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Reconfiguration of the Water–Energy–Food Nexus in the Everest Tourist Region of Solukhumbu, Nepal

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A case study in the Solukhumbu region in northern Nepal reveals that the high number of seasonal tourists—which has doubled in 20 years—has led to growing water, food, and energy demands that have modified agropastoral practices and the use of local resources. This has induced new patterns in the movement of goods, people, and animals in the Everest region and the reconfiguration of the water–energy–food nexus. We use this concept of nexus to analyze ongoing interactions and transformations. Key changes involve (1) massive imports of consumer goods; (2) use of local resources with new techniques (hydropower plants, improved mills, greenhouses, and pipes for domestic networks) that depend on imported materials, which are newly accessible to Sherpas as a result of economic benefits generated by tourism; (3) commodification of local resources (water, hydropower, vegetables, fodder, and flour); (4) an increasing number of electrical appliances; and (5) new uses of water, especially for tourist-related services, including hot showers, watering of greenhouses, bottling of water, and production of electricity for cell phones, rice cookers, and other electric appliances. These new uses, on top of traditional ones such as mill operation, compete in some places during spring when water supplies are low and the tourist demand is high. A transfer of pressure from one resource (the forest) to another (water) has also resulted from the government ban on woodcutting, incentives to develop hydropower, and the competition between lodges to upgrade their amenities by offering better services (such as hot showers, plugs to recharge batteries, internet connections, and local vegetables). Our research finds that water is now central to the proper running of the tourist industry and the region's economy but is under seasonal pressure.

Keywords: *Tourism; water–energy–food nexus; flux; hydropower; watermill; Upper Solukhumbu; Everest; Nepal.*

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Introduction

Regions that experience seasonal flows of tourists have to cope with a temporary rise in population and with growing water, food, and energy demands. In the Himalayas, the Theory of Himalayan Environmental Degradation, following a neo-Malthusian approach (Deprest 1996), has argued that the growing population will be a key influence on resource conditions, especially by exerting pressure on wood resources used for building, heating, and cooking food for tourists (Lucas et al 1974; Fürer-Haimendorf 1975; Bjønness 1980; Hillary 1982; Hinrichsen et al 1983; Karan and Mather 1985; Sherpa 1985). This theory influenced the establishment of protected areas in Nepal, including Sagarmatha National Park (SNP), created in 1976, and its buffer zone created in 2002, leading to strict regulation of forest resource use (Sherpa 1988; Brower 1991, 2000; Stevens 1993, 2003; Ripert et al 2009; Sherpa 2013). Over the past 4 decades, research has focused on a variety of other issues that exacerbate resource conditions in addition to population growth. Key among them are a loss of or changes in

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historic livelihoods and local ecological knowledge due to a boom in tourism as well as further integration of local economies and lifestyles into global markets (Spoon and Sherpa 2008; Spoon 2011, 2013); and climate change and its consequences—rising temperatures and melting glaciers (Ericksson et al 2009; IPCC 2013), increasing glacial lake outburst floods (GLOFs) (Bajracharya et al 2007; Bajracharya and Mool 2009; Byers 2007; Khanal et al 2015), and threats to ecosystem services (Palomo 2017).

Few studies have examined tourism-induced transformations of agropastoral systems (Brower 1991; Sherpa and Kayastha 2009) and of water resources, aside from water pollution (Caravello et al 2007; Manfredi et al 2010; Nicholson et al 2016). Only McDowell et al (2013) address the question of vulnerability to climate-related hydrological changes and a tourism-dependent economy and highlight the drop in access to water for household and tourist uses as well as for hydroelectricity production. It is indeed important to chart the impact of tourism on water systems because the number of tourists has doubled in 20 years. More than 45,000 trekkers and mountaineers now travel the Everest trails between October and November and from April to May (Jacquemet 2018). Therefore, in addition to traditional uses of water, such as operating mills, new uses have emerged, including watering greenhouses, supplying showers and toilets, bottling water, and, most importantly, producing hydroelectricity. In this paper, we show how these changes have led to new pressure on water resources and how the strain on forest resources has ultimately been transferred to water.

To address this, we chose to use the water–energy–food (WEF) nexus, which is particularly conducive to studying the interrelationships between these 3 components and their associated synergies (Reinhard et al 2017; Taniguchi et al 2017; Brouwer et al 2018). Used since 2011, the nexus concept (Hoff 2011; Jobbins 2015; Wichelns 2017) helps to draw conclusions about optimizing resource use and to guide public policies on national or supranational scales (Stevens and Gallagher 2015; Brouwer et al 2018). The concept has also been used on a local scale (Best 2014; Jobbins et al 2015; Stevens and Gallagher 2015; Reinhard et al 2017) to analyze people's access to energy, water, and food or to address specific local issues by using a multisectoral and multistakeholder approach. Criticism of the concept has been raised, notably that it lacks a clear definition or conceptual framework and that the choice of elements to be examined and integrated seems arbitrary, with some scholars suggesting the need to also include land, labor, and human capital (Endo et al 2015; Wichelns 2017). We nevertheless used the nexus concept because it prompted us to integrate all synergies and trade-offs between water, energy, and food.

In addition to applying the nexus approach, we integrated a diachronic and spatial approach in order to consider the effects of tourism on the nexus and to take into account imports of goods and the circulation of animals and people, as well as the restructuring of productive spaces due to the reconfiguration of the nexus. Indeed, before tourism flourished, livelihoods in this area relied on local water, energy, and food (supplemented with trans-Himalayan bartering). Aside from rainfall for agriculture, water was used only for domestic purposes, watering cattle, and operating mills to grind cereals. Food production came mainly from subsistence farming and pastoralism, while firewood and dung provided energy for cooking. Now, as we will see, imported food and materials have changed WEF interactions.

The following sections present our results concerning changes in agropastoral activities and the diversification of energy sources—2 issues related to the boom in tourism. The reconfiguration of the nexus is discussed in the last section, to show how changes have brought to the fore concerns about water.

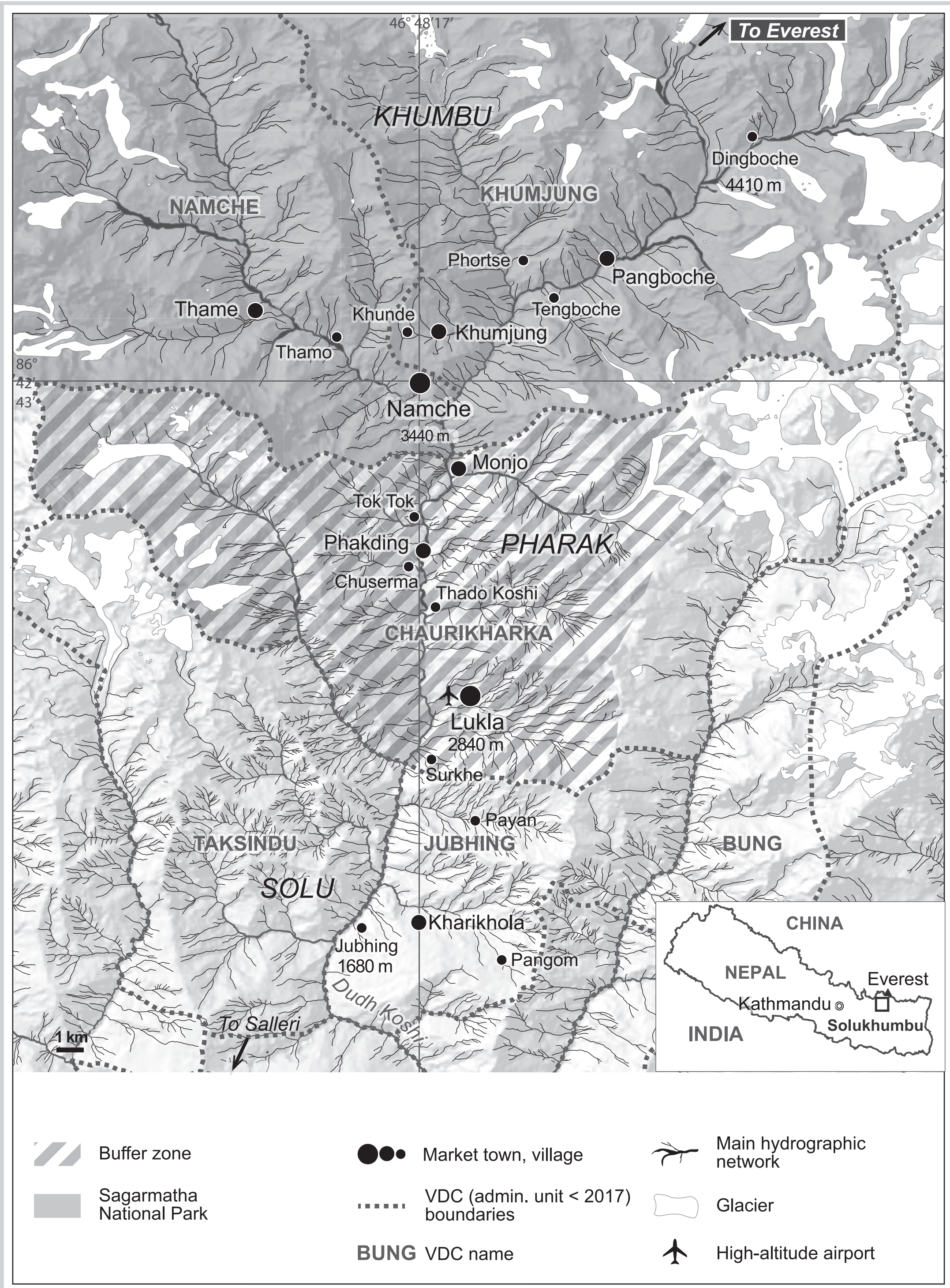
Study area and methodology

The area studied was the upper Solukhumbu, located in the northern part of the Dudh Koshi Valley in eastern Nepal. It includes the following: (1) Khumbu to the north (>3500 masl), which is dominated by Mount Everest and corresponds to the former Village Development Committees (VDCs, prior to administrative restructuring in 2017) of Khumjung and Namche. Located in the SNP, it hosts the highest concentration of tourists visiting the region. (2) Pharak (literally "in between"), where most villages are located at an altitude of 2600 m; it corresponds to Chaurikharka VDC inside the park's buffer zone. Tourists visiting Khumbu pass through Pharak, with most of them arriving in Lukla by plane. And (3) northern Solu, ranging from 1500 to 4500 m, where we studied Jubhing VDC (Figure 1). Although northern Solu is less touristy and has seldom been studied, our field surveys show that it is an important piece in understanding the economy and the dynamics of the whole region.

The study area, which is affected by the monsoon flow, sees an average annual precipitation of about 650 mm in Khumbu and 2050 mm in Pharak (Smadja et al 2015). The population is predominantly Sherpa in Khumbu and mostly Sherpa, Rai, Magar, and Tamang in Pharak and northern Solu.

The questions that guided this research are grounded in fieldwork carried out from 2014 to 2017 as part of a program involving hydrologists, glaciologists, geographers, and agronomists about pressure on water and soil in the region. This article summarizes part of the work done by the program's social science researchers. Its authors (5 researchers, 1 PhD student, and 3 master's students, among whom are 7 geographers and 2 agronomists) were all involved in designing research

FIGURE 1 Fieldwork sites. (Map by L. Lehmann, M. Faulon, and O. Pissoat).



questions as well as in collecting data according to a fourfold method:

1. A closed questionnaire about domestic water and energy uses was supplemented by open-ended questions. Two researchers, 1 PhD student and 1 master's student, posed a series of questions to a sample of 387 housing units (161 houses, 144 lodges, 20 shops, and 56 tea shops). Within these 4 categories, the housing units were randomly selected and their number

defined according to their proportion in each village (Kharikhola, Lukla, Phakding, Namche, Kunde, and Thame). The form included questions for both consumers and service providers about access to water and energy resources during and outside of the main tourist season, about consumption, costs, electrical equipment, sources of investment, degree of satisfaction with the use of the resource, and about interviewees' occupational status (operator, owner, tenant, or lodge manager) and their geographical origin.

2. Semistructured interviews about food production and trade (vegetables, cereals, flour, and fodder) were conducted in the 3 sectors of the study area by 2 other students and 3 researchers. Approximately 120 farmers met in fields or houses were selected among various ethnic groups and age groups for the interviews. This was done to reconstruct the region's agrarian history and to link it to other elements in the agrarian system (public policies, changes in food flows, etc). This method was further supplemented by informal interviews with porters, drivers, and owners of pack animals to obtain data on the frequency of flows and on the nature and geographic origin of the goods transported.
3. A survey about cereal watermills was carried out among about 100 users and all the mill owners of Pharak and northern Solu. The survey focused on technical characteristics, periods of use, distance to the mill, and the origin and cost of ground cereals, as well as their final destination.
4. An exhaustive inventory was made of the region's microhydropower plants, mills, greenhouses, and mule camps. The inventory was integrated into a Geographic Information System to spatialize results, highlight local specificities, and describe the nature and organization of the new flows (especially of goods, animals, and people) that characterize this region (Figure 2).

Data from the surveys on domestic water, mills, and electricity were associated with each geographically referenced housing unit. The dataset provided a common analytical tool and served as a basis for cross-referencing during interdisciplinary meetings of researchers. For example, electricity consumption was linked to the location of power plants, their capacity, and production constraints. Domestic water consumption and greenhouse watering were compared, and the location of power plants and mills were systematically recorded to assess any possible competition between the different water uses. More qualitative data on changes in agricultural production, on the growing number of greenhouses, and on the emergence of new fodder production areas were also analyzed in relation to tourist activity and to lodges' needs.

Consequently, rather than concentrating on purely quantitative data (provided in the students' studies and summarized in the illustrations here), we focused on interlinking the elements of the nexus in order to understand its dynamics. Thus, the bias due to using different data collection methods and teams according to the themes is minimized in the final results. Furthermore, the number of people surveyed (more than 500 for a study area of 2700 households according to the 2011 census) is large enough to provide a good representation of the processes described, especially since the main villages involved in the tourist economy were systematically surveyed.

Impact of the tourist economy on agropastoral activities

Specialization of agricultural areas in Pharak and Khumbu

The activities of most Pharak and Khumbu inhabitants now focus on tourism (serving as guides, porters, lodge managers, etc), leaving them limited time for farming (Sherpa and Bajracharya 2009). The growing trend is to produce more profitable market food (Sherpa 2012; McDowell 2013; Puschiasis 2015; Abadia 2016) and tradeable animal feed (Muller 2016a). Indeed, priority is given to the production of new and more productive varieties of potato in Khumbu (Stevens 1993), to field-grown vegetables (Sherpa 2012; Abadia 2016), and to fodder in Pharak at the expense of buckwheat (Muller 2016a). Greenhouse gardening (Sherpa 2012; Puschiasis 2015) has expanded since the early 2000s with 54 greenhouse owners in Pharak in 2015 compared with 4 in 2005 (Abadia 2016). Domestic networks provide water used to irrigate vegetables. This local vegetable production provides part of the food eaten in tourist lodges—with 12 to 18 t of tomatoes grown in Pharak alone (Abadia 2016)—but this is not sufficient to cover all food needs for tourists.

Most vegetables, other foodstuffs (cereals, oil, and various drinks), and goods needed by trekkers are brought in from Kathmandu or the plains. Supplies are airlifted or carried by porters or pack animals (mules, *zopkios*, a male hybrid of yak and cow, and yaks depending on the altitude) (see Figure 2). About 1200 mules go back and forth between Salleri and Namche 9 months of the year. These convoys emerged in the early 2000s with the construction of a road that connected the plain to Salleri, allowing for products to be transported cheaply without traveling through Kathmandu. Yaks and *zopkios* transport mostly luggage for tourists and expeditions.

The intense movement of pack animals has impacted fodder requirements, particularly near camps where mules stop and feed for the night. This shift led to the conversion of some cultivated land into hay fields and to a

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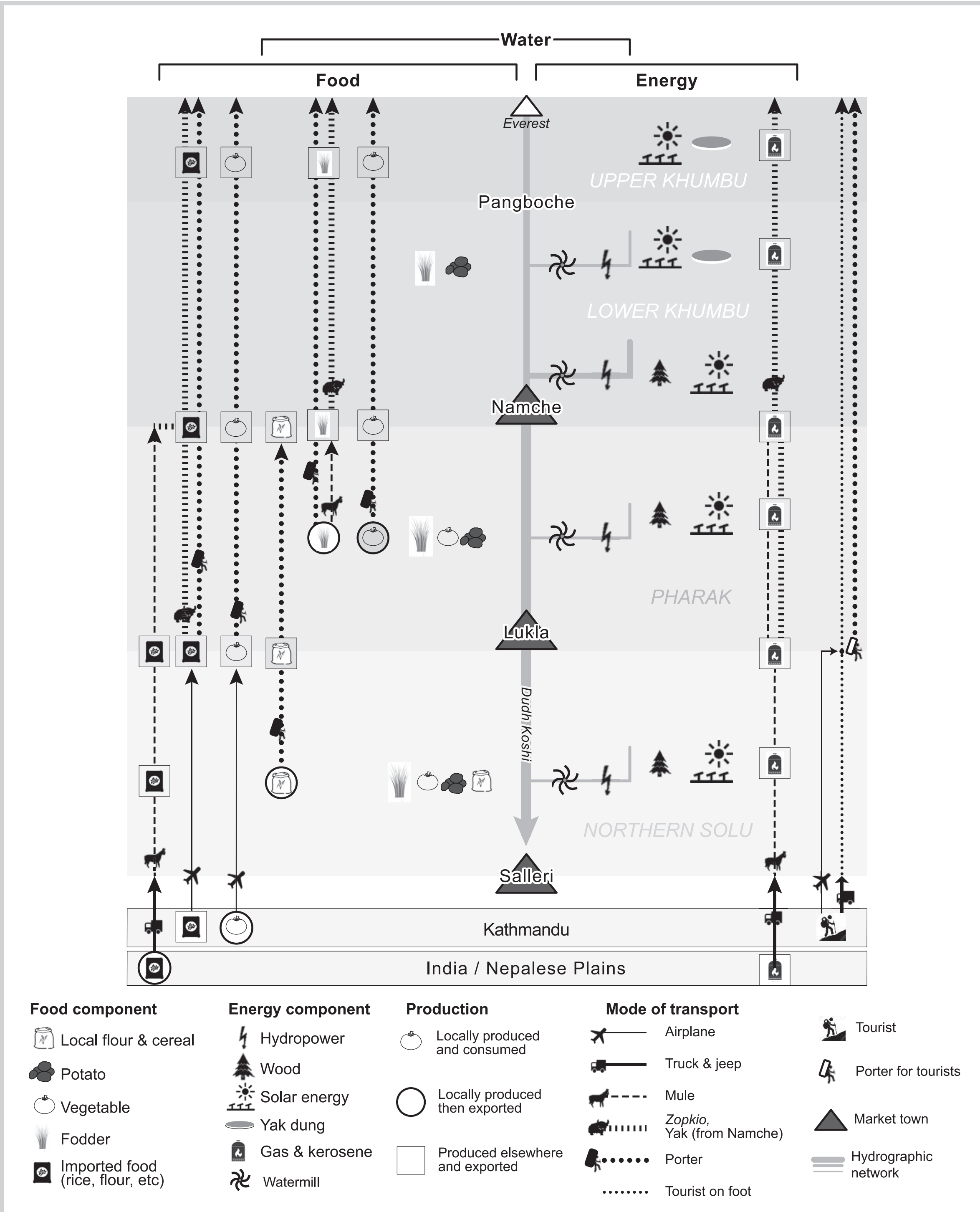
FIGURE 2 Schematic representation of the flux of people, animals, and goods related to the water–energy–food nexus in Upper Solukhumbu. (Designed by A. Muller, O. Aubriot, and M. Faulon, with the help of O. Pissoat; data: Abadia, André-Lamat, Aubriot, Faulon, Jacquemet, Muller, Puschiasis, Sacareau, Smadja).



fodder trade—a new source of income (the price of 40 kg varies from NPR 2000 in Nunthala, northern Solu, to more than NPR 7000 in upper Khumbu, US$ 1 = NPR 106 in 2016) (Muller 2016a). Moreover, the breeding of *chauris* (female hybrid of yak and cow) for dairy products hardly exists now in Pharak (Muller 2016a) and is on the decline in Khumbu (Sherpa and Kayastha 2009); consequently there is now a widespread use of powdered milk.

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A specialization of agricultural areas in Pharak and Khumbu has thus been observed along with the trade of local agricultural products (potatoes, vegetables, and fodder) that are part of a more tourist-oriented economy. Rice, industrial flour, oil, and noodles, all imported for tourists on a massive scale since the early 2000s, are now part of the local populations' diet, gradually replacing the consumption of rustic grains such as millet, barley, and buckwheat.

Flow of produce from Solu to the main tourist area

In northern Solu villages (Kharikhola and Jubhing) lower altitudes allow for more diversified agricultural production, including wheat, millet, barley, buckwheat, potatoes, soybeans, maize, and feed barley (Duplan 2011). Most of this agricultural produce is eaten locally. Some of the cereals are sold in Pharak and Khumbu, either for animal feed (maize) or as distilled alcohol or flour. This flow of flour (Figure 2), discovered thanks to our mill survey (Muller 2016b), dates back only to the early 2000s when improved types of watermills (*sudareko ghatta*), already set up in other parts of Nepal (GTZ 2000; Shrestha and Shrestha 2001), began to be installed by private individuals in Jubhing VDC (where we counted 14 of these in 2016). Their new metal waterwheels, which are more effective than the wooden blades of traditional mills (*ghatta*), have doubled the milling yield. Maintaining the traditional millstone has ensured the production of tasty flour that moreover stores well because the grain is not "heated," unlike in industrial watermills such as those in Kharikhola or Lukla. The development of this flow of products from Solu to the touristy Pharak and Khumbu regions partly explains why there has been no agricultural decline in this area, unlike in other middle-mountain areas (Khanal and Watanabe 2006).

Diversification of energy sources to meet local and tourist needs

The diversification of energy sources, along with the agrarian changes mentioned above, has been one of the major changes over the last 40 years in relation to the thriving tourism sector. In addition to the use of wood and yak dung, new locally produced (hydroelectricity, solar) or imported (gas, kerosene) energy sources are used within the same household. As we will now see, this energy transition involves mobilizing technical devices, all of which are dependent on imported materials.

Regulatory and political-economic context

Prompted by the ban on woodcutting after the creation of the SNP and its buffer zone, inhabitants searched for alternative resources to produce energy. The construction of the first hydropower plant started in 1980 within the park near Thame in Bothe Koshi and was relocated in 1994 following the 1985 Dig Tcho GLOF. Twenty-three other micropower plants, public or private (Table 1), were set up after 1990 due to favorable circumstances. The liberalization of the airfreight market allowed private helicopter companies to carry the equipment needed for the construction of hydropower plants and, since 1994, the use of large-capacity Russian Mi-17 helicopters (Rogers and Aitchison 1998; Saxena 2012) has reduced transportation costs. The deregulation of the energy market has also encouraged private investment (Government of Nepal 1992), and the development of microhydropower plants has been boosted by an international context in which the United Nations encourage access to clean, renewable energies (UNDP 2012). Most power plants located in Pharak and Khumbu are funded by INGOs and private investors, thanks to international networks Sherpas have created via tourism (Puschiasis 2015, 2018; Jacquemet 2018). In the less touristy area of northern Solu, the power plants are mostly funded by the Nepalese government.

Rise in the energy demand and diversity of solutions

Figure 3 shows that sources of energy are more diversified inside the park and buffer zone than outside. In Namche and Lukla, lodges, households, and tea shops have access to all types of energy. By contrast, gas and kerosene are less used above Namche because of the transportation costs and in Kharikhola, since it is situated outside the park where wood is still readily available. Solar energy is another alternative to hydroelectricity for producing light and hot water in high-altitude hamlets where streams regularly freeze (Puschiasis 2015). Nearly all inhabitants of the study area benefit from electricity because of the construction of a microhydropower plant in almost every village. The demand for electricity by locals and tourists has grown since the early 2000s due to the introduction of cell phones (86% of interviewees have one) and televisions (74% have one). Even though hydropower is widespread and strict regulations regarding forest resources in SNP and the buffer zone exist, wood is still used relatively often for cooking in the 3 sectors (Figures 2 and 3), confirming observations made by Salerno et al (2010). Indeed, insufficient electricity production in the spring, which corresponds to low-water periods and the high tourist season, limits the use of kitchen appliances, hence the ongoing use of firewood (Faulon 2015). In less than 10 years, the share of kerosene has gone from being the most commonly used energy source (Salerno et al 2010) to being used by only 4% of households we surveyed. These results show that the situation has evolved rapidly.

Reconfiguration of the WEF nexus due to tourism: New challenges involving water

Changes in the nexus

Before the boom in tourism (Figure 4A), the WEF nexus centered on the use of local resources and on bartering Tibetan salt, wool, and livestock for grain and other

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TABLE 1 Detailed census of hydropower plants from Phortse to Jubhing. (Drawn up by M. Faulon and O. Aubriot; 2014–2016 data: Jacquemet, Faulon, Aubriot, Smadja, Puschiasis).[a] (Table continued on next page.)

Location	Ownership	Year of construction	Main investor	Power (in kW)	Number of buildings connected	Competition mill/ hydropower	Solution if competition, or reason for no competition
Khumbu							
Phortse	Public	2005	British sponsor	–	86	No competition	Not same stream used
Pangboche	Public	1998 and 2004	French sponsor + NGO	15	25 then 116	No competition	Not same stream used
Tengboche	Public	1988	American NGO	20	32	Matched	Mill below plant
Thame	Public	1983 and 1994	Austrian NGO	960	874	–	—
Namche	Public	Project	Khumbu Bijuli Company	30–60	–	No competition	Not same stream used
Pharak							
Monjo	Private	1990	Lodge owner	–	1	No competition	Small plant
Monjo	Public	2010	SNP	50	87	No competition	Not same stream used
Tok Tok	Public	2007	Hong Kong NGO	70	130	Competition	Water mill unused
Chuserma	Public	2010	Hong Kong NGO	35	60	Matched	Mill moved below plant
Thado Koshi	Public	2014	Hong Kong NGO	100	250	Competition then matched	Mill moved below plant
Lukla	Public	2010	Government	70	200	–	—
Lukla	Public	Project	World Bank	300	–	–	—
Lukla Hospital	Private	2005	Swiss NGO	30	–	–	—
Lukla (INOP)	Private	1995	–	10	3	–	—
Lodge in Lukla	Private	2001	Lodge owner	5	1	–	—
Lodge in Lukla	Private	no data	Lodge owner	–	–	–	—
Lodge in Lukla	Private	no data	Lodge owner	6	–	–	—
Lodge in Lukla	Private	no data	Lodge owner	5	1	–	—
Lodge in Lukla	Private	2016	Lodge owner	5	3	–	—
Solu							
Surkhe	Public	2012	Government	3	46	No competition	Not same stream used
Payan (INOP)	Public	1999	Swiss sponsor	1	–	No competition	Plant INOP
Payan	Public	2007	Swiss NGO + government	16	70	Competition	Reduction in use of mill

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TABLE 1 Continued. (First part of Table 1 on previous page.)

Location	Ownership	Year of construction	Main investor	Power (in kW)	Number of buildings connected	Competition mill/ hydropower	Solution if competition, or reason for no competition
Kharikhola	Public	2001	Government	44	450	Competition	Alternating night/day
Kharikhola	Public	2015	Government + village committee	70	567	Competition	Alternating night/day
Pangom	Public	1999	French + local sponsor	30	26	Competition	Reduction in use of mill
Jubhing	Private (HS)	1998	Lodge owner	6	15	Competition	Alternating night/day
Jubhing	Public	2005	Government	20	60	Competition	Alternating night/day
Jubhing	Public	2013	Government	15	50	Competition	Alternating night/day
Bumburi	Public	2009	Foreign sponsor	–	–	–	—

[a)]–: not asked; INOP: inoperable.

products from regions downstream (Fisher 1986; Bishop 1990; Jest 2008; Stevens 2011). The forest played a central role in providing firewood and grazing land for herds. Interactions within the water, food, and energy nexus have taken place mainly through rainfall for agriculture, the diversion of water for mills, the use of wood or dried dung for preparing meals, and forests also acting as water catchment areas.

Since then interactions have multiplied (Figure 4B): water is now required for irrigation in market gardening (link W–F) and for hydroelectricity (W–E), which is used for cooking (W–E–F) and for domestic and tourists' electricity consumption; solar energy (and sometimes gas) are used for the supply of hot showers (E–W) and gas for cooking (E–F). Today, with an economy increasingly based on tourism, the nexus relies on (1) the massive importation of goods, especially food; (2) the use of local resources, but with new techniques relying on imported materials (for hydropower, improved mills, greenhouses, and pipes in domestic networks); (3) an increasing number of electrical appliances; and (4) new uses of water (diverted to power plants, used for watering vegetables, or for flush toilets and showers).

Domestic water, traditionally fetched from streams and springs using buckets, is now mainly piped to collective taps or lodges (the materials are purchased individually, collectively, or through funded projects). Some villagers bottle water from springs after treating it. Destined exclusively for sale to tourists at a high price, bottled water has been transformed into a commercial commodity (Puschiasis 2015); 16 brands exist in the study area (Jacquemet 2016). Thus, all local resources used for tourism are now included in commercial activities, whether they come from an old domestic use (water, fodder, flour, potatoes) or are new (hydropower, vegetables). Because of income derived from tourism and the relationships established with foreign countries via trekking in particular (Sacareau 1997; Puschiasis 2015, 2018; Jacquemet 2018), villagers have been able to leverage new financial, technical, and human networks to generate the economic capital necessary to make investments in energy infrastructures, market gardening, and trade.

The ban on cutting trees and the incentive to develop microhydroelectricity has encouraged villagers in the area to use more water, whose usage is not subject to any limitations or regulations, whether in the park, the buffer zone, or on their periphery. These policies have thus favored the transfer of pressure from the forest to the water resource.

What pressure on water?

The water used in this region comes mainly from mountain streams and is used in homes, for watering greenhouses and operating mills or hydroelectric power plants that turbine it and then return it downstream. The intake and outlet locations of mills and hydropower plants can be problematic because they can compete for the amount of water diverted (see Table 1). Yet there is no competition when the mill is moved under the plant outlet, either out of necessity (Thado Koshi) or when it is strategically integrated into the hydroelectric system, benefiting from the return of the flow by the plant (Chuserma) (Faulon 2015). On the contrary, this competition is the reason why the use of certain mills is limited in Pangom or mills are sometimes not used in Tok Tok. Villagers have accepted this constraint because they

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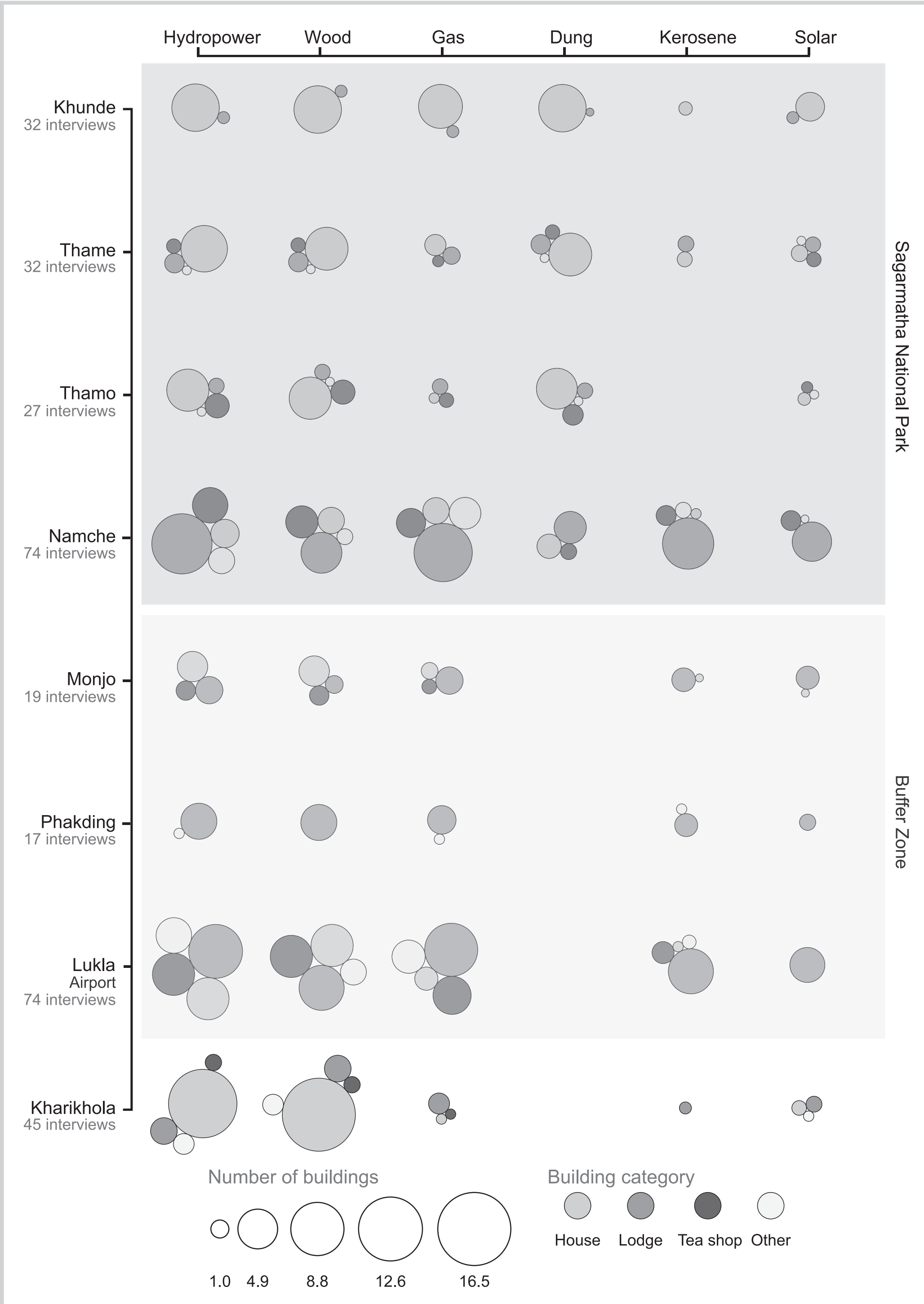
FIGURE 3 Energy mix in the households surveyed in various villages in Solukhumbu during the period 2015–2016, according to the type of building. (Design by L. Lehmann and M. Faulon; 2015–2016 data: Jacquemet, Faulon, Sherpa, Majhi).



prioritized access to electricity. Last, some villages have opted to alternate between day and night when using hydraulic power (Jubhing, Kharikhola). But the growing need for electricity for daytime activities (to power electric sawmills, household appliances, etc) shows the limits of this solution. The equilibrium between elements of the WEF nexus thus lies at the heart of decisions. As for watermills with a metal wheel, they can be installed over streams with a relatively low flow, which, in the nexus, constitutes an optimization of the water resource and

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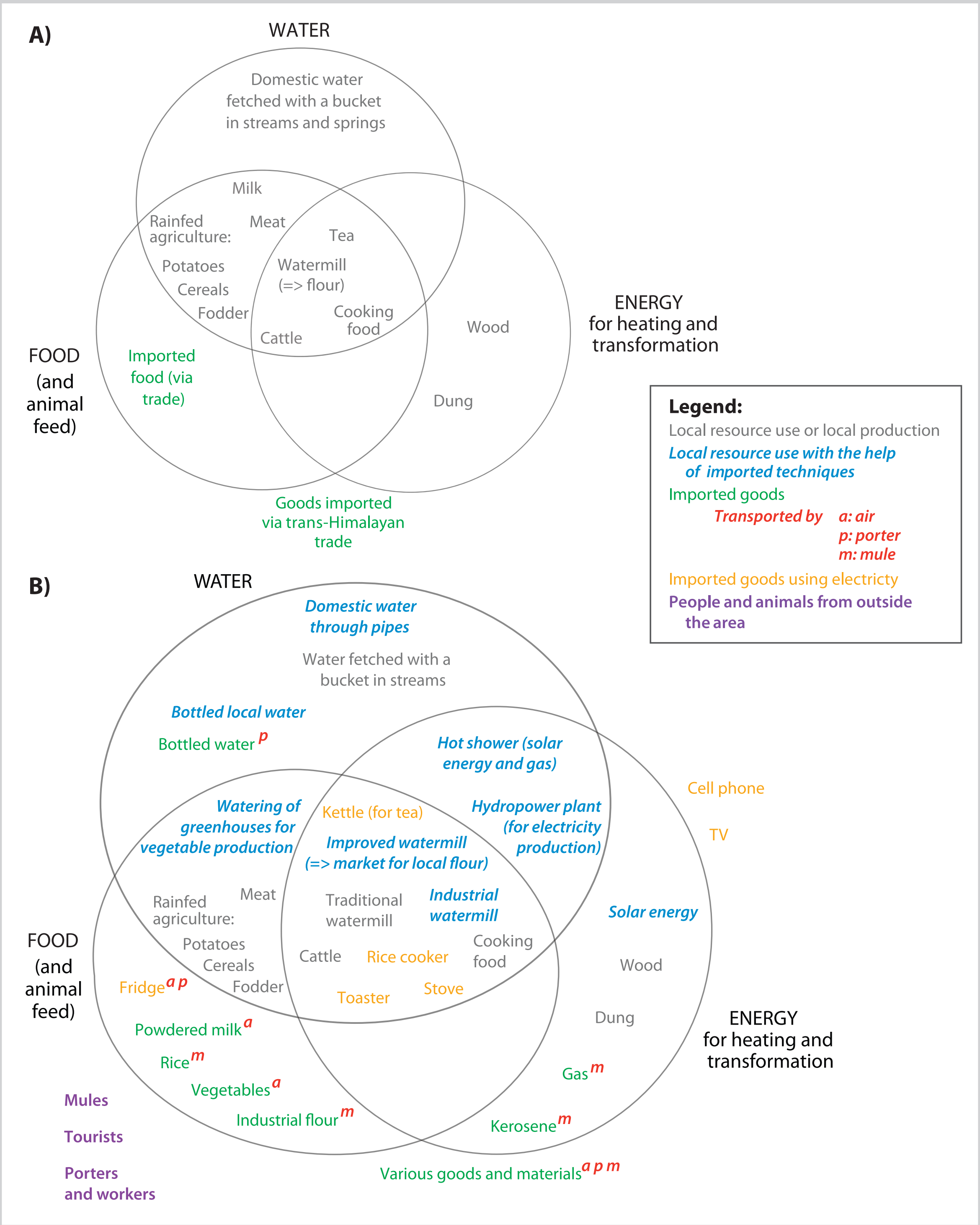
FIGURE 4 The water–energy–food nexus before tourism (4A) and now (4B). (Designed by O. Aubriot).



anticipation of possible water shortages if the resource were to run out due to climate change. However, the long-term effects of climate change on water resource availability are still very uncertain (Bharati et al 2012; Shea et al 2015).

Water diverted for hydropower does not compete with domestic water. Either water intakes supplying the domestic network and power plants are not situated over the same streams (Kharikhola, Phakding, Pangom, Khunde, Namche), or water intakes for houses are located upstream from those for the power station (Sano Gumela, Rimijung) or at the same place but on a stream that is well supplied (Jubhing), notably by meltwaters in the spring (Monjo, Ghât). In Namche, thanks to electricity from Thame power plant, water is pumped from a stream located below the market town to supply its water network.

As for domestic and agricultural water uses, there is seasonal tension in late spring, which is both a period of low flow in streams and a high tourist season with a greater demand for water. Indeed, a villager's daily domestic consumption of water is about 20 L (Puschiasis 2015) while a tourist's is double (Jacquemet 2016). Furthermore, greenhouses have to be watered with 120 L to 250 L per week depending on their size (Abadia 2016). When inhabitants mention a shortage of water, they attribute it to problems of frost (45% of answers), drought (15%), a lack of network maintenance (14%), or water sharing (12%), rather than to tourists' overconsumption (7%) (Faulon 2015; Jacquemet 2016). As for the sources used for locally bottled water, no competition was reported during our investigations.

Although there is seasonal pressure on water owing to tourism, so far competition between its different uses appears to be limited. However, a water shortage could occur and affect all usages if the number of greenhouses were to increase in villages where large numbers of them already exist, such as in Phakding (Abadia 2016), or if the number of tourists were to increase dramatically.

Conclusion

We have shown that tourism is a major driver of change in the WEF nexus in the Everest area. The growing tourism-related demand for water, energy, and food, along with the regulations that limit access to forest resources, could have led to a deadlock situation, as suggested in the neo-Malthusian approach. But this is not the case. Because of various networks and the new economic capital provided by tourism, inhabitants have developed new trade circuits and have used other local resources, putting water particularly to the fore. Tourists receive different kinds of food and energy that require more water and a diversified use of the resource, calling for a change in the cropping pattern. Lodges provide running water, which also generates a significant seasonal demand for the resource. The multiplication of microhydropower plants has provided inhabitants with more comfortable living conditions and has enabled lodges to improve their standing by using domestic appliances and by offering battery-charging services or internet access. This level of electrical equipment, combined with solar energy, is required for lodges since they are striving to upgrade their facilities in a context of strong competition. The increase in market gardening as a result of greenhouses and their irrigation also allows lodges to offer organic vegetables and varied menus appreciated by tourists. Last, the production of bottled water has created new economic opportunities in the region.

Since local food production is not sufficient to meet the needs of the growing tourist market, importing food is necessary during the busy tourist season. Although primarily intended for tourists, imported food is gradually becoming a staple part of the local diet at the expense of traditionally produced cereals. The growing use of pack animals, which also have to be fed, to transport these goods has an impact on agricultural production, such as the development of fodder crops, and on livestock, seen in the decline in dairy cattle.

The use of the WEF nexus combined with a multiscalar analysis (from the farm and household unit to the whole study area) has helped us interconnect the strain on local resources and the new flows of food and animal feed with the tourism industry and its increasing demands on energy, food, and water. The reconfiguration of the WEF nexus is characterized by the commodification of local resources (water, electricity, vegetables, flour, and fodder), which nevertheless generates new inequalities in terms of access to and the sharing of resources (which we have not developed here), especially water (Faulon 2015; André-Lamat 2017).

Finally, we have shown that the boom in tourism in the Everest region has contributed to an increase in water use and to seasonal pressure on water. In a context of climate change, with unforeseeable consequences, this pressure might be amplified. The whole WEF nexus might therefore needs to be reconsidered.

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