Using Remote Sensing Technologies in Relocating Lubrak Village and Visualizing Flood Damages

Ronan Wallace
Academic Director: Isabelle Onians
Macalester College
Computer Science, Data Science, and Cognitive Science
Lubrak Village, Mustang, Nepal
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Abstract

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As weather patterns change across the world, there are communities impacted by climate change that are left unnoticed. In the Himalayan mountain range, communities have suffered, experiencing an increase in flash flooding and droughts. For Lubrak Village in Lower Mustang, the community faces the threats of flash flooding. Over the last ten years, the amount of flash flooding has increased, occurring more than once each monsoon season. After every flood, concrete-like sediment is left behind, hardening across the riverbed and increasing its elevation. As the riverbed elevation increases, this sediment encroaches on Lubrak Village’s agricultural fields and ancient mud buildings, making them more vulnerable to flood damages. In the last monsoon season alone, the village has seen the flood swallowing several fields, as well as damaging two homes. In order to keep the community safe, the community themselves have been in discussion of relocating the village entirely to a new and safer location. However, relocating the village is a challenging task, where complex nuances exist in both aspects of civil engineering and communal opinions. To investigate this issue further, we look to conversing with the community to understand their needs and perspective. From them, we will be able to develop a plan that amplifies the voices of Lubrak Village. Additionally, we use the power of remote sensing and 3D digital modeling to visualize the village and the new proposed location sites. These models will then be used by the architecture planning and development team to better understand the terrain and layout of the village. From these models, the team will be able to make more informed decisions on how to plan and develop the new village. Finally, we briefly explore other pertinent issues in redirecting the flow of the flood, predicting the new riverbed elevation after the next monsoon season, and further visualizing flood damages through detailed modeling.
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1 Introduction

As we walked, I could feel the sun glare down on my cap, unable to reach my already peeling face. Stones and loose soil shifted with every step, occasionally succumbing to our weight, sending pebbles down the cliff and dust into the air. We had to be careful, for one misstep would send us tumbling 700 meters into the valley. My eyes remained at my feet to ensure a safe journey down. However, every few minutes, I couldn’t help but steal a glance at my surroundings. In the distance west of us, the Dhaulagiri mountain range sat, soaking in sunlight on their white covered faces, greeted by an occasional cloud. Gently pressing us from the south and east, the Annapurna mountain range impassively observed our movement, unable to be disturbed as the warmth of the sun blanketed their peaks. Gratitude and awe filled my body at the restful giants, and I thanked them for sharing their beauty with me.

The further we trekked from Muktinath, the more my co-researcher Yungdrung Tsewang Gurung told me about his village, Lubrak. Considered to be one of the few fully Bön practicing villages in Nepal, Lubrak Village nurtures over 800 years of cultural and ancestral significance. Originally established in the 12th century, it is believed that after Lama Tashi Gyaltsen came from Tibet through Dolpo, making the area suitable for settlement after subduing the land’s unruly local spirits. Furthermore, he determined that if a planted walnut tree would grow, then he knew that the Bön religion would survive here. And soon after

![Lubrak Village (April, 2022).](image)

Figure 1: Lubrak Village (April, 2022).
the tree’s flourishing, so began the lifeline of Lubrak where the tree still exists today.[4] As for its name, Lubrak refers to the uniquely snake-line textured cliffs across from the main village. In the Mustangi dialect of central Tibetan language, ‘lu’ means serpentine naga spirits, and ‘brak’ means rock cliffs, forming the meaning ‘snake valley’, or Lubrak.[4]

Sitting at an altitude of approximately 2,950 meters, the current day village and its 56 active inhabitants rely heavily on agriculture to survive.[5] Each of the families are individually farmers with their own allotted land, while also carrying the responsibility of communal jobs, involving one member from each family.[13] Only a handful of mud buildings and guesthouses—the majority of the village—and its adjacent crop fields reside on the edge of the Panda Khola River. A school, two monasteries, several stupas, a children’s hostel, and water tanks span the rest of the land.[5] As I began to imagine the full picture of Lubrak Village, we surmounted the final hilltop, and there five kilometers in the distance, Lubrak Village sat on the valley slope at the feet of its neighboring and towering cliff sides.

Figure 2: Location of Lubrak Village.
2 Flash Flooding

Making our descent into the valley, Yungdrung La\textsuperscript{1} expressed concern and worry for his village. Every year between mid-June to mid-September, the entire valley faces flash flooding disasters. What is normally the three to five meter wide Panda Khola River turns into a creeping 150 meter wide flood. During these monsoon seasons, water flows through the valley to meet with the Kali Gandaki River, carrying all types of sediment and stone with it. The increase of water turns this valley into a concrete mixer, as the sediment-stone-water mixture turns into a type of viscous sludge (see figure 3). As this sludge collects high in the valley, water may not be able to find passage, causing this muddy water to build. Eventually, the sludge gives way, bringing down a rush of aqueous concrete. These flood bursts repeat without fail over two months. These flash floods span the entire riverbed, and swallow any obstacle in its path (see figure 4).\textsuperscript{4, 5}

Increasing floods are thanks to no other than climate change. Increasing global temperatures has been altering the water cycle across all regions in the Himalayas, and its impacts can be directly seen in Lubrak Village.\textsuperscript{4} Because of the Dhaulagiri mountain range, the region of Mustang has sat dry for the longest time in the barrier’s rain shadow\textsuperscript{ii}. However, rain patterns are changing, and what used to be light rain has turned to destructive, pouring showers just over the last six to seven years.\textsuperscript{10, 11, 13} Furthermore, glacial runoff has been increasing over the last five years.\textsuperscript{4} With a growing increase of water flowing through Lubra valley, the village has been facing more and more flash floods each year.

Other indicators of changing weather patterns are seen through the perspective of locals. As Yungdrung La and I reached the Panda Khola riverbed, he motioned to Mt. Nilgiri, hiding behind the ridge to our left. “I used to see ice on Nilgiri, but now the peak is naked.”\textsuperscript{8} Seeing no snow and ice scares long-lived members of the village, where they have the experience to distinguish how weather patterns were 50 years ago to now. No snowfall means old glacial snow is unable to remain compact, leading to quicker and easier melting. Although snow patterns have not been easily determined, locals are confident that snowfall is decreasing.\textsuperscript{9, 13}

As well as changes in snowfall, increased temperatures have been seen in the south of Marpha, a village known for its apple production. Increasing temperatures have forced farmers to stop planting apples because the crop will not survive. Furthermore, this increase in temperature lures mosquitoes to lay and hatch, causing an increase of mosquitoes during the peak monsoon season in Jomsom.\textsuperscript{13}

\textsuperscript{1}An honorific and respectful term when addressing someone in Tibetan.

\textsuperscript{ii}A region of reduced rainfall due to a topographical guard such as a mountain range\textsuperscript{15}
Figure 3: Sludge-like mixture of sediment, stone, and water. [2]

Figure 4: Flash flooding spanning the entire riverbed adjacent to Lubrak Village. [2]
2.1 Flood Damages

For Lubrak Village, this is a fatal disaster. Located on the edge of the Panda Khola River bank, families are sitting ducks, vulnerable to the destruction of these flash floods. For decades, floods have occurred in the valley once every three to five years, and the village lived safely. However, over the last eight to ten years, one or more flash floods have occurred each year. When a monsoon season concludes, newly brought sediment sets and hardens like concrete at the foot of the village, increasing the height of the riverbed. As the riverbed encroaches on the village, Lubrak is more susceptible to damage. Over the last decade alone, the riverbed has increased an astounding 12 meters in elevation, having already destroyed several fields of crops (see figure 5).[5]

![Figure 5: Fields destroyed by flooding from the last monsoon season in 2021.](image)

As a direct consequence of climate change, the surge in flash floods is eating away at the village at a quicker rate (see figure 6). Last season, the monsoon began around June 14th, lasting for over two months.[10] Here, the first houses were damaged, leaving two families to take shelter in another family’s guest house for three months. Jzikmey, a 25 year old local of Lubrak, suffered with his family as his home felt the rush of the flood, filling the lower most room with wet sediment. Having lived his entire life in Lubrak, he felt pain for his family and home, but resided with not being able to do much about it. “It is what it is,” he expressed with sadness. “If the next monsoon is like the last one, the rest of my house will be gone.”[14]

Because the majority of buildings are stacked upon each other going up the valley slope, the main village stands as one entire building. Each building depends on one another for structural and foundational strength. Because of the village’s architecture, however, damage to one home immediately threatens the structural integrity of the entire village, threatening the safety and security of several families and their homes. The next two monsoon seasons alone could leave several families without homes of their own. Jzikmey looked on, “In ten years, if the monsoons continue as they do, the entire village will be gone.”[14]
With increased flooding and rainfall, traditional mud homes are having more trouble in both the winter and monsoon season. In the last three years, original mud roofs leak more and more due to rain damage, creating additional fear in the community. Mud fences and walls continue to wear away from monsoons of increasing intensity.[13] Additionally, roads have been entirely wiped out. For example, before the last monsoon of 2021, a road was built from the Kali Gandaki River across the riverbed to reach Lubrak Village. With a budget of 30 lakh\textsuperscript{iii}, road construction finished after three months of work. Only two months later, the entire road and everything that was put into it was completely destroyed by the following monsoon season.\[5\] Along with roads and residential homes, the community’s livelihood is further threatened as flooding consumes agricultural fields, rendering them unusable. And if all of that wasn’t bad enough, a 70 year old chorten\textsuperscript{iv} of significant religious importance once standing 25 meters tall, finds itself submerged in concrete, destined to fossilize in the debris (see figure 7).

\textsuperscript{iii}1 lakh is 100,000 Nepalese Rupees, and is approximately equivalent to 800 US dollars. In US dollars, a budget of 30 lakh is approximately $24,000.

\textsuperscript{iv}Tibetan for stupa.
As their spiritual livelihood faces the consequences of flooding, the Lubrak community connect these damages with their spiritual beliefs. Some members believe that the floods and consequences from climate change are due to disturbed spirits, and rely on traditional knowledge over scientific data and conclusions. For example, for a good supply of water, ritual is performed near the primary water source or the home of a spirit related to the water source.[12] When examining this issue, it is crucial to understand how all members of the community feel and try to understand what they believe, as spirituality and religious belief is integral in creating solutions that work best with the community’s needs. We will discuss this further in a later section.

The damage done in recent years shows that the riverbed will continue to rise, and the need for a solution is evident and imperative. As flash floods threaten livelihoods of the community, increasing damage threatens the security of culture and traditions as well. Decades of culturally significant land are being wiped out, and Yungdrung La fears that his ancestral culture and traditions will go with it.[5]
2.2 Culture Under Threat

Cultural and traditional ways of living remain in Lubrak as one of the only few fully Bön\textsuperscript{v} practicing villages in Nepal. Although there are other Bön monasteries in Lower Mustang, none compare to the authenticity of how the village is traditionally and religiously maintained.[4] With that, Yungdrung La worries of its survivability in a cultural revolution, followed closely by varying social changes. In search for a more prosperous life along with reputation in their village, younger generations migrate out of Lubrak Village at a young age, leaving their community and elders behind. Spending most of their youth in a culturally foreign city or country, these children learn the ways of other cultures, and rarely do these children return to their village in adulthood to settle down. For those that do, they are subject to relearning culture and traditions.[3] Because of this, there is not much left in Lubrak Village to sustain these culturally significant traditions, and if the village is destroyed without any attempt of saving its significance, a lot of the tradition embedded in the land may be lost. This makes preservation of the village and its traditions imperative. In order to do so, Yungdrung and his community have begun pinpointing problems of utmost priority to solve.[5]

Reaching the main village, Yungdrung La and I explored these problems over black tea and a full plate of dal bhat\textsuperscript{vi}. With time and thoughtful conversation, we concluded that there were four problems that we can work towards. First, in terms of the main village, we discussed plans and development of moving the entire village to a new location. Second, to slow down the damage of flooding, we looked to past initiatives of redirecting the flood, and how current methods can be improved. Third, to understand the flood further, we discussed analyzing flood patterns to predict how the riverbed will increase in elevation after the next monsoon. And finally, using technology to digitally visualize flood damages. In this paper, we will dissect relocating the village in terms of planning, development, and community opinion. For the other three problems, I will touch briefly on them in future research, and can be used as the stepping point for continuing this work. In order to investigate these issues further, we look to remote sensing technologies to gain a deeper understanding of the problem space.

\textsuperscript{v}Pre-buddhist Tibetan belief system.
\textsuperscript{vi}A traditional Nepalese meal consisting of rice, lentils, and other vegetables.
3 Research Methods

Traditionally, when we think of fieldwork, we think of interviews and in-situ observations. All of your senses activate to experience and observe your surroundings, touching, smelling, tasting, seeing, and hearing what is right in front of you. But what do you do when the area you wish to observe cannot be traditionally explored? For example, a relic is too delicate to touch, only a few photos suffice as an observation. Or, in order to observe traditional architecture, one needs an aerial view that doesn’t exist to human reach. With these limitations, a lot of information can be lost when sharing our experiences and findings. And, in regards to flooding in Lubrak, some believe that the village will be wiped out in 10 years max. This makes time limited, and makes the situation imperative to find a solution to help us better understand the problem for making informed plans and decisions. With an increase in innovative technologies, we can utilize the power of remote sensing technologies as the solution to observe the unobservable quickly and efficiently.

3.1 Data Collection

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object, in contrast to in situ or on-site observation.\textsuperscript{[16]} A plethora of different technologies and sensors exist to observe objects without touching them. However, to explore the problems laid out above, only a drone, a phone, satellite, a GPS-tracking watch, and open-source image collections from the internet will be all we need\textsuperscript{vii}.

With these technologies, our goal is to create 3D digital models and detailed 2D maps that will allow us to explore and observe areas of interest (AOI) across Lubrak Village without having to be there in person. If we have a detailed 3D digital model of an AOI along with 2D maps, we can share it with our research collaborators, allowing them to make informed decisions and plans without having to be at the site in person. These 3D models are needed for the information and insight they provide.\textsuperscript{[6]}

3.1.1 3D Digital Modeling

To create these models, a collection of aerial images are needed of each location. To accomplish this, I flew a drone 50 to 100 meters above every AOI, capturing 4K aerial images. To ensure safe flights, flying had to be done in the morning to avoid intense winds that occur past eleven o’clock in the morning. Furthermore, these flights have to occur between eight and eleven o’clock in the morning where sunlight is optimal and the same because there needs

\textsuperscript{vii}Important note: both the drone and phone must be capable of capturing high resolution imagery (anywhere between 1920x1080 to 4096x2160 resolution would work, where higher is better).
to be even lighting across all images used. Over the span of seven morning flights, I collected over 500 aerial images.

However, on my eighth flight, the drone malfunctioned and flew directly into the Panda Khola cliff side at speed. When recovered, the drone was inoperable with three broken arms, a missing camera, and destroyed battery. Because of this, I had to resort to just using my phone camera for creating the rest of the models. To do this, I hiked along the entire Panda Khola cliffside edge, taking photos with a combination of my phone and binoculars. Furthermore, to increase my collection of images, I requested Yungdrung La to find all images of Lubrak Village over the last 20 years. These photos will be used specifically in analyzing and understanding how the riverbed elevation has changed, along with the damage it has caused.

With these collections of images, we use Agisoft Metashape to process sets of images according to the AOI we are trying to represent. Through the process of photogrammetry, I am able to generate and craft a point cloud into a highly realistic, 3D digital representation of the area of interest, and share them with our research team. These final 3D models will be presented in its related section throughout the rest of the paper.

### 3.1.2 2D GPS Mapping

To create detailed 2D maps, I used a combination of satellite imagery and GPS tracking data. During my time in Lubrak Village, I made an effort to walk every main path to build a map of the village’s trail infrastructure. Additionally, I walked the riverbed edge of the village to map the extent of current damage. These maps will be presented in its related section throughout the rest of the paper. Lastly, the use of satellite imagery will be used to improve riverbed elevation analysis and predictions, and will be discussed in detail in its related section.

### 3.1.3 Oral Interviews

One of the last methods in this project was interviews. Having conducted 12 interviews, I believe that I was able to conceptualize the issues Lubrak Village is facing. However, there are still many nuances and intricacies that are still left untouched, and need to be explored further. For now, we can begin by looking at relocating Lubrak Village, and what that means to the community that lives there.

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[viii]: I do not recommend or condone anyone from doing this, for this method is too dangerous and can lead to death without proper training.
[ix]: Professional 3D modeling software used for processing images into usable models for visualization.
[x]: Technique of measuring objects through photographs.
[xi]: A set of data points in space that represent a 3D shape or object.
4 Relocating Lubrak Village

Relocating the main village of Lubrak is no easy task, and several factors must be considered when making any plans and decisions. We must understand how the village is structured, along with how the community interacts with the land they call home. Trying to understand these nuances through the community’s perspective is imperative. At the end of the day, it’s their village, not ours, so we must plan and design closely through the voices of Lubrak, not ours. When it comes to relocating, the community has identified four locations to consider. We will call these locations A, B, C, and D, and will be discussed in depth in a moment. The goal of visualizing and understanding each location is to help village planners in designing a village that best suits the community.

4.1 3D and 2D Surveying and Mapping

To understand these locations, we can survey the village, its surrounding land, and the new locations themselves through creating 3D digital models and 2D maps from the collected imagery data. These 3D models can be used by the architect and development team when planning the new village. For example, I was able to scan the entire valley side as to allow the team to gain an understanding of land features and visualize how the main village is situated in the valley (see figure 8). See Appendix A (figures 15, 16) to view the entire 3D model of the valley. When faced with the problem of relocating, there is a need for understanding how these areas are connected. With these models, we can visually understand the village’s current state, along with seeing how each location would fit in the new village infrastructure. Furthermore, using the collected GPS-tracking data, we can visualize the trail infrastructure to understand how locals navigate their community from area to area (see figure 9).

4.2 Choosing a Location

As we can see from the figures above, each location is different in size and distance from the main village. Within each location, land is distributed equally among the 14 families. These lands are distributed into 14 plots by the heads of the community to be used for either resettlement or development. Each family’s plot is usually 15 by 15 meters in space. One issue with this, however, is the lack of official certificates issued by the government. This can create a lot of issues in land security and sway opinions in relocating, which we will dissect further in a moment.

Along with differences in size and distance, there are several other factors to consider when determining which location to use for relocating the main village. These factors include but
Figure 8: Lubrak Village on the Valley Side: An angled perspective of the 3D digital model representing the valley side.

Figure 9: A map representing the trail infrastructure of Lubrak Village, as well as the new proposed locations for relocation (A, B, C, and D).
are not limited to: soil strength and integrity, access to utilities (water, electricity, roads, agricultural land), closeness to the main village and monasteries, access to materials, trail infrastructure, and spiritual beliefs. All of these factors need to be considered carefully of one location, and diligently compared to one another. To understand how these factors interact with each other, and how locations are chosen, let’s take a look at the children’s hostel as an example.

When Lama Yangton Tashi Gyaltse founded Lubrak, he meditated in caves on top of one of the western hills. This was deemed as a sacred place of Lubrak, and a monastery was built here to protect the caves. Now looking back only 20 years ago, a children’s hostel was built on the west side of the village, around half a kilometer from the main village. It was originally built here because it was adjacent to the Gonpuk\textsuperscript{xii} Monastery, increasing the quality of learning of the Bön religion, an integral part of the children’s studies here. This location was chosen for its wide space and nearness to the monastery, along with its flatness. However, the top soil here is fine, and is easily dusted when kicked. This makes the foundation for buildings weak and loose, and has already caused issues. When the children first moved in, some of the building collapsed due to the shifting soil underneath, forcing students to take shelter elsewhere for well over a year. Another possible site that was considered was next to the newly built school on the eastern side of the village. This was decided against, however, because it was near the ceremonial burning ground and wasn’t seen as safe to have children around.\[13\]

From this example, we can notice how both cultural and geophysical factors intertwine in deciding which location is most suitable to use, showing the importance of identifying all factors of a location that may influence the community’s decision. With the four identified locations, we can break them down by these factors, and evaluate their pros and cons.\[5\]

4.2.1 Location A

Location A is directly adjacent east to the main village, only a stone’s throw away. Here, buildings would be built vertically up and along the slope, and would seem almost like an addition to the main village. As mentioned before, the land here is distributed equally among the 14 families, each having their own 15 by 15 meter plot of land. The soil here is hard and compact, and works as a strong foundation to build on.\[13\] Here, Yungdrung La has already begun building the foundation of his new home. This is an optimal location for its proximity to the original village as well as the Yungdrung Phuntsok Ling monastery. However, it is still very close to the oncoming flash floods, and remains vulnerable to future damage (see figure 10).\[5\] See Appendix A (figures 17-19) to view the entire 3D model of location A.

\textsuperscript{xii}Tibetan for cave
4.2.2 Location B

Location B lies south and high above the village. To get there, one has to hike a 300 meter increase in elevation across one kilometer, lasting around an average 30 minutes upward. Here, a walled-off apple orchard exists on a very slight slope. Spanning approximately 66 square kilometers, the orchard is mostly flat, and has access to water piped directly from glacial runoff. About two-thirds of the orchard has apple trees and is individually sectioned out to families of the village, while the other third is communal land. The area seems like a good location in terms of space, water, and agricultural land, however, access to the land is more difficult. There has been talk, however, of a road being developed from the east side of the village near the new school.[8] The issue with this, however, is the risk of damaging soil integrity, as the increase of road development weakens the soil around it. Additionally, this location is the second farthest area from the main village (see figure 11).[5] See Appendix A (figures 20-22) to view the entire 3D model of location B.

4.2.3 Location C

Location C sits just under a kilometer east of the main village. Here, the terrain is slightly hilly, but is still relatively close to the main village. To get here, one only has to walk one kilometer with little elevation gain. Currently, it is staked with wooden markers to show the boundaries of the distributed land.[8] The area is quite open, and has direct road access, which is a huge plus. One problem, however, is that this location is adjacent to land that is used as ceremonial burning grounds for the dead. Because of this, some community members
feel uncomfortable moving here because of spirits that may reside there (see figure 12). See Appendix A (figures 23-25) to view the entire 3D model of location C.

Figure 11: Location B: An aerial view of the 3D digital model representing location B.

Figure 12: Location C: An aerial view of the 3D digital model representing location C.
4.2.4 Location D

Location D, the furthest from the village, towers the main village on the other side of the river. Here, there is a large amount of relatively vast and flat land. However, there is controversy over the plot, as there is no mutual agreement between Lubrak Village and Kagbeni Village on who it belongs to. Because of this, building here at this moment in time is too controversial. Furthermore, utilities here are scarce, and the location is extremely distant from the main village. For this location, a large budget is required to develop the land, including water access and road development.

4.3 Community Opinions

4.3.1 Location Choice

As we can see, each location has its pros and cons, each differing in which location would be most suitable. To choose a final location, however, all families must be in agreement of which location is best to move to. However, with each family having their own opinions, complete agreement is extremely difficult to achieve, especially in a short amount of time. For example, Jzikmey believes that location A is better suited, for he finds importance in staying near the Yungdrung Phuntsok Ling monastery. Staying close makes it easier to care for the monastery from this location. Furthermore, location A does not require any new road development. Other families, however, believe that location D is the better suited choice for its vast space.

4.3.2 Building Design

Along with which location is the right choice, I explored how the community wants to build on that chosen land. Specifically, I looked at the community’s opinions on what style of buildings should be built. Everyone I interviewed mostly had the same opinion of wanting traditional mud homes to be built. These mud buildings are built with combined techniques of stacked stones for the foundation, rammed earth for the walls, and then topped with earthen roofs. Because Yungdrung La’s new home was being constructed, I was able to create a 3D digital model representing his home in the early stages of construction (see figure 13). See Appendix A (figures 26-28) to view the entire 3D model of the construction of Yungdrung La’s home.

\[\text{xiii}\] A combination of small gravel and mud that is rammed with a wooden post to create a compact and withstanding structure.
For decoration, locals will paint the outside with red and white color, along with storing firewood on the top edge of their flat roofs. One of the important reasons nowadays for maintaining this traditional style in the new village is because it will continue to attract tourists. Tourists want to see these traditional homes, and will bring more money into the community to see them. One issue with maintaining full traditional homes is the issue of leaking from damaged roofs. Due to increasing rain and monsoons, how these buildings are roofed needs to be considered and improved.

When looking at roofing, there are three options, current traditional mud roofs, tins roofs, and modern concrete roofs. As mentioned, mud roofs are becoming more difficult to maintain in changing weather patterns. Ten years ago, some locals started adding plastic in the roof between the grass insulation and mud itself, but it can still be difficult to maintain. Looking at alternatives, a tin roof may seem like the easiest and most logical choice. However, it’s a controversial one. Although rain proof, a tin roof can be ripped off during severe wind storms. For example, the structure on the hill above the main village was built with a tin roof around 12 to 15 years ago to serve as a new community meeting hall. However, five to seven years ago, the tin roof of the community hall was torn off by a severe wind storm. Due to lack of money, the community could not afford to repair it and the remaining structure has been left unusable since. Another problem with tin roofing is that if it is torn off, then it may hurl into other homes, damaging them and putting others lives in danger. One proposed solution is to maintain traditional mud building but incorporate modern design in the roof using concrete. One problem with this, however, is that mud buildings are a lot more effective at retaining heat than concrete buildings (especially important during winters), so there may be significant heat loss through the concrete roof.
4.3.3 Relocation Reluctance

Even if the community agrees on where to move, village communities are generally reluctant to relocate, regardless of the circumstances. For example, because of the earthquake of 2015 in Nepal, a village in Tsum Valley was damaged, leaving the community in need of support. After a new village was constructed above the damaged one, some of the community members refused to move and continued to live in the damaged village. A similar situation is occurring in Lubrak Village. Regardless of the threat of their village and homes being entirely wiped out, some may prefer to live with the disaster until they die with their village than relocate.\[6\] This is a huge problem, because if community members choose this mindset, then the loss of ancestral homes won’t be the only problem. Not only will the home be lost, but those who carry the knowledge to revive dying traditions will die with it, wiping Lubrak Village from existence entirely. No one will be alive to carry on the ancestral culture of Lubrak Village.

Another issue that makes locals reluctant to relocate is land security. Although the village has individually allotted land to each family, the lack of government-issued certificates and recognition leaves families in fear. Having no certificate means that no matter how much they claim a plot of land, the government can come and remove them, invalidating land claims entirely.\[6\] Having guaranteed certifications of land ownership could sway opinions on relocating the village. Other issues include the complexities of planning transportation, logistics, and labor to construct a new village.\[6\] Additionally, some locals worry that any development could negatively disturb spirits.\[12\]

5 Conclusion

Looking at relocating Lubrak Village, we can see that there are several layers involved, each overlapping with one another in their own unique way. Everything is intertwined through hundreds of years of ancestral and cultural heritage. In terms of digital visualization, we can see the effectiveness of this method, and through highly detailed models, understand the power of this method and how it can be used in understanding the community from a structural view. To make informed decisions on where and how to relocate, we can use a combination of remote sensing for digital visualization, coupled with in-person interviews and observations to understand the complexities of Lubrak Village. Through these interviews, we are able to gain a deeper understanding of perspective in the community that will amplify their voices in the planning and development of a new village. Our work is guided by their needs, and cannot be done any other way.
6 Future Research

For this work, there is still a lot to be done. During my time in Lubrak Village, I spent a lot of time thinking about the problem the community of Lubrak is facing, and how technology can be used to assist. With the four identified problems, we explored relocation and what that means to the community. However, there are three other big problems that still need to be worked on. These problems include flood redirection, riverbed elevation predictions, and visualizing flood damages. We will dig briefly into each as to set up others to understand these issues and continue this work with ease.

6.1 Redirecting the Flood

As well as relocating the village, there is a continuing initiative to redirect the flood through man-made intervention. For example, for the last 20 years, gabion wire boxes\textsuperscript{xiv} have been built as barriers against flooding (see figure 14).\cite{7, 13} However, these barriers have not always been effective. As an alternative, the community has been experimenting with digging a trench to control the flow of the flood.\cite{7} Both of these solutions have their own pros and cons, as well as accompanying community opinions on which solution is best. For future work, these issues need to be explored more in depth, for there are significant factors including budget, timeline, and labor to install the best solution. Furthermore, we can tackle this issue from an engineering standpoint by exploring the quantification of flood volume to calculate the exact dimensions of the to-be-built trench.

6.2 Predicting Riverbed Elevation

To understand flooding further, we can look at how the elevation of the riverbed has changed over the last 20 years. With this information, we can see a trend in how the elevation is changing, and use this information to predict where the elevation will be after the next monsoon. This will give insight on which homes will be affected next by the floods, and how much agricultural land will be left for farming. One issue with this, however, is a lack of data. There is currently no formal dataset that provides elevation changes of our area of interest. Because of this, we can look to satellite data over the last 20 years to compile these changes. This can be done by taking satellite imagery and using it to create a digital elevation model (DEM) of the riverbed every year. From this, we can analyze if there is a trend in increasing elevation, and what that looks like for the future.

\textsuperscript{xiv} A cage, cylinder or box filled with rocks, concrete, or sometimes sand and soil.
6.3 Visualizing Flood Damages

When it comes to visualizing flood damages, I would say that this is one of the most important issues to work on. Currently, there is a lack of data and lack of visuals in representing the floods that occur in Lubrak. Because of this, not many people know about the flooding, and those that do, react briefly then forget about the issue a month later after the monsoon. Furthermore, Mustang locals and trekkers are skeptical of the Panda Khola River being dangerous in terms of flooding. These conclusions are made, however, when the river is visually small and tame. These people don’t actually see how catastrophic it can be. Additionally, other villages are skeptical because they experience climate change in terms of drought, not flooding, so they do not believe that there is damage occurring from excess water.

With that, it is imperative to develop a way to visualize flooding and the damages it is causing. After acquiring the riverbed elevation prediction, we can get a general idea of where the elevation will be after the next monsoon season and beyond. We can then visualize this using a 3D model of the village to demonstrate where the new elevation will be, and show how imperative it is to act now. These visualizations can be further used in proposal development for acquiring funding, which can be used directly in efforts to relocate the village and redirect the floods.
7 Moving Forward

Over the next several months, I will continue to work on this project for my honors thesis, including returning to Lubrak Village to acquire more aerial imagery of the riverbed and the main village. This data will be crucial in visualizing the current state of the village and the riverbed itself. Additionally, this is a great method to digitally preserve what’s left of Lubrak Village before it is wiped out entirely by flooding. Furthermore, I will be leading a team of software engineers and data analysts to tackle these issues from an engineering perspective. If any of this work seems of interest, if you have any critiques/suggestions, or you would like an update on the current state of the project, please feel free to reach out to me at rwallace@macalester.edu or ronanlwallace@gmail.com anytime, and I would be happy to connect.
Appendix A: 3D Models

Figure 15: Lubrak Village on the Valley Side: An angled perspective of the 3D digital model representing the valley side.

Figure 16: Lubrak Village on the Valley Side: Varying angled perspectives of the 3D digital model representing the valley side.
Figure 17: Location A: An aerial view of the 3D digital model representing location A.

Figure 18: Location A: An angled perspective from each corner of the 3D digital model representing location A.
Figure 19: Location A: A zoomed-in perspective of the 3D digital model representing location A, specifically around the house under construction. The detail of this model can be seen here.

Figure 20: Location B: An aerial view of the 3D digital model representing location B.
Figure 21: Location B: An angled perspective from each corner of the 3D digital model representing location B.

Figure 22: Location B: A zoomed-in perspective of the 3D digital model representing location B, specifically around the northwest corner of the apple orchard. The detail of this model can be seen here.
Figure 23: Location C: An aerial view of the 3D digital model representing location C.

Figure 24: Location C: An angled perspective from each corner of the 3D digital model representing location C.
Figure 25: Location C: A zoomed-in perspective of the 3D digital model representing location C, specifically around the northwest corner of the apple orchard. The detail of this model can be seen here.

Figure 26: Yungdrung La’s Home: An aerial view of the 3D digital model representing Yungdrung La’s home.
Figure 27: Yungdrung La’s Home: An angled perspective from the two front corners of the 3D digital model representing Yungdrung La’s home.

Figure 28: Yungdrung La’s Home: An angled perspective from the back corners of the 3D digital model representing Yungdrung La’s home.
Figure 29: My co-researcher Yungdrung La and I hiking from Muktinath to Lubrak Village.

Figure 30: Conducting interviews in Lubrak Village.
References


