New Perspectives on Modern Ladakh
Fresh Discoveries and Continuing Conversations in the Indian Himalaya
Edited by Rafał Beszterda, John Bray and Elizabeth Williams-Oerberg
Toruń 2021

Artificial Glaciers and Ice Stupas: The Contemporary Remaking of Ladakh's Place-Based Practices of Water Storage as Modern "Solutions" to Climate Change

Sierra Gladfelter

Institute for Engagement & Negotiation
University of Virginia
sierragladfelter@gmail.com

Streszczenie: Ladakh, położony w himalajskiej, rozległej strefie suchej, to region, w którym dostępność wody od dawna jest ograniczona. Aby przetrwać i rozwijać się, mieszkańcy wsi zależnych od cieków lodowcowych i śnieżnych opracowali złożone systemy zbierania i dystrybucji wody. Zmiany klimatyczne wystawiają jednak na próbę zdolność Ladakhijczyków do przystosowania się, ponieważ lodowce od strony południowej, wzdłuż doliny Indusu, cofają się w zdumiewającym tempie, a rolnicy coraz bardziej zmuszeni są polegać na malejących opadach śniegu, aby zaspokoić swe potrzeby nawadniania pól. W odpowiedzi na ten kryzys, różne instytucje mobilizują mieszkańców wsi do budowy sztucznych lodowców (AG – Artificial Glaciers), o różnych kształtach i rozmiarach, aby pomóc rolnikom w radzeniu sobie z niedoborem wody. Podczas gdy ladakhijski inżynier Chewang Norphel jest często uznawany za twórcę AGs w latach 1980, ten artykuł dokumentuje, w jaki sposób rolnicy, od pokoleń, wznosili i utrzymywali podobne struktury, aby zatrzymać śnieg i lód w dolinach położonych nad ich wioskami. Autorka stwierdza, że współczesne sztuczne lodowce (AG) w Ladakhu, powinny

być rozumiane jako część trwającej ewolucji i współczesnego powrotu do miejscowych tradycji zbierania śniegu i lodu. Mimo, że sztuczne lodowce (AG) zostały wprowadzone i dostosowane na inspirujące oraz nowe sposoby, Autorka tekstu konstatuje również, że wiele współczesnych przedsięwzięć ma swe faktyczne wzorce w tradycji ladakhijskiej, jako „rozwiązania" obecnego kryzysu klimatycznego, a pojawiają się w postaci budzących wątpliwości przywłaszczeń lokalnej wiedzy i fałszywego przedstawienia tego, co te infrastruktury służące zbieraniu lodu są w stanie zapewnić miejscowej ludności.

Słowa kluczowe: sztuczne lodowce, przystosowanie do warunków klimatycznych, Ladakh, niedobór wody, infrastruktura, tradycja.

Abstract: Situated in the Himalayas' vast rain shadow, Ladakh is an arid landscape where water has long been materially limited. To survive and thrive, villages there dependent on glacier and snow-fed catchments have devised complex systems of water harvesting and distribution. Climate change, however, is testing Ladakhis' capacity to adapt as south-facing glaciers along the Indus River valley retreat at astounding rates and farmers increasingly depend on dwindling snowfall to meet their irrigation needs. In response to this crisis, various institutions are mobilizing villagers to construct artificial glaciers (AGs) of various shapes and sizes to help farmers cope with water scarcity. While Ladakhi engineer Chewang Norphel is often credited for inventing AGs in the 1980s, this paper documents how farmers have been actively building and maintaining similar structures to trap snow and ice in valleys above their villages for generations before. This paper argues that Ladakh's contemporary AGs should be understood as part of an ongoing evolution and modern iteration of place-based traditions of snow and ice harvesting. While AGs are being innovated and adapted in inspiring new ways, this paper also argues that many contemporary interventions are reinventing Ladakhi traditions as "solutions" to the current climate crisis through both a problematic appropriation of local knowledge and a misrepresentation of what this ice harvesting infrastructure is capable of providing for local people.

Keywords: artificial glaciers, climate adaptation, Ladakh, water scarcity, infrastructure, tradition.

Introduction

Situated on the western edge of the Tibetan Plateau in the vast rain shadow of the Himalayas, Ladakh is a high desert environment that has long sustained life. There, far above the turquoise Indus River wending its way from Tibet to Pakistan through the Indian union territory of Ladakh,[1] 85 to 90 percent of villages depend on the seasonal flows of glaciers and snow-fed streams for drinking water and irrigation (Norphel and Tashi 2014). In spite of this scarcity, Ladakhis have managed to make life flourish in this extreme landscape by developing complex infrastructure and social systems to support them to harvest, direct, and put to use seasonal flows from melting snow and ice (Nüsser et al. 2012).

While Ladakh has rich traditions of managing limited water resources, it is also a region on the frontlines of climate change with rising temperatures radically reshaping its physical environment. In just the last six decades, Ladakh and Jammu and Kashmir have lost 20 percent of their permanent ice reserves (Clouse et al. 2017), and south-facing glaciers along the Indus have been particularly vulnerable. Farmers describe how many "village glaciers" have severely retreated or disappeared within a single lifetime and report increasingly meager snowfall over the past 30 years, a trend also documented by scientists (Chevuturi et al. 2018). Meanwhile, what little precipitation does occur, just 115 millimeters annually (Thayyen et al. 2013), increasingly comes in more erratic and intense storms. Thus, water scarcity is becoming acute not only due to an overall decline in precipitation, but also from qualitative changes to its timing and form.

Given this context, it is unsurprising that Ladakh has become a locus for interventions focused on helping villages cope with chronic water shortages and the associated effects of climate change. Most iconic, perhaps, are the artificial glaciers (AGs) that a suite of different non-governmental organizations (NGOs), local religious institutions, and corporate donors are building across Ladakh to capture the region's shrinking water resources. Built in alpine valleys either in a stream channel or on a shaded hillside or cliff, AGs rely on a series of stone

[1] In August 2019, the Jammu and Kashmir Reorganisation Bill was passed by the Parliament of India and separated the previous state of Jammu and Kashmir of which Ladakh was part into two separate union territories: Ladakh and the rest of Jammu and Kashmir. This change in political status took effect on October 31, 2019.

check dams to temporarily store water in the form of ice and gradually release it over several months as it melts (Clouse 2016). While such practices of ice harvesting are not new to Ladakh, they have received unprecedented attention and investment in recent years as a mechanism of adaption.

With much of the world now looking to Ladakh and its AGs for inspiration, I argue that a deeper, critical examination of these interventions–particularly how contemporary AGs are framed and represented, and what they ultimately do to serve rural Ladakhi communities–is warranted. Moreover, while AGs have been the subject of a number of studies (Clouse 2014, 2016; Clouse et al. 2017; Hasnain 2012; Nüsser and Baghel 2016) and Karine Gagné (2016, 2019) has examined traditions of ice cultivation in Ladakh's Sham region, until now there has been no detailed account of how Ladakhi traditions inform the shape and structure of modern AGs. Therefore, this chapter describes the evolution of snow and ice harvesting technologies in Ladakh and critically examines the knowledge politics that surround contemporary interventions to adapt, modify, and otherwise technologically "improve" local techniques for a climate-exacerbated water crisis. I argue that while Ladakh's modern AGs are clearly tied to place-based traditions, they also enact a form of knowledge appropriation and misrepresentation as funders take Ladakhis' ancient structures and reinvent them as "sexy solutions to climate change," as one funder described them in an interview, with little or no acknowledgement of their roots.

Methods and Theoretical Approach

The data that informs this chapter was collected during four months of intensive research during the winter and early spring of 2017–2018 in 14 villages of the Sham and Changtang regions of Ladakh that have either had AGs recently constructed or built through a past intervention. In these communities, I worked closely with a Ladakhi research assistant and several translators to conduct 90 in-depth interviews and eight focus groups with project beneficiaries. Besides visiting 12 different AGs to document them at various stages of formation and melting, I also engaged in participant observation with four NGOs building modern AGs by assisting with construction and conducting feasibility studies in villages where future AGs were planned. Moreover, I interviewed 30 different NGO

staff, government officials, engineers, and scientists to understand the complex dimensions of water scarcity in Ladakh and the effectiveness of ice harvesting strategies, past and present.

In interviews and focus groups, I was particularly interested in understanding the relationship between culturally rooted traditions of water harvesting in Ladakh and the emergence of contemporary interventions to build AGs. Therefore, my research asked: 1) to what extent are the diverse AGs today a modern remaking or extension of older place-based traditions of snow an ice harvesting? and 2) through which processes of knowledge politics and interaction have they emerged? My goal was to document and trace Ladakhi traditions to contemporary interventions, while untangling the knowledge politics that surround place-based practices that have been lost and appropriated, displaced and adapted in the process.

In this study, I approach and understand traditions not as static practices tied to a remote past that are either wholly preserved or abandoned in the present. Rather, I examine traditions, such as managing water resources, as dynamic ways of living in a given place. My theoretical approach is inspired by Ingold and Kurttila's (2000: 192) argument for studying tradition as a living process that is "continuous without taking any fixed form." "Change," they state, "is simply what we see if we sample a continuous process at a number of fixed points separated by time" (Ingold and Kurttila 2000: 192). By approaching traditions as dynamic and living, we also avoid forcing place-based knowledge into static categories like "indigenous" or "traditional" that position them in opposition to scientific and technological expertise (Agrawal 1995). This makes it is possible to more accurately account for the complicated ways in which different knowledge practices interact, compete, and coexist in the present.

Within the context of Ladakh, anthropologist Karine Gagné (2016: 195) has noted how, "local knowledge, including water management, [...] is subject to change and must be analysed in light of how the state impacts, directly and indirectly, on cultural practices and arrangements through which people engage with places." There is, after all, much at stake in the specific ways that traditions evolve, interface with other knowledge practices, and blend multiple sources of inspiration. Yet, if we are to honestly account for these politics and outcomes, including whose knowledge wins and loses in this process, we must begin with a broader and more dynamic definition of tradition. Therefore, I examine AGs in Ladakh as a tradition that begins with ancient practices, some of which no longer exist,

but that as a process is still very much alive and in the making as new innovations are folded into contemporary interventions.

The Roots of Artificial Glaciers: Village Systems of Water Capture and Distribution

Long before anthropogenic climate change, year-to-year fluctuations in snowfall could cause disaster for a village if there was insufficient water to irrigate fields come spring (Clouse 2016). While high mountain snow and ice could always be counted on to melt by the summer solstice, the agricultural season was too short to wait until then to begin cultivation. As a result, farmers had to plant and irrigate their fields by May for their crops to mature before winter. In years when there was insufficient snow, farmers suffered while waiting for glaciers to melt in the mountains. In Shara[2], for example, villagers shared a legend about an old grandmother from the village of Ik who was so desperate for water that she carried a basket of ashes up to the glacier and dumped it on the ice to make it melt more quickly. But since ashes are polluting (*grib*) in Ladakhi cosmology, the local deities reportedly grew angry and caused the glacier to retreat.

Given farmers' high reliance on snowfall for irrigation, they invest an immense amount of time and labor into building and maintaining infrastructure to capture and store additional water resources for leaner months. Rock-lined reservoirs called *dzing* (*rdzing*), for example, enable farmers to utilize water around the clock by directing stream water flowing overnight into a tank for storage. In the morning, farmers unplug the *dzing* and direct its water through a gravity-fed system of canals or *yura* (*yur ba*) to irrigate their fields in rotation. This allows otherwise "wasted" water to be captured and put to use. Meanwhile, the porous floors and walls of the earthen *dzing* and *yura* work to recharge groundwater (Norphel and Tashi 2014). In much of Ladakh, this infrastructure continues to

[2] I use Shara here, as is the local convention, to refer to what is actually a series of three hamlets called Shara, Sharnos, and Phuksey. Because Phuksey is the uppermost hamlet, government departments and NGOs who built artificial glaciers above these communities, sometimes refer to the site as Phuksey and sometimes as Shara.

be maintained through an annual event called *yursal* (*yur gsal*), during which the village's *yura* and *dzing* are collectively repaired and cleaned.[3]

Although far less common than Ladakh's networks of *yura* and *dzing*, some villages constructed long walls called *khagag* (*kha 'gag*) to harvest snow for irrigation by breaking the wind in the same way that snow fences are used to prevent drifting along highways in the United States and elsewhere. Villagers in Sakti, situated below the passes Changla and Warila, explained that *khagag* were built in alpine valleys at or above 14,000 feet in elevation to ensure that precious water resources did not blow into another watershed, while also creating large snowbanks on the passes that would remain into the spring. Until the early 2000s when India's National Watershed Development Program (WDP) began funding its own water diversion projects, the village leader or *goba* (*mgo pa*) would organize work groups twice a year to make repairs. "My grandparents would pack *ngamphe* [*rngam phye*, barely flour] in a cloth and go to build *khagag* on the passes," remembered one 89-year-old Sakti resident. "Once in the spring before planting and once in autumn after the harvest." Today, evidence of ancient snow walls can still be seen at Changla, while Warila's structures (Fig. 1) have since been reinforced and extended by the state.

In other places like Takmachik, residents not only harvested snow within their own watershed, but also dug and maintained a high alpine canal to divert snowmelt from adjacent mountain slopes. Takmachik's *Galjur Yura*,[4] for example, was a crude canal excavated by hand across the face of Galjur Mountain at 14,800 feet above sea level. At the time of research, the oldest person in the village was a 96-year-old man who had spent decades traveling the Himalayas as a trader and confirmed that the canal had been built long before his grandfather's time and, as far as he knew, had no origin story. Even at the time of research, the canal extended for 600–700 meters, diverting snowmelt toward Takmachik from a north-facing slope that would otherwise drain to the much smaller village of Urbis. In this way, Takmachik's farmers capture water from neighboring watersheds to ensure sufficient flows in their own.

---

[3] For a more extensive overview of how this infrastructure is socially and culturally embedded in Ladakhi communities, see the work of Angchok and Singh (2006), Gutshow (1997), Labbal (2000), and Tiwari and Gupta (2008).

[4] Villagers were unable to provide the exact spelling of this name in Ladakhi. One possibility suggested was *'gal 'byor yu ra*, but this remains tentative.

Figure 1. These snow walls, though in their traditional location, have since been reinforced with government funds
Photo: Sierra Gladfelter (2018)

While *khagag* and *yura* were traditionally used to harvest snow or divert its meltwater, farmers in south-facing villages above the Indus River like Nang, Igu, and Shara, also built walls across stream channels to create ice from flowing water. Alternatively referred to as *gangsgag* (*gangs 'gag*, lit. "ice block"), *gyang tsik* (*gyang rtsig*), or *raks* (*rags*) within the same village, these dyke-like structures worked to facilitate ice formation and create temporary ice banks by using a series of stone check dams to force water to slow and spread (Fig. 2). While these terraced ice fields might extend for several kilometers and grow up to a meter deep each year above villages, they were designed to melt in the early spring long before snow and ice at higher elevation to provide otherwise scarce water for a first round of spring irrigation.

Although not every village repaired this infrastructure annually, villages particularly dependent on these structures for irrigation like Shara and Igu would coordinate work groups to go to camp in the upper valley (*phu*) and rebuild damaged walls each autumn. If the stream channel had shifted in a flood, villagers built new structures. Farmers sometimes packed the rocks with bushes to make the walls less porous or sealed the bottom with sod (*spang*). In some villages,

like Nang, residents remembered their parents and grandparents carrying sacks of charcoal (*sol ba*) on their backs that had been blessed by monks from Hemis Monastery. Up in the valley, the charcoal would be packed into walls to help facilitate ice formation similar to practices of ice cultivation documented by scholars in other villages of the Sham Valley (Gagné 2016), and in nearby Baltistan where glacier grafting is still actively practiced (Tveiten 2007).

Figure 2. A few original *gangsgag* remain in the valleys above Shara
Photo: Sierra Gladfelter (2018)

"There were so many prayers in the charcoal," explained one elderly resident, "that from a small piece of charcoal the size of your thumb, a heap of ice the size of a yak could grow." Several Nang elders recalled hearing a story in their childhood about their ancestors growing a small glacier in the Labuk *phu* when taking their animals there to graze. People had supposedly brought a piece of ice from a glacier in Stok, across the Indus River, and planted it among the stones. Local people called it *gangpakma* (*gangs bag ma*), their "ice bride."[5]

[5] Although I heard no other stories like this during my research, Nang's *gangpakma* is reminiscent of Tveitan (2007)'s descriptions of glacier grafting still actively practiced by villages, now with NGO support, in Baltistan.

Traditions of harvesting snow and cultivating ice are not ubiquitous across Ladakh in the same way that *yura* and *dzing* are. However, their presence and persistence reveal how complex and comprehensive the water management systems were that Ladakhi farmers developed over the course of generations to survive and thrive in a place where water resources are limited. While this chapter, and the ethnographic work of Karine Gagné (2016, 2019), document some of Ladakh's rich ice and snow harvesting traditions, further research is needed to both understand regional variations and how different practices evolved in response to local topography and climate. Turning now to contemporary AGs, I examine how deeply embedded cultural practices of harvesting ice and snow have inspired the emergence and shape of this modern infrastructure.

The Invention of Contemporary "Artificial Glaciers"

Chewang Norphel, an 86-year-old Ladakhi engineer called the "Ice Man," is almost universally credited with having invented AGs in the late 1980s (i.e. Clouse 2016; Clouse et al. 2017, Dixit 2018, Gulsoken 2018, Vince 2009). However, the structures he developed and made famous during his tenure as a civil engineer with Leh's Rural Development Department (RDD) and later at the Leh Nutrition Project (LNP), are almost identical to some Ladakhi traditions of snow and ice harvesting that farmers have practiced for generations.[6] Norphel, however, claims that he drew his inspiration for his first AG not from the traditions of Ladakhi farmers, but rather from observing the failure of modern infrastructure.

"I was working in the RDD and it was my responsibility to go to each and every village," Norphel explained in an interview in 2018. "Many villages were having problems with water scarcity at that time, and I was thinking day and night about how I could solve their problem." Then, one day Norphel was walking past a broken water pipe near his home in Leh, when he noticed how the water had frozen below the break, glazing the landscape with a thick layer of ice. "I thought, if I could conserve winter wastewater flowing in streams in the form of ice, then maybe it could be helpful for villagers," he stated. "With this, I started making artificial glaciers."

[6] This conclusion was also drawn by Hasnain (2012: 4), who interviewed villagers in Shara at the site of one of Ladakh's "original" AGs.

Local leaders in Nang village, however, insist that Norphel got his idea to build AGs while visiting some of their traditional ice harvesting infrastructure on a survey trip there in 1987. The man who was Nang's *goba* at that time stated in an interview that he had invited Norphel and then-Minister of State, Sonam Wangyal, to visit their village and advise them on how to cope with the water scarcity that they were facing. Norphel responded and came to Nang the fall of 1987. The *goba* took him by *dzo* (*mdzo*), a hybrid yak/cow, up the Labuk Valley to assess the state of their water sources. For two days and one night they stayed in the *phu*. Upon seeing the villagers' old *raks* there, Norphel advised them to strengthen the walls to capture more snow. Later that year, RDD funded one of Ladakh's first modern AGs in Nang's Labuk Valley.

Regardless of which origin story is true, it is worth noting that some of Norphel's earliest and most successful AGs–for which he has received numerous awards including India's prestigious Padma Shri award in 2015 and recognition from the United Nations Development Programme in 2011 (Dixit 2018) – were built in villages that had been already building walls to harvest ice and snow. While AGs built through the 1990s and early 2000s with funding from the WDP were stronger than villagers' *gangsgag*, they did not significantly differ in concept or design. Norphel's wider, higher, and more robust double-layer walls simply strengthened the structures and increased the amount of ice that could accumulate within them.

The valley above Shara, for example, is the site of Ladakh's oldest and most successful AG and is crisscrossed with over 50 walls ranging from 14,250 to 15,200 feet in elevation (Fig. 3). While Norphel's first AG here cost just over 2,300 USD at the time (Gulsoken 2018), over the decades, new walls have been funded by a range of donors from WDP to the Royal Bank of Scotland, and most recently the philanthropic arm of India's Tata Group. However, Shara residents claim that when Norphel first came in 1987 to fund an AG, there were already 30 walls present. One NGO worker from Shara who also led the WDP's intervention there in the late 1990s supported this statement, asserting that what the government and engineers like Norphel ultimately provided villagers was the financial support to build stronger walls in places where they already existed.

In the nearby village of Igu, for example, an AG funded by the Tata Trusts in 2015 laid 20 new walls directly on top of structures that residents had been maintaining for generations (Fig. 3). "We never stopped going to build walls there," stated one 75-year-old man, "even today, people are still going." "Now,

sometimes people complain when they don't get paid," another resident explained, "but they still go to make repairs if the *goba* calls them."

Thus, it is perhaps unsurprising that villagers, particularly older people who grew up building *naks* in the valleys above their villages, make little distinction between government and NGO-funded AGs and their traditional infrastructure. To them, all of the structures are *gangsgag*. Most revealing is the fact that even NGO staff, when they meet with villagers, often use this more familiar and descriptive term, rather than the more cumbersome, *kangri dzusma* (*gangs ri rdzus ma*), a direct translation of "artificial glacier" in Ladakhi.

Figure 3. Igu village's AG built by the Leh Nutrition Project with support from the Tata Trusts on top of traditional walls
Photo: Sierra Gladfelter (2018)

Ultimately, what Norphel offered Ladakhis with his contemporary AGs, was not so much new and innovative technology as external funds to pay villagers for their labor to build stronger stone walls in the places they already existed. Moreover, with annual funding through the WDP, Norphel was able to take this technology and replicate it in other villages that did not have such traditions. Yet, the most successful structures remained in Shara, Nang, and Igu where villagers built new walls on top of old ones, not only in times of scarcity but every year

that there was money. Eventually their valleys began to resemble natural glaciers in the winter with terraced ice fields, a meter deep, stretching for kilometers into the heights of Ladakh's mountains.

These results are certainly impressive. But as one elderly farmer in Nang stated, after reminiscing about the days he spent building walls with his parents as a 10-year-old boy, "Not much has changed. One day, an NGO came and advised us how to make our walls stronger."

Innovation and Adaptation

Inspired by the success and international recognition of Norphel's work, other groups have experimented with building frozen ice reserves using different piping and diversion systems. These systems have included frozen waterfalls referred to as Artificial Icefall Glaciers (AIGs) and free-standing towers called Ice Stupas, which at the time of research were being replicated in over a dozen villages across Ladakh.

Invented by Ladakhi engineer and social reformer Sonam Wangchuk, the Ice Stupa's name comes from its conical shape, resembling a traditional Buddhist *stūpa* or reliquary mound. The structure is created using a gravity-fed piping system that builds sufficient pressure over the course of its 2.3-kilometer length pipe to project water out of a vertical sprinkling system that can be extended upward as the structure grows (Fig. 4). Wangchuk claims that because the Ice Stupa's dome has less surface area than Norphel's terraced icefields, its melting is delayed, allowing the structure to be constructed at lower elevations and in closer proximity to villages.

"Chewang Norphel was my inspiration," Wangchuk shared during an interview in 2018. "He is where I started." While Wangchuk admitted that he never visited any of Norphel's AGs, he said that he understood what Norphel was trying to do. "We met and talked about the problems he was facing," Wangchuk explained. "He said how [AGs] have to be built very high so villagers do not go and maintain them." After this, Wangchuk considered how he might redesign AGs to make it possible to build them at lower elevations, so they would be more accessible for villagers. "That's when I thought if I built a structure in the shape of a cone, that has a low surface area but high volume, I might be able to bring it all the way to the banks of the Indus."

Figure 4. An Ice Stupa team member checks ice formation during the winter of 2017–2018
Photo: Sierra Gladfelter (2017)

That winter (2013–2014), he and students from the Students' Educational and Cultural Movement of Ladakh (SECMOL) built a prototype of the Ice Stupa on their school grounds in Phey using willow boughs, plastic PVC pipe, local shrubs, and netting to create a foundation for the ice. Although they struggled for months with frozen pipes and blockages, they successfully erected a two-story structure. "We were all betting how long it would last into the summer," Wangchuk recalled. "April 30th was the wildest guess, but by May 1st it was still one story tall."

The next year, after raising 125,000 USD through a crowdfunding website, Wangchuk and his team constructed a larger Ice Stupa over 20 meters tall to irrigate 5,000 trees planted on land owned by Drikung Chetsang Rinpoche's monastery in Phyang (Strochlic 2017). While the Ice Stupa continues to be built each year by a team of SECMOL graduates and other volunteers that Wangchuk oversees, the project has become controversial and has even faced several legal battles from the downstream village of Phey. Residents here have resisted the diversion

of water to the Ice Stupa Project (ISP) to "green" Phyang's desert at the expense of their irrigation needs, as they see it.

While the ISP has been legally forced to turn its taps off twice over this conflict, local contestations over water rights rarely receive attention outside of Ladakh (exceptions include Parvaiz 2018 and Sharma 2017). For example, in the midst of local conflict, Wangchuk was awarded the Rolex Award for Enterprise in 2016, including 100,000 Swiss francs to expand his project (Doval 2016). While this global recognition has only exacerbated the ISP's relationship with certain local villagers, the Ice Stupa itself continues, nonetheless, to serve as a global icon and source of inspiration for how communities can creatively innovate place-based solutions to climate change. Even within Ladakh, people from Leh and across the region flock to the site on weekends and holidays to take pictures in front of the frozen cone and post them on social media. Especially for younger generations, the Ice Stupa has become a symbol of what it means to be Ladakhi, embodying a people's creativity and resilience against the odds of climate change.

In this way, the ISP has helped to create a space in which tradition–and true Ladakhi innovation–continues to be practiced and kept alive. Each year 10–12 Ladakhi youth dedicate the winter to building the Ice Stupa, trouble-shooting its problems, and developing best practices. Some of the most creative ideas to improve its design, like incorporating local seabuckthorn bushes to accelerate ice formation, were those of Wangchuk's students. Moreover, in recent years, the Ice Stupa has inspired a number of spinoff projects and innovations to Ladakh's traditions of snow and ice harvesting and interventions. One such example is Chetsang Rinpoche's AIGs, which his team of monastics have been building in water scarce villages of Ladakh's Sham region since 2016. These structures, which take advantage of local topography and do not require the construction of physical infrastructure, involve little more than connecting a pipe to a spring and burying it for several hundred meters to the site of a shaded cliff. There, the water is sprayed on the rock wall, forming thick sheets of ice throughout the winter. Using flexible plastic pipes that can easily be moved and adjusted, and recovered if they freeze solid, villagers are able to "grow ice" on both vertical and horizontal surfaces (Fig. 5).

Recognizing the growing interest in Ice Stupas and AGs, the ISP organized its first competition to encourage the spread of Ice Stupa technology and community-led innovation in AGs more broadly during the winter of 2018–2019. Thirteen teams from villages across Ladakh, many of whom are comprised of

local youth, were trained and provided with all the necessary piping and construction materials to built their own Ice Stupas. Of the villages that participated in the challenge, the teams that build the three largest structures won cash awards of 50,0000, 30,0000 and 20,000 Indian rupees. The idea was that this money would be reinvested in developing new technologies for building AGs that are inexpensive and flexible enough that people will be willing to invest their own time and money into them for the return in irrigation water.[7] Perhaps unsurprising given Shara's longstanding traditions of ice harvesting, it was the team from this village that won first place in the competition with its two ice stupas, 108 and 56 feet high, that contained approximately seven million litres of water. In this way, snow and ice harvesting traditions continue to evolve and take on new shapes within the Ladakhi landscape.

Figure 5. An Artificial Icefall Glacier in Atitse, built for the first time in the winter of 2017–2018
Photo: Sierra Gladfelter (2018)

[7] Compared to Norphel's AGs, which cost between 5,000 to over 30,000 USD and the ISP which cost 30 lakh Indian rupees (approximately 42,000 USD) to set up, AIGs are only a fraction of the price at 15,000–45,000 Indian rupees (approximately 210–635 USD). Therefore, at the time of my research, these were the only structures that villagers were contemplating building with their own resources.

Discussion: The Effects of Intervention

a. Restructuring Local Ownership and Expectations

While global warming is complicating Ladakhi farmers' access to irrigation water, and AGs may be one way to help people survive its effects, it is important to recognize that modern AGs are not a radically new and innovative adaptation to climate change in the way they are often framed. Rather, as I have shown above, contemporary AGs fill a similar role that older traditions of snow and ice harvesting have for many Ladakhis. Moreover, there is a certain irony in the fact that as modern AGs have been built and extended across Ladakh, fueled by a global interest in investing in place-based solutions to climate change, their older sister traditions not only go unrecognized, but have been systematically displaced and marginalized in the process.

As India's WDP funded twelve years of interventions, community infrastructure once collectively built and maintained came to be seen as state property. Even when AGs were built in the same places as traditional *gangsgag*, repairs became rare as communities looked to the state for maintenance. When Norphel built his first AG in Nang in 1987, for example, villagers stopped repairing their traditional walls that same year. It was not that the government-funded structures were so technical that maintenance was beyond the capacity of local farmers. Rather, residents who were paid to build "modern" AGs, no longer saw this infrastructure as theirs nor their responsibility to upkeep. From then onward, the community came to depend exclusively on funds from RDD to support the remaking of their traditional *raks,* now rebranded as AGs.

This alienation of villagers from their traditional ice harvesting technologies and collective practices of maintenance was not intentional in interventions. In fact, Norphel and other engineers building AGs during the WDP era were frequently frustrated when their interventions failed to produce any sense of community ownership. They saw their projects as community-driven and the expectation of RDD was always that village beneficiaries would bear ultimate responsibility for maintenance (Nophel and Tashi 2014). However, their "build-and-abandon" approach to implementation, particularly after paying people to labor during construction, not only failed to generate much sense of local

ownership, but also radically reshaped collective labor practices and the social structures that supported them (Hasnain 2012).

The consequences of this are most obvious in places where Norphel experimented with building more complicated AGs that involved gated diversion canals that could be used to siphon a regulated amount of water off the main stream channel. While diversion-style AGs could be built outside of the steam channel, thereby reducing their vulnerability to flood damage, they were also more expensive to build and complicated to operate (Clouse 2014). During the winter, there was a constant risk that the delivery canal would freeze solid and the ice had to constantly be broken up with sledgehammers. However, once the water reached the AG's walls, it had to flow on top of the already accumulated ice. During visits to new project sites, I witnessed NGO staff and villagers struggling for hours to use soil, bushes, and grass to redirect the flow of water over these AGs. Many older projects, like an AG built under the WDP in Takmachik, never even saw water reach its walls due to leaky canals that failed even after villagers tried to patch them. For many communities, the constant monitoring and repairs required by these structures eventually became too much to sustain even when responsibility was shared via rotation systems (Fig. 6).

As a result, of the 30 or more AGs built under the WDP, almost all have since fallen into neglect and disrepair. Many were destroyed by summer floods even before the project's finances could be settled. Moreover, as the WDP program dragged from four years to twelve, a certain form of knowledge appropriation occurred whereby local traditions of construction and maintenance were slowly allowed to wither away and die even as modern remakings of them were replicated and disseminated to other villages. There, the structures were new and innovative, allowing the implementers to become "climate heroes" for solving Ladakh's dual water and climate crises (Maniusyte, n.d.). When projects were successful, the implementers received awards. When they failed, villagers were blamed for not taking proper ownership.

"[Villagers] are simply after money, not work," Norphel complained in an interview in 2018, describing how difficult he finds it is to inspire people to rebuild damaged walls today. "Unless they get paid, they won't go to work. Now we're paying people to make even a small headwork."

What is obscured in this statement, however, is the role that the very projects Norphel implemented at RDD and later LNP had in restructuring villagers' relationship with their infrastructure. Moreover, it also ignores the fact that

in many parts of Ladakh, farming is becoming a less desirable and economically viable source of income for villagers. Particularly in communities closer to Leh and with greater access to its markets, rates of rural to urban migration are high (Tiwari and Gupta 2008). Many men live in Leh where they work wage-based jobs in the growing tourism industry, leaving villages empty except for the elderly and women.

"Now lots of fields are abandoned not from a lack of water, but a shortage of labor," explained one villager. As families no longer depend on agriculture alone for their subsistence and have fewer able-bodied people available to help, it is unsurprising that many villagers do not want, or simply cannot afford, to spend several hours each day going to check on intake gates and break up ice in blocked diversion canals. Peoples' immediate survival is not tied as closely to the availability of irrigation water as it was in the past. This is not to say that agriculture and the need for water will no longer be necessary, but rather that the shape interventions take and what is expected of people must also evolve. Young Ladakhis, after all, increasingly dream not of becoming farmers like their parents, but of living a more comfortable life in Leh.

Yet this reality is rarely acknowledged in the design and implementation of most interventions. Nor is the fact that AGs in their modern form have been built in Ladakh for over 30 years with varying degrees of success. Instead, the narrative more commonly conveyed in publications celebrating AGs today from National Geographic to Bloomberg Business Week (Dixit 2018; Gulsoken 2018; Kohok 2017; Maniusyte, n.d; Popescu 2018; Stewart 2018; Strochlic 2017; Tousignant 2017), is one in which isolated villagers, the victims of climate change, struggle to practice subsistence farming until they are saved by Ice Stupas and AGs.

What is missing in this myth, however, are many of the realities of Ladakhi people's lives–their traditions, their knowledge, their struggles, and their own choices about how to adapt not only to a changing climate but a changing economy as well. While global warming *is* having profound impacts on Ladakh's physical landscape and agricultural systems, Ladakhis' lives and the worlds they navigate are much more complicated.

Figure 6. Villagers in Nang must break up ice in in the diversion canal to their AG on a rotation basis throughout the winter
Photo: Sierra Gladfelter (2017)

The director of LNP at the time of research, who has been building AGs under Norphel's guidance for 30 years, understood this. He acknowledged during interviews in 2018 that for these structures to remain a viable option for coping with water scarcity, their designs must be as simple and easy to manage as possible. For this reason, he had begun to advocate for a return to more basic in-stream AGs–almost identical to farmers' *gangsgag* and *raks*. During a conversation at LNP's headquarters in Leh, he explained how AGs built in the stream channel require the least amount of maintenance. Using Shara's in-stream AG as an example, he pointed out in aerial photos how even its partially-damaged walls still work to accumulate ice albeit at a smaller percentage of their full capacity. This is in contrast to diversion-style AGs that produce little or no ice with even a minor failure along the intake canal. Moreover, because most of Shara's walls are still made of basic stone, they can be easily modified and reassembled to accommodate changing patterns in local hydrology, whereas concrete and crate wire increase construction costs and also make walls less mobile.

Regardless if AGs ultimately evolve to become more technologically advanced or become more cost effective and resilient by going back to the basics, the

fact remains that they will never provide a sustained solution to climate change or water scarcity for Ladakh in the long-term. Like the traditional structures that predated them, AGs only preserve, for a few months, water already present in the mountains. Fundamentally, no matter how high-tech they become, if Ladakh's natural glaciers continue to disappear and the skies refuse to snow, AGs will do very little to secure Ladakhis from, let alone undo, an impending climate crisis. This humility, however, is often lacking and is perhaps one of the greatest dangers and injustices of contemporary interventions.

b. Reinventing Ladakhi Traditions as "Climate Solutions"

While the ISP invites visitors to its website to, "join Ladakh as it gears up to fight climate change and melting glaciers" (Ice Stupa Project, n.d.), the Tata Trusts proudly highlights how their AGs are "rescuing Leh's water-starved villages" (Tata Trusts, n.d.). "Receding glaciers have reduced the availability of agricultural and potable water in Ladakh and threatened the existence of communities," one article published by the Tata Trusts (2017) reads. The article continues, however, with a description of how the Trusts' AGs offer a "quick and assured solution" to what otherwise would be a climate-exacerbated disaster for rural villages.

Neither the ISP's website nor any of the Tata Trusts' program descriptions, however, make any mention of Ladakhi snow and ice harvesting traditions. Nor are the decades of mostly failed attempts by the government to build AGs across Ladakh acknowledged. Dozens of AGs, built under the WDP and left damaged or abandoned in the headwaters of villages, are documented only in the memories of villagers and in the stacks of handwritten ledgers I once spent two days sifting through in an old RDD office on the outskirts of Leh. Yet in this omission, Ladakhi farmers are not only robbed of the credit they deserve for having invented AGs to begin with, but the limits of how their technologies have been applied and modified over the past three decades, fail to inform contemporary projects that claim to serve and even save them.

This leads to the dual injustices of knowledge appropriation and misrepresentation as funders take Ladakhis' ancient structures and reinvent them as "sexy solutions to climate change," as one representative of the Tata Trusts referred to them in an interview. The reality, however, is that while AGs may have helped farmers survive times of scarcity in the past, they were never a weapon to combat

climate change and are certainly not a solution to this global disaster today. Contemporary AGs are, at most, a way to cope with climate change's most immediate effects and hold on, at least for now, to life in this landscape.

On an individual level, Ladakhis implementing contemporary interventions know this. "[AGs] are just an adaptation technique," one LNP project lead humbly stated. "They are not a solution to climate change." Just like the traditional walls that predate them, and that often lay under them, AGs were never designed to do more than mitigate the effects of seasonal scarcity.

In some villages, however, AGs are not how people necessarily want to adapt to climate change, particularly as livelihoods continue to expand beyond agriculture. This disconnect between village priorities and the interests of funders was most evident when I joined LNP staff on a visit to Sabu to plan the next iteration of an AG there. All the village's powerful men had gathered and an LNP representative was about to explain their proposal when someone spoke up. "You have built AG here three times before," an agitated man stated, "and each time the community did not take ownership." He went on to describe various interventions during the WDP that have all since fallen into disrepair. "They have had no impact." After an awkward moment, the *goba* quickly steered the conversation back to the projects that Tata was interested in funding. He understood the reality that many communities must navigate, and that another village leader articulated so clearly in an interview: "If you build artificial glaciers then you will get funds, if not, [the funders] will go somewhere else with their money. So we build."

During my research in Ladakh, I had the opportunity to attend several other "participatory exercises" in villages, including a meeting between Tata Trusts staff and three local NGOs building AGs on their behalf. Staff from each NGO had recently returned from the field where they had been asking villagers about local water issues and their priorities for interventions. As each group presented their findings, however, frustration began to mount among participants. Tata already had plans to invest up to 400,000 USD into building 28 AGs across Ladakh by the end of 2021. Yet among the dozen villages surveyed, only one had ranked AGs a top priority.

"But *our* priority is artificial glaciers," a representative from Tata asserted. "The maximum amount of money must go to artificial glaciers." One NGO worker, clearly frustrated by this, responded, "But artificial glaciers are not priority one, two, three or even four of the villagers." The representative of Tata

went on to explain how funds to repair *dzing* and *yura*–the villagers' primary concerns–could perhaps be gotten from elsewhere. With this, a new column was drawn down each of the village profiles taped around the room and the list of potential projects were reranked according to Tata's priorities. The NGOs were instructed to continue with their studies in the remaining villages but were advised not to spend much time.

"[Tata] wants to build artificial glaciers hell or high water, no matter what comes out of the exercises," a Ladakhi consultant overseeing the participatory process later stated. This produces a dynamic where, regardless of how urgent the climate crisis is and the need for Ladakhis to adapt, communities are finding themselves in situations where traditions that were once theirs have not only been appropriated from them but are now being forced upon them by outside institutions who claim to know better the solution to their "problem."

Meanwhile, the water crisis looming over Ladakh that catalyzes so many interventions will be felt first in Leh not in villages, by tourism more than agriculture. It is ironic that at the same time donors invest hundreds of thousands of dollars into helping traditional agriculture survive climate change, many farmers are moving to Leh to open guesthouses. Here, new hotels and restaurants are drilling borewells and pumping water from glacier and snow-fed aquifers to service hundreds of thousands of tourists with piped water and flush toilets each year. Nevertheless, Ladakh's water "problem" continues to be sited in villages, and the solution in the form of AGs.

Conclusion

This chapter has examined the relationship between culturally rooted traditions of water harvesting in Ladakh and the emergence of contemporary interventions to build AGs. In doing so, I have argued that modern AGs should be understood as part of an ongoing evolution of place-based traditions of snow and ice harvesting. However, in untangling the knowledge politics that surround contemporary interventions, I have found that rather than a singular story, there are multiple ways to read and analyze the evolution of snow and ice harvesting practices in Ladakh and how they have changed Ladakhi communities in the process. I present two here.

The first is perhaps the most obvious: a story of appropriation, dependency, displacement, and misrepresentation. Engineers like Norphel and Wangchuk continue to win awards for their innovation, claiming credit and accepting praise without acknowledging the Ladakhi traditions in which their technologies are rooted. Meanwhile, 30 years of government and NGO-funded interventions to build AGs have both eroded local social institutions and displaced practices of maintenance as more highly engineered structures have come to be associated with a certain type of expertise not possessed by common villagers. Moreover, as corporate donors have entered Ladakh as the most significant funder of these structures, they bring with them their own priorities in site selection and design, often romanticizing village life and ignoring local priorities and realities. Finally, many contemporary interventions have coalesced a narrative that AGs are somehow a place-based "solution" to climate change, which is a fundamental misrepresentation of what they actually accomplish.

On the other hand, one could also read the transformation of Ladakhis' ice harvesting technologies as a story of creative innovation, diversification, and new opportunities for investment in locally driven adaptation to climate change. One could claim that rather than appropriating traditional knowledge, Norphel and Wangchuk have innovated and strengthened it, borrowing the basics and applying their technical training as engineers to adapt and diversify traditional designs and make them more accessible and efficient with new materials and technologies like crate wire, concrete, pipes, and plastic.

While funders can seem "like a cool breeze that comes and goes," as one Ladakhi NGO worker reflected, the presence of outside donors like the Tata Trusts also provides resources to do more experimentation to make technologies more resilient to flash floods and cloud bursts which may become more frequent with climate change. At the same time, outside investment from donors also enables Ladakhi NGOs to strategically position themselves within contemporary conversations around adaptation, drawing attention and investment by framing Ladakh as both a victim of climate change and an innovator of creative coping strategies. Finally, while no AG provides a real solution to climate change, Norphel's AGs and Wangchuk's Ice Stupa have elevated the problem of climate change in Ladakh in the world's consciousness and have provided a space to educate hundreds of Ladakhi youth about the challenges they face. In this way, the ISP and Chetsang Rinpoche's AIGs are beginning to inspire a new generation of Ladakhis to experiment themselves with snow and ice harvesting technologies.

In the end, both of these readings of how Ladakhi traditions of snow and ice harvesting have evolved have truth in them. AGs, in any form, are deeply embedded in Ladakhi heritage. The engineers and leaders who have taken and adapted these technologies are also from Ladakh, and even the largest external investors in AGs are Indian, with Ladakhi organizations playing a major role in framing and marketing AGs as a place-based mechanism for coping with the effects of climate change. Particularly if we follow Ingold and Kurttila (2000) to the end in understanding traditions as continuous processes that may take on different shapes, textures, and arrangements over time, then Ladakhi efforts at snow and ice harvesting seem to be a tradition that is very much alive and still in the making. Certainly, like most living traditions, it has not been without displacements, appropriations, and misrepresentations along the way, but it has also evolved in new and creative directions as well. In this way, Ladakhi practices of capturing and storing ice continue to help people survive scarcity even as it comes to mean something profoundly new and different within the context of climate change.

Acknowledgements

This chapter is based on research funded by the Fulbright Nehru Student Research Grant program in 2017–2018 while the author was affiliated with the University of Colorado Boulder. The views expressed here, however, are entirely those of its author and do not represent the views of the Fulbright Program, the U.S. Department of State, or any of its partner organizations. This research would not have been possible without the support of staff at Leh Nutrition Project, the Ladakh Ecological Development Group, the Ladakh Environment and Health Organization, and the 2017–2018 Ice Stupa Project team. Additional thanks go to Eben Yonnetti, Elizabeth Williams-Oerberg, Rafał Beszterda, John Bray, and other anonymous reviewers for their insightful comments on earlier drafts of this chapter. Finally, I am especially grateful to Chosdup Mehru, my endlessly enthusiastic and committed research partner and translator. Without him and the generosity of so many Ladakhis who shared their time, traditions, and perspectives, this research project would not have been possible.

References

Agrawal, Arun. 1995. *Dismantling the Divide between Indigenous and Scientific Knowledge*. "Development and Change" 26 (3): 413–439.

Angchok, Dorjey and Premlata Singh. 2006. *Traditional Irrigation and Water Distribution System in Ladakh*. "Indian Journal of Traditional Knowledge" 5 (3): 397–402.

Chevuturi, A., A.P. Dimri, and R.J. Thayyen. 2018. *Climate Change Over Leh (Ladakh), India*. "Theoretical and Applied Climatology" 131 (1–2): 531–545.

Clouse, Carey. 2014. *Learning from Artificial Glaciers in the Himalaya: Design for Climate Change through Low-tech Infrastructural Devices*. "Journal of Landscape Architecture" 9 (3): 6–19.

Clouse, Carey. 2016. *Frozen Landscapes: Climate-Adaptive Design Interventions in Ladakh and Zanskar*. "Landscape Research" 41 (8): 821–837.

Clouse, Carey, Naomi Anderson, and Taylor Shippling. 2017. *Ladakh's Artificial Glaciers: Climate-Adaptive Design for Water Scarcity*. "Climate and Development" 9 (5): 428–438.

Dixit, Kushagra. 2018. *Chewang Norphel: How a 'Crazy' Engineer Solved Ladakh's Water Crisis*. "The Economic Times", 12 March 2018. https: //economictimes.indiatimes.com/industry/miscellaneous/chewang-norphel-how-a-crazy-engineer-solved-ladakhs-water-crisis/the-man-who-creates-artificial-glaciers/slideshow/63265652.cms.

Doval, Nikita. 2016. *Educationist Sonam Wangchuk Wins Rolex Award for Enterprise*. "Live Mint", 17 Nov 2016. https: //www.livemint.com/Politics/oqVWNXghQxgmn9NCa054RP/Educationist-Sonam-Wangchuk-wins-Rolex-Award-for-Enterprise.html.

Gagné, Karine. 2016. *Cultivating Ice over Time: On the Idea of Timeless Knowledge and Places in the Himalayas*. "Anthropologica" 58 (2): 193–210.

Gagné, Karine. 2019. *Caring for Glaciers: Land, Animals, and Humanity in the Himalayas*. Seattle: University of Washington Press.

Gulsoken, Deniz. 2018. *The Ice Man of India is Solving Water Scarcity with Artificial Glaciers*. "Kinder", 23 August 2018. https: //www.kinder-world.org/articles/solutions/the-ice-man-of-india-is-solving-water-scarcity-with-artificial-glaciers-16726.

Gutschow, Kim. 1997. Lords of the Fort, Lords of the Water, and No Lords at All: The Politics of Irrigation in Three Tibetan Societies. In *Recent Research and Proceedings of the Sixth International Conference on Ladakh, Leh* (Vol. 6): 105–115.

Hasnain, Mohammad. 2012. *Artificial Glaciers in Ladakh: A Socio-Economic Analysis*. India: *GERES*.

Ice Stupa Project. n.d. *Artificial Glaciers of Ladakh*. Accessed 13 February 2019. http: //icestupa.org/.

Ingold, Tim and Terhi Kurttila. 2000. *Perceiving the Environment in Finnish Lapland*. "Body and Society" 6 (3–4): 183–196.

Kohok, Shivaani. 2017. Can Ice Structures Solve a Himalayan Water Crisis? *Innovators, BBC World Service*, 3 October 2017. https: //www.bbc.com/news/business-40404852.

Labbal, Valerie. 2000. Traditional Oases of Ladakh: A Case Study of Equity in Water Management. In *Sharing Water: Irrigation and Water Management in the Hindukush- Karakoram-Himalaya*, edited by H. Kreutzmann, 163–183. Oxford: Oxford University Press.

Maniusyte, Ieva. n.d. Chewang Norphel, Ice Man's Dams in the Himalayas. *Climate Heroes*. Accessed 10 February 2019. https: //climateheroes.org/heroes/chewang-norphel-ice-mans-dams-himalayas/.

Norphel, Chewang and Padma Tashi. 2014. Snow Water Harvesting in the Cold Desert in Ladakh: An Introduction to Artificial Glacier. In *Mountain Hazards and Disaster Risk Reduction*, edited by H.K. Nibanupudi and R. Shaw, 199–210. Tokyo: Springer Japan.

Nüsser, Marcus, Susanne Schmidt, and Juliane Dame. 2012. *Irrigation and Development in the Upper Indus Basin*. "Mountain Research and Development" 32 (1): 51–61.

Nüsser, Marcus, and Ravi Baghel. 2016. Local Knowledge and Global Concerns: Artificial Glaciers as a Focus of Environmental Knowledge and Development Interventions. In *Ethnic and Cultural Dimensions of Knowledge*, edited by Peter Meusburger, 191–209. Sham: Springer.

Parvaiz, Athar. 2018. *Ice Stupas Spark Conflict between Farmers in Ladakh*. "India Climate Dialogue", 27 June 2018. https: //indiaclimatedialogue.net/2018/06/27/ice-stupas-not-cutting-ice-with-some-farmers-in-ladakh/.

Popescu, Adam. 2018. *Man-Made Glaciers Could Fix the Himalayan Water Crisis*. "Bloomberg Businessweek", 8 August 2018. https: //www.bloomberg.com/news/articles/2018-08-08/man-made-glaciers-could-fix-the-himalayan-water-crisis.

Sharma, Arjun. 2017. *Artificial Glaciers for a Himalayan Desert: Solution or Hype?* "Mondiaal Nieuws", 21 September 2017. https: //www.mo.be/en/analysis/artificial-glaciers-himalayan-desert-solution-or-hype.

Stewart, Jessica. 2018. *Artificial Glaciers Are Helping Provide Critical Water Supply in the Himalayas*. "My Modern Met", 4 June 2018. https: //mymodernmet.com/ice-stupas-ladakh-himalayas/.

Strochlic, Nina. 2017. *The 'Ice Stupas' That Could Water the Himalaya*. "National Geographic Magazine", April 2017. https: //www.nationalgeographic.com/magazine/2017/04/explore-desert-glaciers/.

Tata Trusts. n.d. *Leh Livelihood Development Initiative*. Accessed 13 February 2019. http: //www.tatatrusts.org/section/inside/leh-livelihood-development-initiative.

Tata Trusts. 2017. *Artificial Glaciers to the Rescue in Leh*. April 2017. http: //www.tata-trusts.org/article/inside/artificial-glaciers-to-the-rescue-in-leh.

Thayyen, Renoj, A.P. Dimri, Pradeep Kumar, and G. Agnihotri. 2013. *Study of Cloudburst and Flash Floods around Leh, India, during August 4–6, 2010*. "Natural Hazards" 65 (3): 2175–2204.

Tiwari, Sunandan and Radhika Gupta. 2008. Changing Currents: An Ethnography of Traditional Irrigation Practices in Leh Town. In *Modern Ladakh: Anthropological Perspectives on Continuity and Change*, edited by Fernanda Pirie and Martijn van Beek, 281–300. Leiden: Brill Academic Publishers.

Tousignant, Lauren. 2017. *Artificial Glaciers Saved This Remote Village from a Water Crisis*. "New York Post", 21 July 2017. https: //nypost.com/2017/07/21/artificial-glaciers-saved-this-remote-village-from-a-water-crisis.

Tveiten, Ingvar Nørstegård. 2007. *Glacier Growing: A Local Response to Water Scarcity in Baltistan and Gilgit, Pakistan*. Master's thesis, Norwegian University of Life Science.

Vince, Gaia. 2009. *Glacier man*. "Science" 326: 659–661.

About the Author

Sierra Gladfelter (MA, Geography, University of Colorado Boulder, 2017) is a human geographer and climate adaptation practitioner. She has studied the entangled impacts of climate change and development on vulnerable communities across South Asia, sub-Saharan Africa, and the United States. Following her graduate training at the University of Colorado Boulder, where her Master's thesis examined a set of development interventions to mitigate the impacts of chronic flooding in southwestern Nepal, Gladfelter spent eleven months in India as a Fulbright-Nehru Student Research Fellow researching community-based adaptations to chronic water scarcity. This study is based on the extensive interviews and focus groups she conducted during this time. Gladfelter currently works in Charlottesville, Virginia as an independent consultant and project manager for the Institute for Engagement & Negotiation at the University of Virginia.