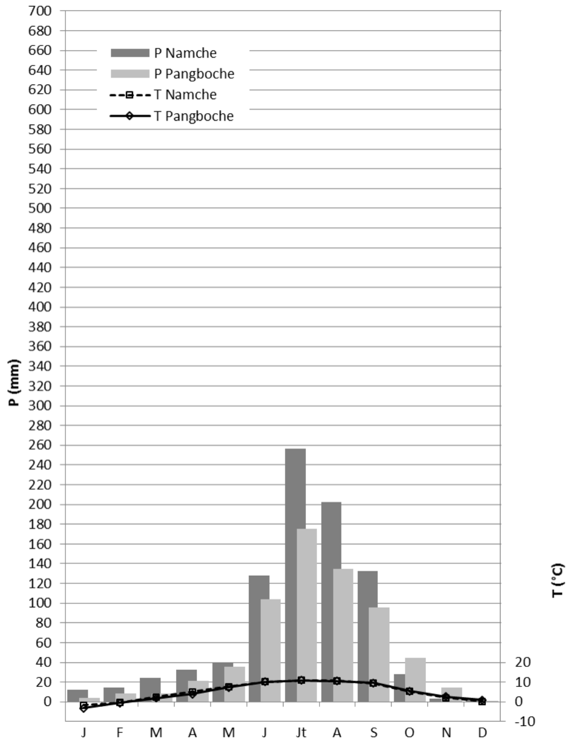
(potatoes, buckwheat) and transhumant cattle breeding (yak and hybrids) serve tourism, which is now the main economic activity.

Figure 3. High mountains. Pangboche hillside, February 2011

Situated at more than 3,800 m in altitude, the village of Pangboche lies just below the Tauche glacier (6,540 m) whose meltwater partly supplies streams and fountains. The village (*yul*), which is divided into several hamlets situated between 3,950 and 4,100 m, lies on a south-east facing slope, on alluvial terraces, where it is protected from the winds. Rain-fed crops consisting of potato and buckwheat are grown in fields bounded by low dry-stone walls. The north-facing side, sheltering the last of the high-altitude forests, is devoted to cropping hay and to storing it in huts (*yersa*). Pangboche is also a village where tourists stop on their way to the base camp of Everest, whose summit can be seen in the background.

(PHOTOGRAPH: O. PUSCHIASIS).

Figure 4. Ombrothermic diagrams. High mountains



- NAMCHE BAZAR (3,570 M A.S.L.), DATA COLLECTED BY EV-K2-CNR FROM 2002 TO 2006 AND IN 2011. CUMULATIVE AVERAGE PRECIPITATION IS 876 MM/YEAR AND THE AVERAGE TEMPERATURE IS 5.1°C.
- PANGBOCHE (3,850 M A.S.L.) DATA COLLECTED IN THE FRAMEWORK OF THE PAPRIKA PROGRAMME IN 2011, 2012 AND 2013. CUMULATIVE AVERAGE PRECIPITATION IS 646 MM/YEAR AND THE AVERAGE TEMPERATURE IS 5.0°C.

13 Villagers mentioned winters being less cold (thus, they used fewer blankets in bed at night[16]) and mountain streams melting earlier. They regretted that the summits had started to become “black” (snowless) since 1995 (a benchmark year because of a devastating avalanche). On the whole, snowfalls are less frequent, less abundant and cover the ground for a shorter length of time, although since 2009 some unprecedented late snowy episodes have occurred in spring, until mid-April. Snow that serves as an insulating blanket and retains soil humidity has not been replaced by rain. Consequently, potato, fodder and buckwheat yields are said to be on the decline, the first two due to a shortage of water, the third because of frost. In addition, over the last decade, villagers have noticed greater variability in monsoon rainfalls and unusual rains at the end of September and in October, impacting the drying of fodder and disrupting the beginning of the tourist season in autumn. A higher level of unpredictability concerning meteorological conditions has been observed by everybody; nevertheless, the inhabitants of Pangboche were not preoccupied by the availability of water in mountain streams: their main concern was the quality of water, which is impacted by tourist activities (pollution linked to waste water).

Middle mountains

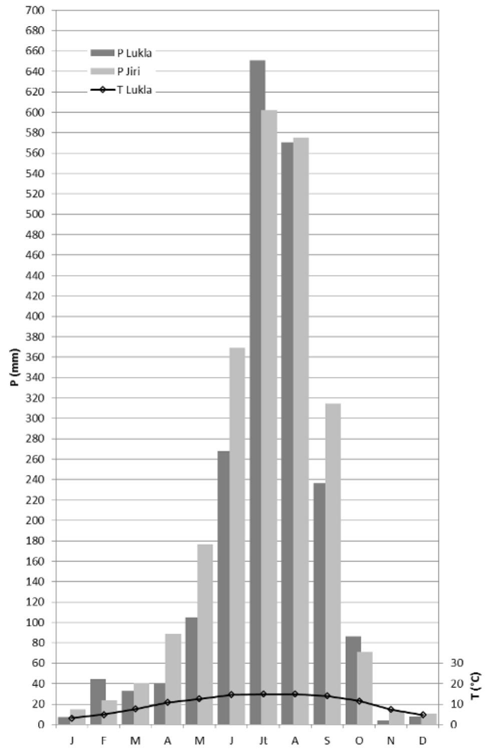
14 The middle mountains (4,500 - 1,500 m a.s.l.) are characterised by long slopes with no glaciers, yet the summits are covered with snow. Apart from snow meltwater, they benefit from rainstorms in spring, and from the abundant monsoon rainfalls during the summer, all of which makes for a good water supply. One hundred and fifteen interviews (15% of households in the VDC) were carried out in the Khari Khola catchment (Jubhing VDC, Solu-Khumbu) (Fig. 5).[17] Mean annual precipitation is estimated to be 3,000 mm at an altitude of 2,500 m, with a mean temperature of 15°C[18] (Fig. 6). Except for irrigated rice at the bottom of the slope, crops are mainly rain-fed (maize, millet, wheat, potatoes, barley) and cultivated on terraces. Above 2,500 m, forests and pastures are used by yak hybrids throughout the year and also by cattle during the monsoon. Here also, part of this production is reserved for tourists but there are fewer than in the high-mountain area.

Figure 5. Middle mountains. Khari Khola catchment, April 2014

Long slopes range from 1,500 to 4,500 m, from subtropical to temperate zones, and then to alpine zones. The slopes are shaped into terraces from 1,600 m to 2,500 m a.s.l. on which there are three cropping cycles over a period of two years: maize associated with potatoes, wheat or barley and then millet. Dwellings are scattered over the mountainside at mid-slope. Above 2,500 m and as far as 4,500 m a.s.l., forest, exploited for firewood, timber, fodder or litter, and altitude pastures (*kharka*) cover the entire area.

(PHOTOGRAPH: J. SMADJA).

Figure 6. Ombrothermic diagrams. Middle mountains



- Jiri (2,003 m a.s.l.), data collected by DHM from 1971 to 2012. Cumulative average precipitation amounts to 2,301 mm/year.
- Lukla (2,660 m a.s.l.), data collected by Ev-K2-CNR in 2005, 2007, 2009 and 2013 for precipitations and in 2003, 2005, 2007, 2009, 2011 and 2013 for temperatures. Cumulative average precipitation is 2,053 mm/year and the mean temperature is 10.1°C.

Precipitation at both stations appears to have been underestimated insofar as the measurements taken over several months in the Khari Khola catchment in 2014 show the total annual precipitation to be nearer to 3,000 mm between altitudes of 2,000 and 3,000 m.

15 Villagers have noticed few changes in their agricultural practices and in climatic conditions over the last twenty years apart from, just as in the high mountains, less frequent and less abundant snowfall that covers the soil for a shorter length of time. Nowadays, snow falls at an altitude of 2,000 m or more, whereas in the 1990s, it still fell at an altitude of 1,800 m. Contrary to the high mountains, villagers have not observed any change in agricultural production; this may be linked to the drop in snow cover because, as they said, snowfall has been replaced by rain. They also reported less frost that damages crops, even though streams and some of their sources freeze over during winter above 2,700 m a.s.l.

16 Over the last decade, there has been unusual rainfall in September-October, but the pattern of spring or monsoon rainfall was said to have remained practically unchanged: the onset of the monsoon and its intensity vary from year to year, but this has always been the case, as the villagers interviewed pointed out. On the other hand, they complained about the unprecedented violent hail storms in 2009, which devastated crops and forests on the right bank of the Khari Khola.

17 Furthermore, although some villagers, well-aware of climate change discourses, attributed the recent introduction of bananas, and orange and lemon trees at 2,000 m

a.s.l. to the increase in temperatures, most of them had not seen any shift in altitude for plant species, or any particular change in their date of flowering.

Low mountains

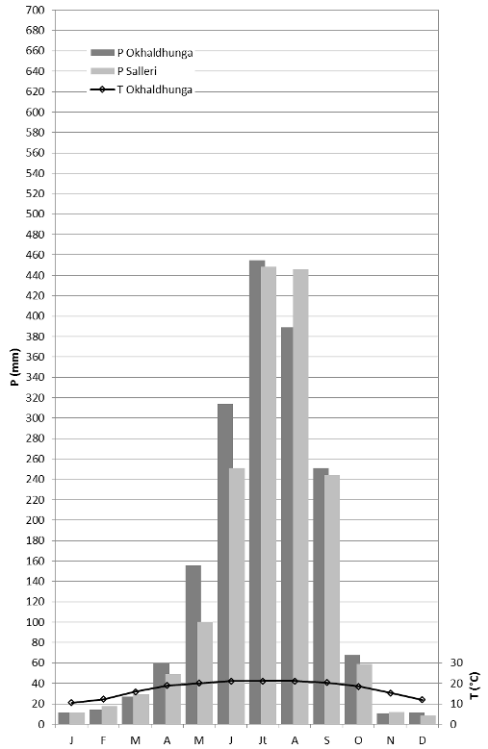
18 The low mountains (2,400-400 m a.s.l.) benefit neither from rain from storms nor from snowmelt in the spring. They usually experience a very marked dry season before the monsoon. Sixty-six interviews (15% of households) were carried-out[19] in Mangaltar VDC (1,200-400 m a.s.l., Khotang district) (Fig. 7). Annual averages are estimated to be less than 1,500 mm for precipitation[20] (which is rare from November to March), and 20°C for temperature[21] (Fig. 8). Rain-fed crops (maize at the beginning of the monsoon, followed by millet) and irrigated crops (rice in summer, sometimes wheat and potatoes in winter) are grown on terraced slopes. Cattle are kept in stalls.

Figure 7. Low mountains. Mangaltar on the left bank of the Dudh Koshi, February 2012

Culminating at between 400 and 1,200 m, the milieus range from subtropical to tropical. Terraced slopes midway up the mountainside are covered in rain-fed crops, maize, millet and lentils, which grow in *bari* fields. On the lower part of the mountainside, terraced plots are irrigated for rice cultivation (*khet*), by diverting water from either temporary or permanent streams, which are tributaries of the Dudh Kushi river, or water resurgences. Steep slopes are used as pastures. The upper part of the mountainside is covered in pine-tree forest. Trees grown along the side of terraced plots are essential to provide fodder for cattle all year round. When the photograph was taken, rare rainfall followed by tilling had helped prepare the land for sowing maize.

(PHOTOGRAPH: J. GRIMALDI)

Figure 8. Ombrothermic diagrams. Low mountains



DATA FROM KHOTANG BAZAR (1,295 M) AT THE SAME ALTITUDE AS MANGALTAR AND IN A SIMILAR NATURAL MILIEU ARE PARTIAL AND OF LITTLE USE (ANNUAL PRECIPITATION IS LESS THAN 1,500 MM OVER A 22-YEAR PERIOD, BETWEEN 1971 AND 1996).
- OKHALDHUNGA METEOROLOGICAL STATION (1,720 M A.S.L.). DATA COLLECTED BY DHM FROM 1986 TO 2012 FOR TEMPERATURES AND FROM 1971 TO 2012 FOR PRECIPITATIONS. CUMULATED AVERAGE PRECIPITATION IS 1,766 MM/YEAR AND AVERAGE TEMPERATURE IS 17.3°C.
- SALLERI METEOROLOGICAL STATION (2,378 M A.S.L.). DATA WERE COLLECTED BY DHM FROM 1975 TO 2012. CUMULATED AVERAGE PRECIPITATION IS 1,677 MM/YEAR.

19 Villagers in this unit did not mention a rise in temperatures, but shorter and more intense cold periods in winter. Associated with more frequent and thicker mist (*hussu*) for the last fifteen years or so, they were said to harm cattle and damage winter crops.

20 Here again, villagers underlined the inter-annual variability in the dates at which the monsoon starts and in its intensity, to which they have always adapted. Nevertheless, over about the last ten years, monsoon rains were said to have started later than usual and to be less intense leading to a more pronounced drought in winter and spring. They associated this with a decrease in the flow from streams and springs, which resulted in greater difficulties regarding the drinking water supply for the household and cattle.

Terai plain

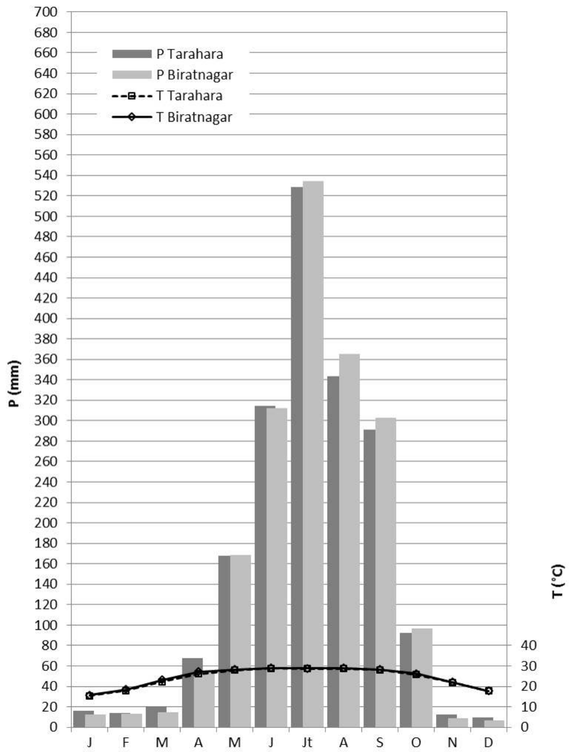
21 In the Terai (200-70 m), two sites were selected in Sunsari District, Balaha (Inaruwa municipality), which benefits from Koshi waters for irrigation, and Pipara (Bhadgaon-Sinuwari VDC) (Fig. 9). One hundred and forty-eight interviews were carried out (representing 11% of the total number of households).[22] The annual averages are 1,880 mm for precipitation and 24.3°C for temperature (max: 30°C, min: 18.6°C)[23] (Fig. 10). The main crops are irrigated rice and winter-cropped wheat; animals are permanently stalled.

Figure 9. Terai plain. Rice fields in Sunsari district, October 2010.

IN A TROPICAL MILIEU BETWEEN 70 AND 200 M IN ALTITUDE, THE PLAIN IS DEVOTED TO INTENSIVE WINTER WHEAT FARMING AND IRRIGATED RICE, PARTLY DUE TO KOSHI WATER. SINCE 1970, MANY MIGRANTS HAVE ARRIVED FROM THE MOUNTAINS, RADICALLY TRANSFORMING THE ECONOMIC AND SOCIAL LIFE OF THE PLAIN.

(PHOTOGRAPH: A. AUBRIOT)

Figure 10. Ombrothermic diagrams. Terai plain



- Tarahara (200 m a.s.l.). Data collected by DHM from 1987 to 2012 for temperatures and from 1971 to 2010 for precipitations. Cumulated average precipitation is 1,877 mm/year and average temperature is 24.1°C.
- Biratnagar (70 m a.s.l.). Data collected by DHM from 1971 to 2012 for temperatures and from 1970 to 2007 for precipitations. Cumulated average precipitation is 1,889 mm/year and average temperature is 24.5°C.

22 In winter, there was said to be fog and a more intense cold in the plain, with the same characteristics and consequences as in the low mountains. Other changes were also reported but they varied too much from one person to another to be regarded as clear tendencies: unusual rainfall in spring; the destruction of crops by hail during this season but, as we were told, the crops are new, not the hail; monsoon rains lasting seven consecutive days before the 1970s whereas now they do not last more than two days; abundant rain falling at just the right time in the past for the crops, though other villagers have hardly noticed any changes, since they regard variability as one of the monsoon's inherent features. Villagers with no access to irrigation water from the Koshi mentioned that the monsoon had been starting later over about the last fifteen years.

23 No mention was made of any change in farming practices in connection with these climatic variations.

Contributions and limitations of the data collected

Figure 11. Main climatic variations mentioned by populations in the four geographical units studied

	HIGH MOUNTAINS	MIDDLE MOUNTAINS	LOW MOUNTAINS	TERAI PLAIN
Winter (December-February)	Higher temperatures Earlier melting of streams Snow stays on ground for a shorter length of time, less frequent and less abundant snowfalls Snow not replaced by rain precipitation	Higher temperatures Less frost Snow stays on ground for a shorter length of time, less frequent and less abundant snowfalls Snow replaced by rain precipitation	Shorter but more intense cold periods Fog more frequent and denser Less frequent rains	More intense cold periods Fog more frequent and denser
Spring (March-May)	Unusual snowfalls up until mid-April	More violent hailstorms	Droughts more and more frequent	
Monsoon (June-September)	Accentuation of monsoon variability over time		Later arrival of rains Less intense rains	Later arrival of rains (for those with no access to irrigation water from the Koshi)
Autumn (October-November)	Unusual rains at end of September and in October	Unusual rains in October-November		

A rise in temperatures felt in the high and middle mountains

24 Villagers noted a significant increase in temperatures in the high and middle mountains, while there was little mention of this phenomenon in the low mountains and in the Terai plain where the key event was rather the new rigour of cold periods. This does not mean that there is no warming in the last two units but simply suggests that certain factors may influence the way changes are perceived: in fact, at altitude, warming has direct visual consequences, since it is manifested by the shrinking of the snow cover.

25 These results echo those obtained by climatologists who have reported an increase in temperatures in the Himalayas (0.04°C per year over the last 25 years, Kulkarni *et al.*, 2013), higher than the global average (0.74°C from 1906 to 2005, IPCC, 2007), and an intensification of warming with altitude (Shrestha *et al.*, 1999; Sharma, 2009; Shrestha and Aryal, 2011; Singh *et al.*, 2011; Kulkarni *et al.*, 2013).

26 However, it is not possible to establish a direct link between these increases in temperatures and new practices insofar as: (i) in the high mountains, the shift in times for potato-planting reported by some farmers could be attributed to the choice of varieties used or to the overlap of agriculture and tourism calendars in spring (March-May) rather than to climate variations; (ii) in the middle mountains, newly planted banana at an altitude of up to 2,000 m is relatively unproductive given the altitude, and many fruits and vegetables have been introduced all over the Himalayas in the last three decades. It remains to be proven whether this introduction is due to global warming.

Less snow

27 At altitude, a reduction in snowfalls (number, quantity and duration) has been noticed by all the local populations, which confirms the findings of most studies on this subject (Vedwan and Rhoades, 2001 for the Kullu; McDowell *et al.*, 2013 for the Khumbu; Chaudhary and Bhawa, 2011 for Ilam and Darjeeling). It is all the more important to take this phenomenon into account because nowhere in the Himalayas[24] are these

precipitations measured correctly and because they are underestimated in the models, which are therefore unable to highlight a trend towards a decrease on an annual basis (Savéan, 2014). Nevertheless, relying on interviews also has its limitations. For example, direct observation of snowy episodes compared a few months later with their recollection by local populations showed that they were only mentioned if snow remained on the ground for at least a day and hindered the people's daily activities.

28 A comparison of the information collected during interviews with measured and modelled data also confirms the way populations minimise snowy episodes (Puschiasis and Savéan, forthcoming). Thus, villagers may well say that it has not snowed, even though satellite images prove the contrary. However, we were also able to observe that snow that had fallen during the night had mostly melted by the time (10 a.m.) the MODIS satellite passed over the Himalayas, and was therefore not recorded. Hence, combining different sources of information (measurements, modelling, observations, and interviews) is the best way of assessing changes in snowfall precipitation. In the field of environmental studies, many researchers (Dekens, 2007; Mercer *et al.*, 2012) emphasise the need to integrate local and scientific knowledge.

29 Our interviews clearly reveal that the altitudinal limit of snowfall has been higher (above 2,000 m) for about twenty years and that snow remains on the ground for a shorter time, probably due to the increase in temperatures.

30 Data collected in the high mountains indicating that snowfall precipitation has not been replaced by rainfall precipitation corroborate observations by McDowell *et al.* (2013) while data showing that it has been replaced by rainy precipitation in the middle mountains are new.

31 Lastly, it seems that the decrease in snow cover in the high mountains causes the ground to freeze more, which is detrimental to crops, while in the middle mountains it seems to be accompanied by less frost, which is beneficial to crops.

32 Although a decrease in snow cover results in a drop in fodder production in the high mountains, it appears that changes in the use of pastures, including in the middle mountains, have little to do with a change in snow cover. Instead, they are guided by economic and social dynamics, such as the reduction in transhumance dairy farming, which is demanding in terms of manpower, that prompt people to turn to the tourism economy (Duplan, 2011).

Greater variability in the rainfall pattern

33 Data collected for rainfall precipitation show a great deal of variety, which makes it difficult to interpret them. This is especially the case for monsoon rains, the dates and quantities of which fluctuate from year to year. As a result, the interviews did not enable us to ascertain a trend, which echoes data from the modellers (Dimri and Dash, 2011; Gautam *et al.,* 2013) and the hydrologists in our project (Savéan, 2014), whose results show the difficulty of identifying variations in measured rainfall over the past 30 years in Nepal, hence any emerging trends in the changes it has undergone.

34 Nevertheless, villagers mentioned unusual rainfall in the high and middle mountains (in September–October and October–November, respectively) over the last ten years. These trends are confirmed by rainfall records only in the middle mountains for the year 2011

(Savéan, 2014). By contrast, a decrease in winter and spring rains was reported in the low mountains.

Unmeasured weather events

35 During the winter, in the low mountains and in the Terai, mists (*thualo*) and fog (*hussu*) along with periods of more intense cold have affected plant growth over about the last fifteen years. These occurrences were also identified in the same geographical units by Manhandar *et al.* (2011). In the middle mountains, the violence of hailstorms during spring is considered to be a new phenomenon, which echoes one of the conclusions drawn by Su *et al.* (2013) for Mustang. These processes have rarely been analysed by climate scientists and are not taken into account in simulations, even though they play a major role in agricultural yields.

Uncertainties about changes in the flow of water from springs and streams

36 It emerged from our surveys that when villagers complained about a water shortage, it was often due to a management problem and/or to a damaged network, to a diversion of water towards a hydropower turbine, or to new water uses (market gardening, tourism, etc.). Moreover, multi-branch water pipes, as well as water-collecting tanks installed in the 1980s, make it impossible to estimate spring discharges: changes in the flow of water are only observed at outlets, which makes it difficult to identify their causes.

37 In the low mountains, explicit mention was made of springs and streams having a lower water flow due to reduced winter precipitation. However, this finding needs to be modified slightly by taking into account the changes in water resurgence management that have been introduced over recent decades (Grimaldi and Hugonnet, 2013).

38 By contrast, in Pangboche, in the high mountains, despite a five-fold increase in water consumption during the tourist season, a severe reduction in snow cover and greater variability in the monsoon rains, villagers did not complain of a lack of water from springs and streams, which are partly fed by meltwater from glaciers and permafrost.

Geographical units and population groups more likely than others to be affected by climatic variations

39 Based on several studies, Chaudhary and Bawa (2011) drew the conclusion that people living at high altitude appear to be more sensitive to climate change than those at low altitude insofar as they mention climatic variations and their effects more often. Our data merely comparing the high mountains with the irrigated Terai plain agree with this assumption — even though, as we have shown, the way these changes are assessed might well be questioned. However, if the four selected units are taken into consideration, then the results are much more complex. In fact, our data show that people in the high mountains and the low mountains appear to be more sensitive to climatic variations, while those from the middle mountains and the Terai plain are less sensitive to these variations.

40 Moreover, of the four units studied, the low mountains appear more likely to be affected by climatic variations. As they intrinsically experience very marked dry seasons outside the monsoon season, they are particularly sensitive to any change in the rainfall pattern (shift over time, volume) on which the flow of water taps and monsoon-rain-fed crops are highly dependent. Our enquiries reveal a heightened pre-monsoon drought that may have severe consequences for agricultural production. It is worth noting that the issue of climate raised in these low mountains is not about glaciers retreating or the decrease in snow cover but about less abundant and more irregular rains. Here, "the right moment" for rain to come, which is partly how villagers define climate, sums up well what is at stake regarding current climatic variations because it is mainly the modification of the "normal" seasonal pattern that proves to be the greatest problem for farmers.

41 In the middle mountains, the villagers interviewed did not complain of a water shortage and have only noticed minor climatic variations, besides inter-annual variability, which has always been high. Agriculture, which is mainly rain-fed, also relies on variations in the rain pattern. However, rain is abundant here and better distributed over the year than in the low mountains; forests on the upper part of the slopes contribute to a good regulation of the hydrologic cycle, and numerous factors enable farmers to limit the risks: the altitudinal zoning of crops, the diversity of production, and pluriactivity linked to tourism in particular (Duplan, 2011). In agreement with the findings of Dixit *et al.* (2009)[25], it appears that, in these middle mountains, population groups that are more likely to be affected by possible climate changes are those with the least diversified income. This is also the case for high-mountain people whose economic activities are based exclusively on tourism: unusual autumn rainfalls that seem to have been a recurrent phenomenon for the last ten years or so have led to the closing of Lukla Airport on several occasions, preventing tourists, equipment and food from arriving in the valley.

42 In the Terai, a pioneering zone with high levels of migration from the mountains, local perceptions and knowledge about climate change and its consequences are highly influenced by the numerous demographic, hence environmental, transformations that the plain has undergone since 1970 (Aubriot, 2014). It is therefore difficult to identify obvious trends, given the excessively strong bias.

Conclusion

43 Research conducted within the framework of the Paprika programme has underlined the great uncertainty that affects quantified data just as much as those collected from the population. Villagers mentioned climatic modifications that may have repercussions on the water resource. Whether similar or different from one geographical unit to another, and with variable consequences, these modifications may create or accentuate difficulties but do not affect people's way of life to the extent that they have to make changes to it: no threshold has been crossed. Is it because in eastern Nepal, which is well-watered by rainfall, there is enough water? Is it due to inertia? Is it because there are economic alternatives? Or else because "unlike what the media like to exaggerate, climate change is a slow process whose most severe consequences gradually appear over time in a far from spectacular manner"[26]? (Dounias, 2010: 246). These questions remain open.

44 Nevertheless, our enquiries highlight the fact that the low mountains of Nepal and certain population groups with only one economic activity are the most likely to be

affected by climatic variations. Pending more accurate data, the questions raised about climate change therefore serve as leverage for addressing issues related to spatial and social justice, sustainable development, and adaptation (cf. Magnan, 2010; Le Bars, 2010; Buytaert, 2012; Hallegatte, 2009), which is probably the best way to prepare for any of the potential changes forecast. Besides, La Branche and Lutoff (2011: 5) regard climate change as a "meta-risk" insofar as it does not produce new risks but heightens certain already existing ones.

45 Lastly, the patently obvious gulf between, on the one hand, journalists' statements and studies or development programmes fuelling a well-established, widespread scenario and, on the other hand, ongoing scientific research, is somewhat reminiscent of the way environmental issues have been addressed since they emerged in the 1970-80s and particularly of the development of the Theory of Himalayan Environment Degradation (THED) about land use, forest resource management, soil erosion, etc. Though widely challenged since then because it was partly unfounded, this theory has strongly influenced environmental policies. In the Himalayas, since the end of the 1990s, the climate change issue has taken over from THED. The discussion Metz (2010) proposes to explain the impact of this theory is valid for the discourse on climate change. As he underlines,[27] development policies and programmes require a narrative that erases any uncertainty, is general, and lacks any effect of scale. Once this narrative has been assimilated and appropriated by development planners, it becomes the "cultural paradigm" and dominates the development institution (Metz, 2010: 25). However, climate change, especially in the mountains, cannot tolerate generalisations that remove uncertainty. The diversity of the milieus, the high variability of climatic features, and the multiplicity of factors of change make it a subject of study that calls for very detailed multi-scale temporal and spatial analyses.

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NOTES

1. Whereas the mistake made by the IPCC (Intergovernmental Panel on Climate Change) in 2007 put the spotlight on the Himalayan glaciers by predicting their disappearance in 2035.
2. ANR PAPRIKA (2010-2013): ANR-09-CEP-005-05/PAPRIKA. It gathered together glaciologists, hydrologists, atmospheric chemists, modellers, agronomists, and geographers.
3. Here we do not address the problem of GLOFs and landslides, which are possibly related to climate change: they are the subject of numerous studies (Bajracharya and Mool, 2009; ICIMOD, 2011; Fort, 2014; etc.).
4. Chaudhary and Bawa, 2011; McDowell, 2013; Su *et al.*, 2013; etc.
5. Shah, 2010; Sharma, 2010; Shahi, 2013; National Trust for Nature Conservation, 2012.
6. An increase in rainfall may in fact lead to increased flows but with greater variability (Miller *et al.*, 2012).
7. However, current models are based on data from national network stations.
8. Here we do not broach the questions of adaptation and vulnerability but make contributions that may provide food for thought.
9. Units used by the Statistics Office, among others, to distinguish districts by ecological zone.

10. We call a "village" a hamlet or a group of hamlets forming a consistent territorial unit with regard to the use of resources. A VDC, Village Development Committee, is an administrative unit that includes several hamlets, or even villages.

11. cf. note 4.

12. Remarks made by a farmer in Solu-Khumbu, recorded in April 2014.

13. There were more than 36,550 visitors to Sagarmatha National Park in 2013 versus only 3,600 in 1979 (Nepal Tourism Statistics, 2013: 63).

14. Interviews carried out between November 2010 and December 2011 by O. Puschiasis, a PhD student in geography.

15. Data collected during the Paprika programme in 2011, 2012 and 2013.

16. Note, however, that the use of new textiles may contribute to feeling the cold less.

17. By T. Duplan (2011) and P. Buchheit (2011), agronomy students (February to June 2011), by O. Aubriot and J. Smadja (5 weeks in October 2010 and April 2013) and by J. Smadja (1 week in April 2014).

18. In Jiri (2,003 m a.s.l.), precipitation amounted to 2,301 mm from 1971 to 2012 (according to DHM), and in Lukla (2,660 m a.s.l.) 2,053 mm was recorded for 2005, 2007, 2009 and 2013, and the mean temperature was 10.1°C (data from EVK2). However, according to measurements taken over several months in 2014 by hydrologists working on the programme in the Khari Khola catchment, precipitation between 2,000 and 3,000 m in altitude would be higher than 3,000 mm/year.

19. By J. Grimaldi and M. Hugonnet (2013), agronomy students, and by M. Rai, a Nepalese Master's student in geography at Tribhuvan University (from February to June 2012).

20. Based on data from Khotang Bazar meteorological station (1,295 m a.s.l.) which is closer to Mangaltar in altitude but which has only partial, precipitation-related data (annual average for the period 1971-1996 is 1,140 mm) and on data from Okhaldunga meteorological station (1,720 m a.s.l., average annual precipitation for the period 1971-2012 is 1,760 mm).

21. We have increased by 3°C (to take into account the 600 m difference in altitude) the temperature recorded at Okhaldunga (1,720 m) for the period 1986-2007 (average: 17.3°C; maximum: 21.6°C, minimum: 12.8°C).

22. By S. Khanal, a Nepalese Master's student in geography from Tribhuvan University, in February 2011, and by O. Aubriot (over 9 weeks between April and October 2010, April 2011 and April 2012).

23. Precipitation and temperature data are the average of those from Tarahara meteorological station (200 m) recorded over a 17-year period (taken between 1971 and 2011) and those from Biratnagar meteorological station (70 m) over a 30-year period (between 1971 and 2007).

24. According to M. Savéan, 2014, the margin of error can range from 20-50% to 110% depending on the authors. Only the extent of the snow cover, not its thickness, is calculated on the basis of satellite images.

25. "It is a fact that people with diverse income sources adapt more easily than those with few sources of income. The diversity of sources is more important than the level of income. For this reason, poor families are not necessarily the most vulnerable to stresses and hazards." Dixit *et al.*, 2009: 29.

26. Translated from French by the authors.

27. Using the words of Roe (1991) and Hoben (1996).

ABSTRACTS

In the Himalayas, where the increase in temperatures is higher than the world average, climate change is expected to impact water resources in a particularly significant manner. Whereas climate specialists using measurements and simulations play down this statement by underlining uncertainties and differences between the west and east of the range, the media and development agencies tend to paint a uniform picture of a water shortage now and in the future. As part of an interdisciplinary programme (glaciology, hydrology, agronomy, geography) in the Koshi basin in Nepal, we discuss these remarks, while stressing the need to distinguish between situations according to the geographical units and to take into account the cultural, social and economic context when addressing this subject. The investigations that we carried out at four fieldwork sites, which are representative of Nepalese milieus, aimed to find out whether populations noticed any variations in water resources that affected their practices (farming, livestock breeding, tourism) and if they attributed them to climate change. Our results show contrasting situations and changes in practices with no obvious connection to the climate. Among other things, they provide information about snow, a parameter that has been measured incorrectly and underestimated in simulations, and they show that populations are more affected by fluctuations in rainfall patterns than by the melting of glaciers and the snow cover. Lastly, they highlight the geographical units and population groups most likely to be affected by climatic variations.

INDEX

Keywords: climate change, Nepal, water resource, local knowledge, agriculture, tourism

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