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Enriching college students through study abroad: a case of Nepal Field Experience Part 2

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Abstract— **With a view of providing an unsurpassed opportunity to college students, who are mostly from Louisiana, in gaining a comprehensive understanding of Global Climate Change issues, we completed the first Nepal Field Experience Pilot Study Abroad from May 21-June 8, 2019. A total of fifteen students from the University of Louisiana at Lafayette, Louisiana, USA, and one graduate student from University of Arizona, Arizona, USA, participated in the program. Students examined and documented the effects of climate change impacts on agriculture, water resources, wildlife, local communities, forest resources, and other ecological and environmental settings of the country. They identified various climate change mitigation and adaptation measures that had been implemented and noted gaps between policy measures and ground realities. Research topics selected by the students included the following: climate change impacts on wildlife, water pollution, structural geology of Nepal, changing rainfall patterns and adaptation, climate change and agricultural production, geology of Kathmandu valley, air quality of Kathmandu valley, changing hydrology of glaciated landscape, climate change and geohazards, emerging diseases and pests on agricultural crops, climate change adaptation by local communities, green infrastructure and climate-smart technologies, climate change impact on drinking water sources, the roadside geology, and emerging diseases, parasites and zoonotics. Each student completed their individual research project, synthesized the results, and presented to local stakeholders in conference organized by a nonprofit nongovernmental organization, Asta-Ja Rsearch and Development Center (Asta-Ja RDC), Kathmandu, Nepal. Findings of the study reveal that Nepal is experiencing huge impacts of climate change in multiple fronts including atmospheric conditions and snowfall, temperature rise, occurrence of droughts and flooding, changes on monsoon pattern, emerging diseases and pests on crops and livestock, and declining drinking water sources. Environmental pollution, especially the air and water pollution and waste management, was very serious affecting public health, aesthetics, and even the tourism of the country. In order to reverse environmental degradation and enhance climate change adaptation, immediate implementation of effective, comprehensive, coordinated, and well-thought-out climate change adaptation and environmental initiatives are necessary. Nepal Field Experience was a lifetime learning experience for the students.**

Index Terms— Study Abroad, Global Climate Change, Environmental Quality, Geology, Nepal

I. Environmental Quality

A. Air quality

The city of Kathmandu is one of the most densely-populated cities in the world, cramming over five million people into an area of 665 square kilometers. Kathmandu Valley spans three Nepalese districts: the entirety of Bhaktapur District, approximately 85% of Kathmandu District, and about half of Lalitpur District. Non-governmental organizations such as the Organization for Economic Cooperation and Development (OECD) have developed an environmental framework for Kathmandu Valley, addressing five main issues: 1) air quality and traffic management, 2) settlement patterns, 3) water resources, 4) waste management, and 5) natural disaster preparedness, focusing primarily on earthquakes and land subsidence.

Kathmandu's air pollution is severe, making it hard to breathe and even see the surrounding mountains (Photo 6).

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Kathmandu Valley is bowl-shaped. As a result, the polluted air is trapped and lingers above the city. Air quality experiences seasonal changes, getting worse in the winter and improving during the summer months; however, the trend shows that air pollution is consistently increasing annually. The city of Kathmandu apparently lacks enforcement of environmental rules and regulations. Vehicles including buses, trucks, motorized bikes, scooters, taxis, and personal cars emit a large amount of soot from their exhaust. Particulate matter is another serious pollutant in Kathmandu's air. In our experience, the low visibility conditions in Kathmandu's smoggy air detracted from the city's natural beauty and obscured a number of tourist sites. This is a major issue for Nepal's government if it is to continue to market itself to the world as a world-renowned tourist hotspot. Only after a major rainstorm the night before we left Nepal were we able to experience the real beauty of the country. The bad weather cleared out the smog and settled airborne particulates, allowing the Himalayas to be visible.

PHOTO 6. AIR POLLUTION IN THE CITY OF KATHMANDU, NEPAL.

Source: taken by the co-authors of this article

The $PM_{2.5}$ concentration of Kathmandu Valley clearly indicates the presence of very poor air quality in the area (Table 2). This is a result of a number of factors. The largest source of air pollution, of course, comes from motorized vehicles. The majority of the vehicles that operate in the city of Kathmandu use diesel fuel, which generates harmful emissions and contributes to increased levels of particulate matter and soot. A study carried out by ICIMOD and researchers from Tribhuvan University discovered that the majority of pollution created by motorcycles could be fixed with simple routine maintenance on their motorcycles at a cost of roughly 1000 NPR (ICIMOD, 2016). Construction work also appears to be a major source of particulate matter in the air, as heavy trucks needed to clear land and carry building materials send dirt from the road airborne. Brick production is another major source, as kilns scattered across the city require immense heat from burning to fire clay into bricks. The burning of biomass and trash, which is common in Kathmandu, is another source. According to the Minnesota Pollution Control Agency, burning trash leads to the formation of poisonous substances such as styrene, benzene, and formaldehyde, as well as the creation of smoke. Even simple daily activities like sweeping dust outside shops and in streets stirs up the settled particles and suspends them in the air, contributing to the haze.

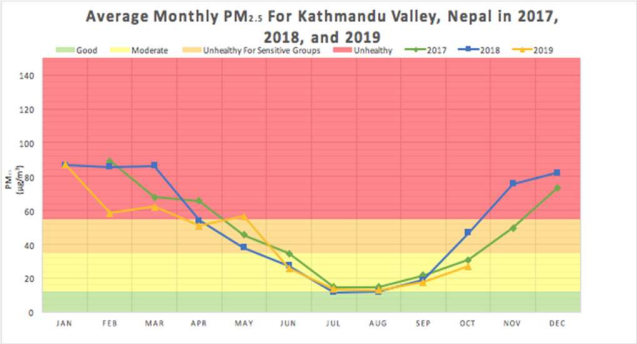
TABLE 2. $PM_{2.5}$ AIR QUALITY INDEX (AQI) OF KATHMANDU VALLEY FROM JANUARY TO JUNE FOR THE YEARS OF 2017-2019.

Year	Sample size	Range	Average	Median
2017	4,140	8-431	130.9	138
2018	4,140	68-224	147.6	156
2019	4,140	31-438	128	128

Source: US EPA

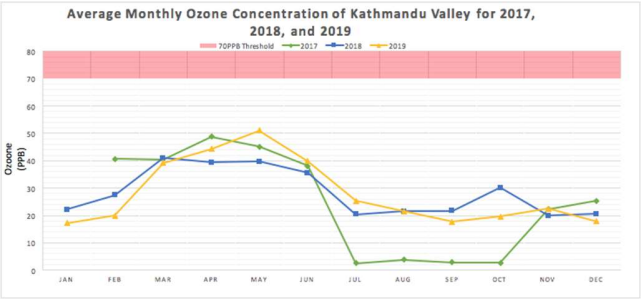
Particulate Matter 2.5 is a measure of suspended particles and liquid droplets in the air that are smaller than 2.5 microns in size. The sources of particulate matter range from burning organic and inorganic material, combustion of fossil fuels, and car exhaust. The danger of these particles is that they are small enough to be inhaled into the lungs. According to The United State's Environmental Protection Agency, the subsequent health effects of routine exposure to dangerous levels of $PM_{2.5}$ leads to irregular heartbeat, aggravated asthma, decreased lung function, and even premature death in individuals with pre-existing heart disease. $PM_{2.5}$ has damaging effects on the environment as a whole as well, such as depleting nutrients in soils, contributing to acid rain, and damaging to sensitive farm and forest crops. The US EPA has defined thresholds in which $PM_{2.5}$ concentrations are considered to be harmful. Any acute exposure to $PM_{2.5}$ concentration over the threshold of 35 $\mu g/m^3$ for a 24 hour period is unhealthy for any individual exposed to it. Ozone is a gas that is found in abundance in the stratosphere, its function serves to protect the earth from the sun's harmful ultraviolet rays. However, Ozone that occurs at the ground level, or tropospheric ozone, have harmful effects on the individuals that inhale ozone in high concentrations. Tropospheric Ozone is formed through a series of complex interactions between oxides of nitrogen and volatile organic compounds in the presence of heat and sunlight. The source of these compounds come from industrial plants, the exhaust of cars, and/or from power plants. The US EPA has defined the harmful effects of ozone as chest pains, airway inflammation, and reduced lung function. Ozone can also worsen the effects of bronchitis, emphysema, and asthma. The US EPA has set the threshold of harmful levels of ozone at 70 PPB. An analysis of the air quality data of Kathmandu Valley reveals that the residents in the Valley are having chronic exposure to $PM_{2.5}$ throughout the months of November through May (Figure 3). This trend is consistent throughout the three years analyzed. Even throughout the months of June through October the level of particulate matter never drops below the moderate threshold. Chronic exposure to moderate amounts of particulate matter, above 12$\mu g/m^3$ and below 35 $\mu g/m^3$, might not be as harmful as chronic exposure to $PM_{2.5}$ but certainly it is not good for the health of these citizens. The ozone concentration seems to stay below the US EPA's threshold of 70 PPB throughout the entirety of the year with the exception of a few outliers in the data set (Figure 4).

FIGURE 4. AVERAGE MONTHLY CONCENTRATIONS OF $PM_{2.5}$ IN KATHMANDU VALLEY, NEPAL (2017-2019).



Source: US EPA

FIGURE 5. AVERAGE MONTHLY CONCENTRATIONS OF OZONE IN KATHMANDU VALLEY, NEPAL (2017-2019).



Source: US EPA

As a result of the poor air quality, the citizens of Kathmandu frequently wear face masks when walking outside to protect their health. Almost every local we talked to was coughing as if they had smoked a pack of cigarettes a day for their whole lives, even children. The poor air quality in Kathmandu is so prevalent that it was even noticeable on the animals that live on the streets. Kathmandu is home to a large number of stray dogs. During the group's stay in the city, petting the stray dogs sometimes caused the dogs to cough and hack up foreign objects – primarily black soot – from their lungs. Being exposed to such poor air quality for one's entire life can lead to chronic obstructive pulmonary disease, or COPD. In the United States, approximately 4.2% of the population suffers from COPD, usually as a result of chain smoking (Doney, 2014). In Nepal, it is estimated that anywhere from 23-42% of the Nepalese population has COPD (Gautam, 2017).

B. Water quality

Besides the ongoing issue of serious water scarcity in Kathmandu, available water – in the forms of surface water, ground water, and government-installed water sources – are polluted and often contaminated by coliform bacteria. Much of the water infrastructure in Kathmandu is damaged, allowing the pollutants to enter the drinking water. Water pollution in Kathmandu is a man-made issue caused by urbanization (Photo 7) and climate change that has been amplified by water scarcity. The major source of water pollution in Kathmandu is community and sewage waste. Kathmandu produces more than 40 million liters of waste water per day. As of 2015, there were seven waste water treatment plants in the Kathmandu Valley. However, only two are in operation and three in partial operation, so they cannot meet the waste disposal needs. Most households use septic tanks that drain liquid into waterways. The limited operation of solid waste management facilities has polluted the waterways and threaten the introduction of microplastics. In the city, there is a lot of trash everywhere, causing the rivers and streams to be heavily polluted with brown-colored water and providing the whole city of Kathmandu with a distinct repulsive odor.

In the past, locals in the Dhobi Khola watershed would use the stream for bathing and washing clothes. This is no longer plausible due to untreated sewage being discharged into the stream (Table 3). The untreated sewage is likely the cause of the obvious odor that was noticed in the watershed. Aside from the obvious odor, we observed a high total of suspended solids, high turbidity, and a large amount of trash in the stream (Photo 8). It was clear that the stream was not remotely sustainable for aquatic life. Flooding is also a method of transport of pollutants and pathogens into nearby communities.

PHOTO 7. SURFACE WATER POLLUTION IN KATHMANDU, NEPAL

Source: taken by the co-authors of this article

The floods in the Dhobi Khola watershed have also swept away multiple bridges that have been constructed along the stream. Locals noted that floods are becoming more frequent and that homes along the stream are often affected by the flooding.

TABLE 3. OBSERVED WATER QUALITY OF THE DHOBI KHOLA WATERSHED, KATHMANDU.

Site	Observed water quality
Site 1	Most polluted of all the four sites. Water flow was very obstructed and slow and water was very turbid. The water smelled heavily of fecal matter, which was made obvious by septic tank run off visibly flowing into the river. The area where runoff was evident also had bubbles appearing on the surface, a possible sign of life, methane, or hydrogen sulfide, resulting in the probable high biochemical and chemical oxygen demand of the river water here. There was also a dead rat lying in the river; the cause of death was not known, but it was lying on top of a plastic bag.
Site 2	Water was moving slow, was less turbid than site 1. The set of walls were wide. Area smelled slightly of fecal matter, most likely from septic tank run off. Large deposits of silt and litter sit along the edges and center where water is especially slow. The city has made an effort to plant vegetation along the river, but all plants were in cement containers, so they offer no

	vegetative barrier against pollutants and litter.
Site 3	Very turbid water. Water has significant amount of litter in and at the banks of the river. In this area, like much of the river in the urbanized area, there were built-up walls on either side of the river with sewage lines from septic tank run off flowing into river. The bottom of the walls has visible erosion to them, and speaking to locals, it was learned that the walls were only about three years old. Solutions to reduce undercutting on the wall consists of rock barriers at the bottom, which reduce water velocity, but also make the river narrower; continuous solutions like this could lead to increased flooding in the future as the river has less area to flow. According to the interviewed local, the government plans to build a line to divert septic system discharge downstream to the Bagmati river. This area has experienced flooding, so the wall and adjacent road is taller than the houses around it to act as a barrier.
Site 4	By far the cleanest, but still had a notable amount of litter in and around the water, some of which were empty cement bags from previous construction in the area. Water was only slightly turbid in this area and there was no apparent smell coming from the water. In this area a dog was drinking the water and a person was swimming. There were houses nearby the river, but they were separated by some vegetation. Between site three and four there were several people with their ducks and cattle sitting in the river, presumably kept for meat and milk, respectively. Any pollutants in the water could not only affect the animals, but also humans that rely on them for food.

Source: prepared by the co-authors of this article

Groundwater is also polluted due to leaking of poorly-maintained septic tanks. Because of insufficient limits on wells and other means of extraction, the Kathmandu Valley Aquifer is overtaxed, leading to drawdown of groundwater. It is estimated that 50% of the aquifer is susceptible to groundwater pollution, and that 83% is susceptible to pollutants. With many wells drawing from shallow sources in the Kathmandu Valley, along with an ever-increasing demand from the urban population, the availability of drinking water has potential to experience severe shortages in the near future. Also, the nearly unrestricted development of new construction sites with little regard to the treatment of water and implementation of proper septic systems is a growing issue. The eventual introduction of untreated sewage into local streams due to lack of infrastructure exacerbates the problem of the presence of multitude of biological contaminants – such as fecal coliform – in addition to a host of other diseases ranging from cholera to hepatitis.

The rapidly expanding population and subsequent pressure placed on watershed areas and aquifers results in a deficit of aquifer recharge and contamination of water. According to the Kathmandu Upatyaka Khanepani Limited (KUKL) annual report from 2018-2019, the daily demand of water in Kathmandu is approximately 415 million liters per day (mld) while the production capability of utility services is a meager 116.7 mld. In addition, about 20% of that production is lost due to leakages in the delivery system. This has led to the creation of private companies that offer a more dependable supply via water tankers and shallow wells. Regardless of the sources, private or public, a 2017 study by the District Public Health Office found that 66% of water consumed in Kathmandu was tainted with bacteria such as E-coli and fecal coliform.

PHOTO 8. STUDENTS OBSERVE AND ASSESS WATER QUALITY OF DHOBI KHOLA IN KATHMANDU, NEPAL

Source: taken by the co-authors of this article

Phewa Lake in Pokhara was invaded by flowering water hyacinths. Water hyacinths are an invasive aquatic plant that has a very fast growth rate. The local people work daily to handpick these plants near the edges of the lake in an effort to control the spread, as they can affect boating in the lake. Boats cannot pass through these plants. Water hyacinths can also affect the environmental conditions as they lower dissolved oxygen of the lake water and reduce lake diversity. These plants also create ideal conditions for mosquitos and other disease vectors.

II. EFFECTS OF CLIMATE CHANGE

A. Changing atmospheric conditions and snowfall

Atmospheric conditions and snowfall patterns around Kathmandu Valley have been affected due to climate change. The presence of a thick haze in the atmosphere, chilly winter nights, and snowfall in the mountains surrounding Kathmandu Valley are some of the examples of recent climate change impacts. Nagarkot experienced snowfall for the first time in recent history on February 14, 2007. The occurrence of snowfall came as a surprise to the local community because the last time they experienced snowfall was in 1945. Since then, Nagarkot has had two additional snow events in February and March of 2019. In times of snow, there are fewer pests and diseases, affecting agriculture in the area and lowering mosquito population. On the other extreme, overall temperatures have begun to rise and locals fear increasing diseases, pests, and water scarcity in the coming years. This area relies heavily on tourism for its livelihood, which is beginning to decline as a result of increased levels of smog blocking the view of the Himalayas in recent years.

B. Temperature rise and changes on precipitation and hydrology

It is a well-established fact that Nepal is experiencing temperature increases and the incidences of extreme weather conditions in recent decades. Monsoon patterns are changing

and the number of rainy days is increasing, resulting in more flooding. Kathmandu is experiencing an increase in temperature that exceeds the Intergovernmental Panel on Climate Change (IPCC) predicted value of 1.0°C increase by 2029. Increases in temperature, coupled with changes in rainfall patterns, have affected agriculture, forestry, wildlife, hydrology, mass-wasting, and several other bio-physical and socio-economic factors. Building communities resilient to natural disasters due to climate change impacts has become a necessity.

The seven most popular lakes in Pokhara Valley include: Phewa Lake (4.43 sq.km), Begnas Lake (2.5 sq. km), Rupa Lake (1.4 sq. km), Maidi Lake (0.41 sq. km), Khaste Lake (0.21 sq. km), Gunde Lake (0.05 sq. km), and Dipang Lake (0.026 sq. km). Dipang Lake has changed into a small pond due to climate change and its effect on hydrology. The decrease in the sizes of these lakes have been a major environmental concern in recent years.

C. Agricultural production

Nepal includes three broad physiographic regions: High Mountains, Mid-Hills, and the Terai. Rice and wheat are the two major crops that are grown in the Terai, while maize and finger millet are the main crops grown in Mid-Hills and High Mountains regions. Other non-staple crops grown in Nepal include legumes, seasonal vegetables, potatoes, and other cash crops. Nepalese agriculture is largely dependent on rain. Since the major staple crops are cultivated during monsoon season, the degree of rainfall has a significant impact on productivity and food security in Nepal.

Field observations showed that various crops in the field were short and shrub-like rather than tall like they should be. Terracing was noticed in the mountains, which can protect soils against erosion. Agricultural fields in Nepal are not in one area; they are spread out in random locations throughout the countryside. Livestock were also observed frequently. According to Poudel and Duex (2017), over the past 10-20 years, 12.2% springs had dried up and 73.2% have decreased flow in the Thulokhola watershed in Nuwakot district of Nepal.

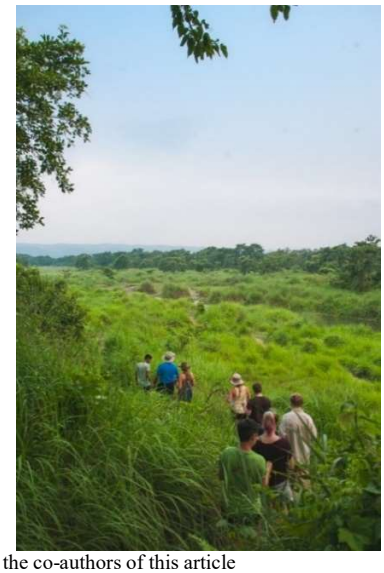
Diseases and pests on crops are rising due to the warmer climate. Pests are typically found in lower altitudes, but due to the warmer climate they are also becoming a problem in higher altitudes as well. Diseases and pests can strain the economy because agriculture is a very significant part of Nepalese economy. Diseases and pest on crops also have a negative impact on the health and well-being of the people and animals who consume these agricultural products. Some of the examples of diseases and pests noticed recently include the following: leaf blight and aphid infestation in potatoes, rhizome rot in ginger, leaf blight and yellow rust in wheat, root borers on corn, and borers in rice. Failure of these crops was due to increasing pesticide requirements and delay of planting and growth due to lack of timely rainfall.

We observed marijuana plants growing wildly almost everywhere: in the country side, in the city, and along roadsides. While recreational marijuana is illegal in Nepal, its enforcement in the country is extremely lax. As a result, it was no surprise that some locals sold marijuana to compensate for income loss due to crop failure.

D. Wildlife

Students visited the Chitwan National Park (Photo 9) and talked to local communities and learned that there has been a decrease in total rainfall but an increase in extreme rain events that cause flooding. The floods cause damage to nearby communities, kill wildlife in the park, and lead to an increase in disease in the animals directly after flooding events.

PHOTO 9. STUDENTS VISIT CHITWAN NATIONAL PARK IN CHITWAN, NEPAL.



Source: taken by the co-authors of this article

Aquatic life in the park is affected by large water lily populations that decrease water flow, which can lead to lower levels of dissolved oxygen. Populations have been increasing in recent years after fishing was banned in the area. The 2017 flood killed around 1200 animals including deer and blue bulls, which left the tigers without prey. The tigers were left to eat the dead animals which caused them to die from food poisoning. Before the flood, there were 125 tigers; after the flood, there were only 97. Several rhinos were swept away by the floodwaters. For those rhinos that survived, most contracted diseases after the flood and died. The rice crop was damaged badly and it was too late into the season to replant rice. Herbivorous animals such as elephants and bears lost 88% of their grass due to the mud covering it. This forced them to enter human settlements for food. It is said that around 20 elephants entered human settlements at Parsa's Thori in a herd daily. Gharial crocodiles were also in danger because they need fresh and running water for their survival. This case of Chitwan National Park clearly shows how global climate change and floods have severely affected wildlife in the region. Local people stated that floods are becoming more frequent. Another phenomenon learned was that many birds used to migrate to Nepal from Siberia in the past, but they do not do it anymore.

Employees of the national park told students that they believe the monsoon has been coming earlier each year and that the

temperature has been becoming more of a problem each year. During March and May, there is a decrease in rainfall and an increase in windstorms. In 2017, there were major effects from nitrogen and phosphorus getting into the water, affecting aquatic animals and other wildlife. The lily population has blocked water flow. To get the wildlife back to this park, 6 or 7 rhinos were reintroduced to the area. In an effort to mitigate such devastation from a flood, many officials have suggested early warning systems, flood control, and planned evacuation routes.

E. Earthquakes, landslides, and glacial lake outbursts and flooding

It was clear that the city of Kathmandu has not fully recovered from the devastating 7.8 Gorkha earthquake on April 25, 2015. About 9,000 people were killed and thousands more were injured. More than 600,000 structures in Kathmandu and nearby towns were either destroyed or severely damaged. In order to prevent another devastating catastrophe from occurring, our group suggested the implementation of diversified media accessibility, early warning signs, zoning regulations, risk map development, and, with the help of institutions, more multi-hazard risk assessment approaches. Locals are in dire need of being informed and educated about earthquake safety measures. Until seismologists are able to predict earthquakes, these methods are necessary to save lives.

Landslides are one of the most frequent and dangerous natural disasters in Nepal. Many landslide scars were noticed along the main road, as well as multiple unstable slopes susceptible to sliding in the near future. Landslides in this region typically occur two to three days after heavy rainstorms. Signs of an impending landslide include loud noises and new cracks or bulges in the ground. Landslides along major thoroughfares, which follow rivers, tend to dam and/or divert streams, create sunken or down-dropped roadbeds, and completely block travel by road. Since Nepal relies on just a few major roads connecting the country together, road blockages threaten to halt ground transportation through the country, causing inter-country trade and access to goods and government services to essentially halt until the road can be cleared. If a major landslide occurs, securing the slope, digging out the debris, and repairing any broken infrastructure can last several months.

Nepal also struggles with glacial lake outburst floods. Glacial lakes are a large pool of melted glacial ice formed between the toe of a glacier and a moraine. As glaciers continue to melt, the amount of water dammed by the moraine increases. Eventually, as a result of too much water or an earthquake, the moraine begins to deform and collapse, releasing the large torrent of water downstream. In 2012, Pokhara experienced a glacial lake outburst flood that caused great damage to the community. Huge pieces of debris carried by the flood water destroyed many structures along the Seti River. This flood also destroyed a large area of farmland north of Pokhara.

F. Emerging diseases, pests, parasites and zoonotics

Nepal is rampant with vector-borne and zoonotic diseases, which are becoming a major health threat to the Nepali people. Temperature, humidity, rainfall, and wind are all important factors that influence the transmission of these diseases, and climate change is exacerbating the issue. For example, increases in temperature are shifting species' habitats farther north and to higher elevations, changing the nature of how humans are interacting with wild species. The ecology, development, behavior, survival, and transmission of vector-borne diseases – or illnesses caused by parasites, viruses, or bacteria that are transmitted to humans by a vector (such as mosquitos, flies, and ticks) – are strongly influenced by climate. Nepal is endemic for five major vector-borne diseases: malaria, lymphatic filariasis, Japanese encephalitis, visceral leishmaniasis, and dengue fever. Similar to vector-borne diseases, zoonotic diseases are infections that are transmitted between animals and people. These diseases can be transmitted to humans by either consuming the infected animal's meat or being bitten by the infected animal. Some of the zoonotic diseases in Nepal include toxoplasmosis, Leptospirosis, cysticercosis, fasciolosis, and rabies. Anthropogenic changes to the environment and unsanitary conditions that allow for the development and transmission of these diseases are the two main reasons for their presence and prevalence in Nepal.

III. CLIMATE CHANGE ADAPTATION

A. Green infrastructures

Nepal has a great potential to implement climate change adaptation through hydropower development. Nepal, with its tremendous variation in elevation, has a high suitability for hydropower development. Heavy rains that fall during the rainy season can be stored in the reservoir behind a hydropower dam and utilized during the dry season.

Kathmandu Valley has a watershed area of approximately 664 km^2. The climate is subtropical and has annual summer monsoons. The average temperature in the summer is 24°C and 13°C in the winter. The annual precipitation average is 1,700 m (ranging from 9 mm in November to 364 mm in July), around 80% of which falls during the monsoon season. In Kathmandu, longer dry seasons and increased flooding due to these changes can be devastating. About half of the water supply for Kathmandu Valley comes from surface water (Warner et al., 2007). With the quality and the amount of surface water decreasing, the general public seems to believe that groundwater is infinite and cleaner. This mentality is detrimental because not only it is untrue, but it also discourages active cleanup of contaminated surface water and the development of green infrastructure.

Green infrastructure is usually related to water management implemented in a way that uses natural or semi-natural areas. Development and implementation of green infrastructure has several benefits, including usually being cost effective and resilient, providing recreational spaces, and increasing the

property value of the surrounding areas. It also reduces the ground level ozone and urban heat island effect, absorbs air pollution by filtering particulate matter, and provides habitat for small wildlife (Chunn-Heer, 2019).

Green infrastructures that were observed in Nepal included rooftop gardens (Photo 10), rainwater harvesting, drains, and retaining walls. Rooftop gardens were found on almost every building.

PHOTO 10. ROOFTOP GARDENS IN KATHMANDU

Source: taken by the co-authors of this article

They are used to provide families with vegetables and ease economic strain, but are also used to decrease the amount of runoff during storms. The amount of water retained is dependent on the size of the garden and the size and the number of pots in it. Rainwater harvesting is another common method for using storms to mitigate water shortage in the city. This method has been used since ancient times. In the Kirat regime (about 2500 years ago), rain-fed ponds and springs were dug, which were expanded during later regimes by linking them to stone spouts in the cities. Once a year during the Sithi Nakha festival, this system was cleaned; however, when piping was introduced to the Kathmandu area, it fell into neglect and at least 400 of the stone spouts and several wells have dried up (Shrestha, 2009). In the present, a common system of rainwater collection involves using a catchment area, conveyance pipes, and a storage jar. Drains are another type of green infrastructure. Several roadside drains throughout the city of Kathmandu – both open and enclosed – were observed. These drains are presumably meant to channel runoff to protect the roads from erosion; however, they were neglected and consequently filled with sediment and trash. The tops of the drains were often broken, allowing trash to be swept in along with the water. Retaining walls were observed on the both side of the Dhobi Khola, which were meant to protect the nearby residents and businesses from floods. They were constructed of soft stones, such as limestone, and were deteriorating with significant signs of erosion. To improve the water quality of the Dhobi Khola watershed, human involvement and education should be the first step. In addition, Best Management Practices (BMPs) should be implemented.

Diverting sewage and decreasing the trash in the streams in urban areas will help the waterways recover from many years of pollution. Installing water purifying systems in private businesses or individual households is another adaptation activity that can yield positive results.

B. Institutional activities on climate change adaptation

International agencies such as the United States Agency for International Development (USAID) have been working on several climate change adaptation projects in Nepal. USAID has implemented several programs including the Nepal Hydropower Development Program, the PAANI program, and the Hariyo Ban Program. USAID's Hariyo Ban Program aims to increase ecological and community resiliency, biodiversity, and conservation in order to reduce climate change vulnerability. This program has established geographical priorities for areas that are threatened, implemented conservation plans for threatened species, and also has developed plans for climate change adaptation. The PAANI program of USAID is an ongoing project to improve watershed quality and biodiversity and to implement water related policies. USAID helps Nepal boost food security, sustainably manage natural resources, improve access to quality health care and education, strengthen democratic governance, and builds its capacity to mitigate and respond to natural disasters. The PAANI program of USAID is implemented to protect the aquatic biodiversity of Nepal's waterbodies. The loss of aquatic life is the largest threat when developing hydropower. USAID's Nepal Hydropower Development Project (NHDP) is working on developing sustainable and environmentally-sound hydropower facilities in Nepal.

The International Center for Integrated Mountain Development (ICIMOD) is a regional intergovernmental educational and knowledge-sharing center serving the eight regional member countries in the Hindu Kush Himalaya: Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. ICIMOD's activities on bridging the gap between communities, scientists, and policy makers (government) is fascinating (Photo 11).

PHOTO 11. STUDENTS ATTENDING A SEMINAR ON ICIMOD'S ACTIVITIES IN THE REGION.

Source: taken by the co-authors of this article

Communities want to do what is best for their environment, but their efforts are usually unplanned and not suited for long-term effects. Scientists have the knowledge to formulate solutions suited for long-term sustainability, but they need government funding and most of the time the government is not worried about the long-term health of the environment. The policy makers have the funding and scientists to help with climate change, but they tend to make selfish decisions that are

not in the best interest of the local communities. These gaps should be bridged for better environment and climate change adaptation. According to ICIMOD, by 2100 it is predicted that the Hindu Kush Himalaya glaciers will lose 36% of their mass if large efforts are not made immediately to decrease global greenhouse gas emissions and limit temperature rise to 1.5° C. If global emissions continue to follow the current trend, there will be a predicted 64% mass loss of ice. Climate change will also lead to changes in precipitation patterns, which, paired with increased glacial melts, will pose threat of increased flooding for downstream communities. One measurement to mitigate damage caused by flooding is ICIMOD's regional flood outlook system for the Ganges and Brahmaputra basins. Using weather prediction, precipitation estimates, and past climate data, they usually are able to predict flooding three days before the event. This gives them the time to issue flood warnings and save lives.

Governmental agencies such as the Nepal Agriculture Research Council (NARC) conduct agricultural research in the country to lift the economic level of the people. NARC conducts qualitative studies on different aspects of agriculture, identifies problems and solutions in agriculture, and assists the government formulating policies and strategies regarding agricultural development. Animal health is impacted by changing climate. Vaccinating animals against emerging new diseases and parasites, providing good feed to animals to keep them healthy, and providing protection from newly-introduced diseases are some of the climate change adaptation measures implemented in Nepal.

In Nepal, many NGOs such as Asta-Ja Research and Development Center (Asta-Ja RDC) are working on climate change studies and adaptation. Asta-Ja RDC is a non-profit and non-governmental agency that works directly with the community for poverty alleviation and socio-economic transformation of Nepal. Asta-Ja focuses on eight essential resources: water, land, forest, medicinal and aromatic plants, manpower, animals, crop plants, and climate. Among several projects, Asta-Ja RDC is providing seeds for family nutrition and income generation along with establishing community awareness on environmental issues. Asta-Ja takes on community outreach programs. When natural disasters occur, Asta-Ja is there to help the communities by giving out seeds, clean water, and food. Not only do they supply these communities with necessary commodities, they teach the communities how to plant the seeds, obtain clean drinking water, and make simple changes in their villages to adapt to changing climate.

Private businesses are also doing climate change adaptation independently. For example, the Hotel Country Villa in Nagarkot presents an example of water conservation practices at a private sector level. Hotel Country Villa has placed multiple rain barrels on their property, installed a personal water filtering system to reduce water waste from water jugs, and reused non-potable water to maintain their gardens. The fact that Hotel Country Villa is doing this independently without any government initiatives is astounding. It is important for large businesses to be taking these steps, as it has a greater positive impact. Such activities may have to be incentivized through government regulations or tax-based incentives. It is important for the future of Nepal to make large-scale changes.

IV. REFERENCES

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The complete list of references will be featured in the final paper of this Scientific Journal.