Project Report

Landslides, Favelas, and Rio de Janeiro Climate Crisis

GTD 511

Diplomacy Lab | Humanities Lab

Baker, K. J., Dixon, H., Littleton, J., Lugo
Robles, D., Pulido, N., and Summers, R.

Table of Contents

Executive Sumary

Favelas are communities of high-density populations that are set on formal and informal slums located in and around Brazil's main cities. In the case of Rio de Janeiro, many of these communities are located in mountainous or swampy terrain that, due to terrain constraints, deforestation patterns, rapid urbanization, and lack of resources, make them more prone to landslides caused by increased rainfall precipitation. For over 30 years, Rio de Janeiro has experienced an increment of these landslides as climate change affects the city by way of increased temperatures that increase the likelihood of rain anomalies. The effects of this can further destabilize the livelihood and homes of these citizens and their potential to overcome their precarious circumstances.

Key Words:

Favelas
Landslides
Rainfall
Precipitation
Construction
Community
Mitigation
Adaptation
Emergency Management
Rocinha

Evidence of favela vulnerabilities can be observed through economic, environmental, and social lenses that affect their ability to prepare, mitigate, and respond to landslides. Efforts by governmental entities and community organizations have tried to address the situation, yet landslides continue to disrupt favela citizens and their surrounding neighborhoods. New ways of collaborative advocacy must be explored to enhance current tools to handle these dangerous situations and new frameworks of policy are needed to help empower these communities to properly deal with landslides.

This document aims to understand and aid in managing the ongoing landslide crisis affecting vulnerable groups in Rio de Janeiro. By researching the causes of landslides (erosion, structural support, societal, building placement), determining existing limiting factors (land/legal restrictions, finances, geography, topography), and creating short, middle and long-term goals, to offer new insights to manage landslides in Rio de Janeiro.

Research Focus

1
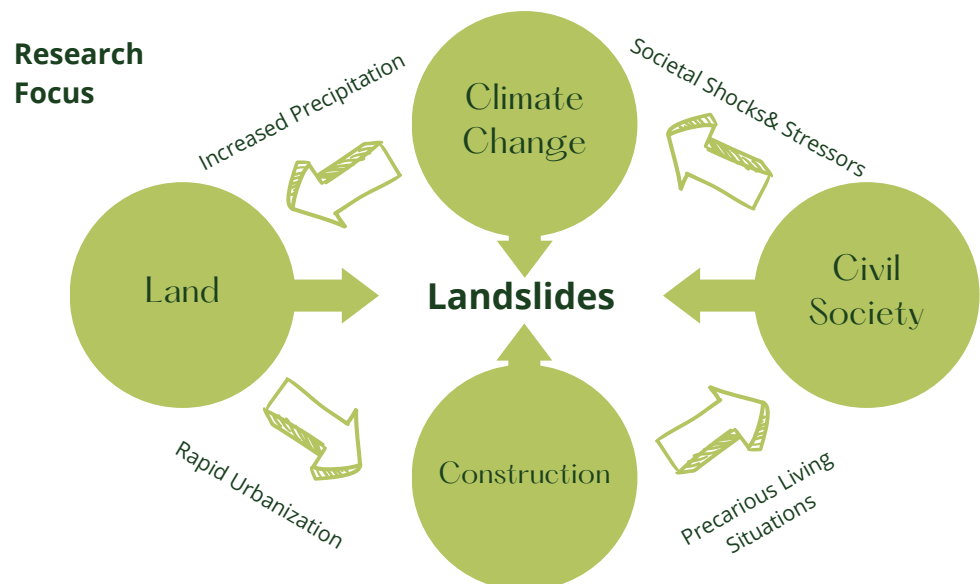
Report Objectives

Understand

- Societal, economic and environmental nexus that affect favelas ability to handle landslides.
- Understand current efforts by shareholders regarding to mitigate landslide crisis.

Analyze

- Topological, societal, and economic factors play into the ongoing problem of landslides in favelas, and how climate change exacerbates them.

Contribute

- Generate information regarding the relation of landslides and favelas in Rio de Janeiro.
- Provide a set of recommendations at various levels of implementation to support inclusive mitigation and adaptation of favela residents to the landslide crisis

Introduction
Favelas in Rio de Janeiro

Favelas in Rio de Janeiro sprouted organically at the end of the 18th century to house a growing urban underclass composed of internal immigrants and laborers (Green & Skidmore, 2021). Nowadays, they represent nearly 22% of Rio de Janeiro's population (IBGE, 2010), which in raw numbers comes close to 1.5 million residents (Catalytic Communities, ND). In the past, residents of favelas were composed of lower-income residents; nowadays, wage increments have seen a rise of the middle class among their residents (Catalytic Communities). However, Favela Residents have historically faced challenges related to racial, economic, and environmental tensions (Green & Skidmore, 2021). These shocks and stressors have created a series of barriers that hinder relations of trust between governmental actors and residents, which makes it difficult to collaborate on possible solutions. These barriers further exacerbate the vulnerabilities of those living in favelas and the increased risks imposed by climate change.

Favelas are considered areas of 'high risk' for natural disasters (Hanna, 2019). This is because of several factors that combine their location of steep slopes/mangrove swamps and economic inequalities (Chavez, 2019). These vulnerabilities have been exposed in recent decades through flash floods and landslides caused by heavy rains and climate change. Culminating in the loss of homes, loss of life, and displacement of communities.
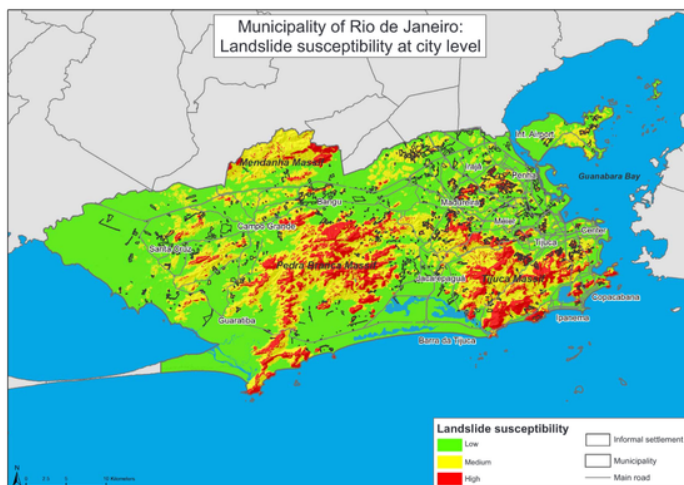
Map of the Rio de Janeiro Municipality exhibiting susceptibility to landslides Retrieved from
https://www.mdpi.com/2076-3263/9/5/203

Luciano Oliveira

Interviewee

3

Over the last couple of decades, organized groups have formed within the favelas in Rio de Janeiro to take control of these highly populated communities. One well-known organized group is known as the Militias. This group comprises influential leaders who take ownership of these favelas and play the middleman between the people living in these communities and the government. For example, the militias barricade the entrance where they let residents in and will not let them drive up; instead, they have to walk up to their houses or destination. The militias are not engaged in drug trafficking, but they are heavily armed. They make the residents in these favelas pay a protection fee for electricity and illegally obtained internet. In addition, the militias are the only distributor of general municipalities. Every favela has its own organized form of militia, and the resident's ad hears their rules.

As part of the governmental efforts to face the incremental incidence of landslides in Rio de Janeiro, a series of efforts have been generated since the 1980s to address the environmental risk. This includes mapping risk areas, rain gauging, alarm systems, Doppler Radar technology, slope containment construction, drones, and barometers (Hanna, 2019). However, time has shown some unreliability from these instruments, which is also exacerbated by the trust-related issues between favela residents and governmental agencies (Hanna, 2019; Green & Skidmore, 2021).

Governmental trust relations with favela residents are complicated matters that change depending on the administration. An example of this can be seen in the approaches of both Jair Bolsonaro and current president Luiz Inácio Lula da Silva. While Bolsonaro's approach criminalized Favelas, Lula's approach supported Favela's social and economic development (Dias, 2022). This contention can also be seen at the municipal level. Back in 2005, the local mayor provided citizens with land titles to residents of Vila Autódromo, which were later revoked in 2013 to make way for urban development aimed at the 2016 Rio Olympic Games (Parkin, 2015). Favela eradication is not new to Brazil. It is part of the historical violence residents expect, along with other forms, such as drug violence and police repression experienced in the '80s and 90s (Green & Skidmore, 2021).

However, residents of Favelas are hopeful in terms of what the future may hold. During their most recent elections, their turnout was among the highest in the country, especially in Rocinha (Dias, 2022). This is because in the past, Lula's government provided support for public housing, libraries, healthcare units, sports complex, among others (Dias, 2022). Additionally, his presidency saw the creation of the Pacifying Police Unit. A descala-

"We can use legalism to say that favelas need to be demolished, because they are occupations of land, or to defend them, because after all are Brazilian victims of a perverse economic and historical model. Either society embraces and hosts these areas, or nothing will change. For this reason the police make an appeal: go up the hill, it is part of the city."

State Security Secretary Beltrame, 2009
(Green & Skidmore, 2021)

4

tion measure by the government to induce change in favela-police relations and reduce the drug trade (Green & Skidmore, 2021). However, the success of these initiatives is hard to quantify and citizen distrust continues (Ashcroft, 2014; Green & Skidmore, 2021),

The interconnectedness of favelas' social, environmental, and economic factors severely affects their ability to prepare, mitigate, and respond to the risks imposed by landslides. Many changes must be made at different policy levels in collaboration with the communities, private sector, and grassroots organizations to attend to the issues faced by favelas. As sustainable challenges rise, the issues affecting disproportionate communities will spill into the rest of society, and we must address them now to safeguard human life and support society's evolution.

Trust

Trust is a main focus, not only in terms of trusting the warning systems and methods being implemented but also in the government and the organizations that are carrying it out. As highlighted in the prior section on warning systems, at present, trust is low in both the government and the current warning systems implemented within the Favelas in Rio de Janeiro.

Goncalves (2013) highlights the intersection between the political and the social, noting how even the trust placed in warning systems and evacuation plans can be politicized with intentions not necessarily aligning with the well-being of citizens. He argues that risk can be used to remove citizens from areas that may be advantageous and considered strategic for governments in their future city developments.

Due to their informal nature, Favelas are at the forefront of such repurposing, relocation, and clearing policies and efforts. This can be exemplified in the run-up to the Rio De Janeiro 2016 Olympics, where favelas were cleared, and dwellers were relocated to build new sports facilities and venues for the games. Having a recent history of such activities and using events like landslides to facilitate such actions contributes to the mistrust of the Brazilian Government and the current warning/prevention systems in place.

As such, having a high level of mistrust makes the implementation of prevention methods harder to enforce as citizens are less willing to engage with the models despite the potential benefits of doing so.

Current Political and Social Initiatives

Rio de Janeiro Handling of Landslides

Favelas face several challenges when it comes to urban development. From their inception, they faced social, economic, and environmental risks that have been eased and exacerbated in their relation to government entities and their agendas (Green Skidmore, 2021). From a social perspective, favelas are often associated with poverty, crime, and violence, and they are often stigmatized by mainstream society, leading to discrimination and social exclusion (Green & Skidmore, 2021).

From an economic perspective, favelas can stand at odds with economic growth and development. Many residents of favelas cannot secure capital or access credit to purchase homes in desirable locations (Chavez, 2019), which can lead to high levels of poverty and inequality. If the city of Rio de Janeiro decides to claim ownership over any of these lands through Eminent Domain, they can cease their housing (2015); even when that puts them at odds with the constitution's guaranteed housing (Catalytic Communities, ND).

From an environmental perspective, favelas are significantly impacted by their natural environment and climate-related activity. The lack of proper infrastructure and the removal of natural vegetation increases the hydro-conductivity of Rio de Janeiro's sloped environment. As more terrestrial material is removed, the soil retention also loosens, increasing the risk of future flooding, erosion, and landslides as climate change increases precipitation in the area (Hanna, 2019). This has resulted in deadly flash floods and landslides that have disrupted community living and social networks.

Public Services

Food and water scarcity throughout Rio de Janeiro has always been prevalent among the people. The city and state governments have continually failed the favelas regarding public services, sanitation, medical care, and transportation. Economic decline has hit the country somewhat hard throughout the last few decades. It has been reported that the poor comprise roughly 13% of the population, and nearly 19% of the population is housed in slums/favelas. "The city's poor make up about 13% of the population, and nearly 19% of them live in slum neighborhoods with inadequate infrastructure, transportation, schools, and health facilities" (Ceratti, 2014, p. 2). Problems amongst public service were ultimately slightly resolved in January of 2009 by Municipal and Federal Governments by approaching a world bank for a Development Policy Loan (DPL) to alleviate their debt burden. The loan was later approved in July 2010 to finance the existing debt. Ceratti states, "The Rio de Janeiro Municipal Development Policy Loan, approved in July 2010 for US$1.045 billion, financed a portion of Rio de Janeiro's existing debt and served as a platform for dialogue about policy issues, especially in Monitoring and Evaluation systems, Public-Private Partnerships, pension reform, and budget management." (Ceratti, 2014, p. 4)

Transportation

Transportation, or the lack there of in Rio de Janeiro, is highly prominent, especially throughout favelas. The indifferent mountain ranges and hills throughout the city make it very hard for sustainable transportation to be used. Some well-known ways of transportation include two trains on the Supervia suburban railway. Due to significant weather and natural disaster inconveniences, "two trains on the Supervia suburban railway broke down, causing many inconveniences to passengers. Some, upset by delays, caused damage to a station and even set fire to some of the train's wagons." (Rose, 2013, p. 1) With an unstable support of transportation, this causes insecure transportation amongst the people in the the favelas and causes extreme problem in regard to local life.

Medical Care

Primary healthcare is an extremely important aspect in any country's success in health systems. Given that primary health and medical care isn't widely available to low and middle-income countries, this is an important problem in Rio de Janeiro that the locals are well aware of. Having strong and reliable medical health systems provides steps towards sustainable development. The main variable surrounding medical care in Rio de Janeiro surrounds the lack of medical and ICU doctors as well as emergency or unplanned hospital administrations. Thomas Hone of The Lancet Regional Health of America states, "In Rio de Janeiro, PHC, through the FHS, was substantially expanded beginning in 2008, and was prioritized in poor areas lacking services. By 2016, over 50% of the population in the city were covered. This study evaluates the expansion of PHC in the city of Rio de Janeiro aiming to explore associations between FHS usage and emergency ambulatory care sensitive condition (ACSC) hospital admissions and readmissions." (Hone, 2022, .11) Having a lack of doctors to perform service especially in readmission cases is very unfortunate and is reported to need much attention by locals in the city. It is a well-known problem throughout Rio de Janeiro and is wanted for consideration.

Sanitation

Local sanitation problems throughout Rio de Janeiro has always been prominent throughout the favelas. It has been shown that in Rio de Janeiro, only about 30% of the population is connected to local sanitation services. "According to the Ministry of Cities, 30% of the population in Rio de Janeiro is not connected to a formal sanitation system, and even in areas with formal connections, only about half of sewage waste is treated before entering into waterways and eventually the ocean." (Ministry of Cities, Hosek, 2023, p. 1) This is shown in comparison to surrounding cities such as Sao Paolo having 96.1% of local access throughout the cities and Belo Horizonte holding 100% of local access to sanitation. This is extremely interesting information to put toward thought in terms of these surrounding cities having more than +60% of sanitation services. A couple problems that sanitation surrounds involve people consistently missing work and students missing school. It has been shown that students with access to local sanitation have a lot more success in educational systems. "Every year 217,000 workers in Brazil miss work due to gastrointestinal problems linked to poor sanitation, each missing an average of seventeen hours of work. Children suffer from missing school as well. Studies show that children with access to sanitation have 18% higher educational attainment than those without access." (Hosek, 2013, p.7) The problem at the head point of all of this is a lack of education surrounding sanitation. In Rio de Janeiro, sanitation isn't looked at as a primary problem because of other problems people give more attention to such as healthcare, security, local drug usage, and transportation.

Social and health
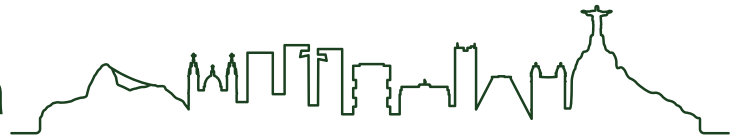
Families in Favelas have lived there for a long time, some their entire lives. Older family members bought houses, and as these families grew, the verticalization of the row and detached homes created to house several family members distributed in different apartments throughout their original dwellings. Because of this is where the term nuclear family became a used term. Due to building construction and multiple people living in these apartments/ living spaces, there are many health conditions among the residents. These residents suffer from more respiratory problems, dengue, and increased tuberculosis incidents. In addition, poor health access, transportation issues, and unhealthy sanitation diseases are rising within Rocinha.

Within favelas in Rio de Janeiro, landslides and rainy seasons are between December and April. According to the article Travel Guide, in the rainy season in Rio de Janeiro, temperatures reach 82 degrees with high humidity, and the annual average rainfall is about 1,200mm (Admin, 2020). Due to poor drainage systems, lack of sanitation, and overcrowding, favelas have high rates of respiratory infection and viruses transmitted by mosquito bites. These favelas' most common infections and viruses are tuberculosis, influenza, and Zika. Because of the poor sanitation and the weather conditions, more mosquitoes throughout the neighborhoods, causing cases of Zika to spike during these seasons. According to the Centers for Disease Control, the Zika virus had circulated throughout Rio de Janeiro before doctors reported the first case (Passos et al., 2017). A common infection amongst young children is an acute respiratory infection that infects children under five. A Journal of Medical Virology mentioned, "Acute respiratory tract infections are the main cause of morbidity and mortality amongst children older than five years old." (Góes et al., 2019). Because respiratory infections are transmitted through droplets and hand-to-hand contact, these infections spread amongst populated areas such as favelas. Specifically in Rocinha, the biggest favela in Rio de Janeiro, an estimated 200,000 people live there. Since houses in Rocinha are crowded and this area is overpopulated, it is easier for transmission amongst these infections and viruses to spread like wildfire.

Infection and virus numbers would decrease with a better sanitation system and the creation of spaces amongst houses. In addition, educating the locals about these infections and viruses would benefit all locals in better understanding of how these infections and viruses are transmitted, lowering the rate. Ensuring most people are vaccinated will also help reduce these numbers because vaccines are efficient, especially from December through April, since humidity is high during these months. Ensuring children and elders receive the flu vaccine would benefit the community and lower morbidity and mortality.

Climate Change
## Rainfall and Precipitation in Rio de Janeiro

High humidity and high rainfall are critical aspects of why Brazil is so susceptible to landslides. The commonality of disastrous landslides is one of the most significant issues in Brazil, creating economic and human life losses throughout the years. With Rio de Janeiro being one of Brazil's largest and most populous cities, its surrounding favelas receive much attention regarding this issue. In 2011 Rio de Janeiro received the 8th most catastrophic landslide leaving more than 30,000 people displaced, homeless, or dead (Hanna, 2019). After this disaster, Earth Science experts report, "the Brazilian federal government created the National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN), which has as its main objective the issuance of natural disaster warnings (landslides, floods, and flash floods) to about 1000 Brazilian municipalities" (Rosi et al., 2019). The diagram below shows the total landslides from 2008-2018 and the rain gauges that measure landslide susceptibility in the principal municipalities of central Rio de Janeiro.
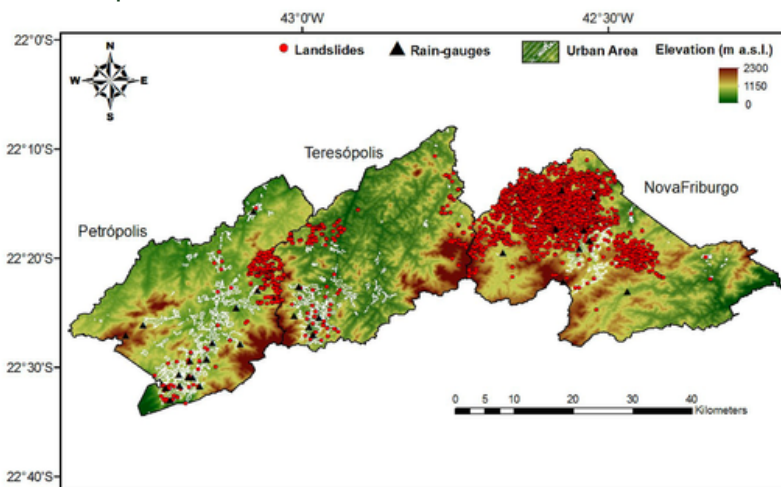
Landslides in the Mountain Region of Rio de Janeiro: A Proposal for the Semi-Automated Definition of Multiple Rainfall Thresholds. Retrieved from https://www.mdpi.com/2076-3263/9/5/203

This data was analyzed from three of the largest municipalities in Rio de Janeiro: Petropolis, Metropolis, and Nova Friburgo, being the most central to the city. While the whole area is susceptible to displacement, Nova Friburgo had the most during this data collection set, with 2938 landslides, leaving 368 in Petrópolis and 205 in Teresópolis. With this new natural disaster monitor center,

Rio de Janeiro's goal was to know when and where these landslides would occur and how impactful they would be to the surrounding communities. In theory, this idea should benefit the people in the surrounding communities, but the outcome was not as beneficial as the government expected. Nova Friburgo had nearly as many false alarms as correct alarms from these disaster monitors, with "131 false alarms... generated in 10 years" (Rosi et al., 2019). Having, on average, one false alarm every month for the entire ten years of this data collection proves that there needs to be a better system for analyzing rainfall and precipitation more successfully. The diagram below shows the commonality of false alarms compared to correct alarms, and the outcome is alarming itself.
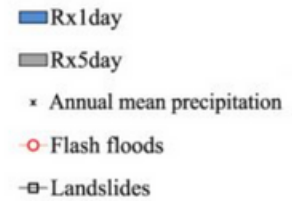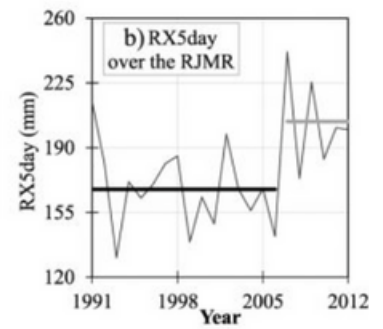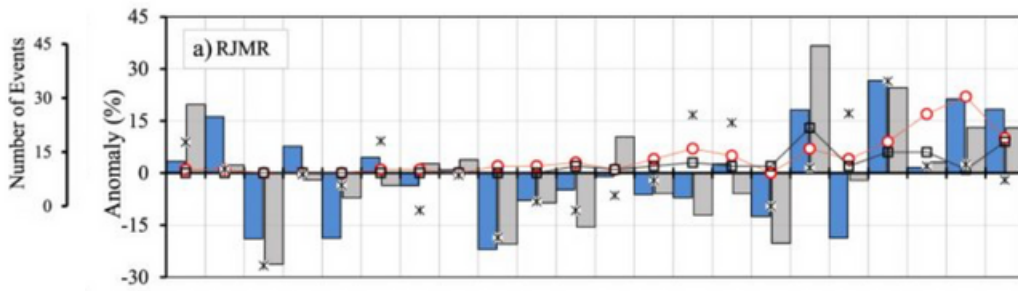
Rio de Janeiro's location and topography, in combination with increased rainfall from climate change, increases its vulnerability to landslides (Hanna, 2019). Rainfall becomes a 'trigger' mechanism for landslides, especially during the rainy season from December to November (Hanna, 2019; Smyth & Royle, 2000; Chavez, 2019). The Graph above by Avila et al. 2016 showcases a 12-year period in which rain anomalies were recorded. Every single year recorded landslides occurrences in the area of Rio de Janeiro. While factors such as lack of vegetation can increase the potential for landslides (Smyth & Royel, 2000), soil degradation is the main contributor to Rio's

landslide problem mixed with intense rains (Hanna, 2019). Because of this, intense rainfall can occur in one day, while landslides might occur on another day due to the water saturation from the intense rainfall (Hanna, 2019). This reduces the effectiveness of alarm systems in the vicinity that rely on models of rain precipitation gaging and expected 'trigger' points to announce the possibility of a landslide (Hanna, 2019).

As climate change continues to rise, the incidence of slides, as a crisis produced by increased rainfall and soil degradation, continues to wreak havoc on vulnerable communities in Favelas. The graph to the side showcases this series of activities, hitting an all-time high between the year 2000-2018 (Hanna, 2019). Additional landslide readiness and mitigation investments are needed, especially on the detection systems and community awareness front.
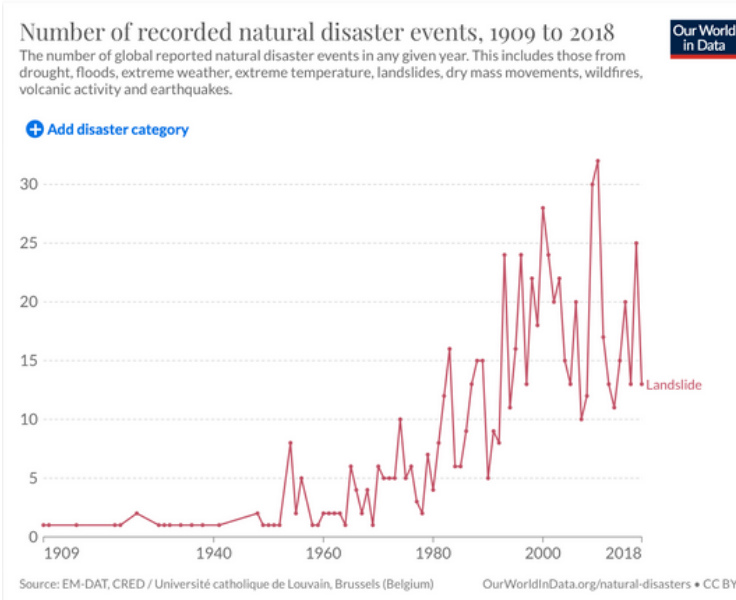
Geology of Rio de Janeiro

Rio de Janeiro's soil is diverse due to its complex geological history and topography. The most common type of soil is known as Ultisols, which is a type of weathered soil with lots of clay lacking in fertility (Smyth & Rohle, 2000). Ultisols is commonly found in the mountains and coastal areas.

There are also other types of soil, such as Oxisols, which are highly weathered and rich in iron and aluminum oxides, and Entisols, which are young and undeveloped soils found in areas with recent volcanic activity.

The soil in Rio de Janeiro has unique features that are influenced by the region's tropical climate, which brings lots of rain and humidity. This causes intense weathering and leaching that make the soil less fertile. The city's hilly terrain and urbanization have also caused extensive erosion and sedimentation that affect soil health.

Landslide Warning Systems

Alarming the public about landslide susceptibility is very important for minimizing damage. Currently, municipalities in Rio de Janeiro, such as NovaFriburgo, have a majority of the alarm system introduced by the National Center for Monitoring and Early Warning of Natural Disasters (CEMADEN).

There is a variety of literature on how to ensure the implementation of a successful warning system, with the core principles being based on ideas of education, trust, and the community itself. Changing one's perception of risk and trust in the system itself would increase its effectiveness and reduce the instances of alerts being ignored in favor of protecting homes, possessions, and livelihoods, which due to their high levels of economic vulnerability, is of a greater priority than their personal safety. The combination of numerous false alarms and failed activation further aids in the current distrust of the warning systems.

In addition to false alarms, these alarm systems are disproportionately placed through the favelas and municipalities; CEMADEN should work on improving the system and work with nonprofits to disperse them throughout the marginalized areas in the favelas.
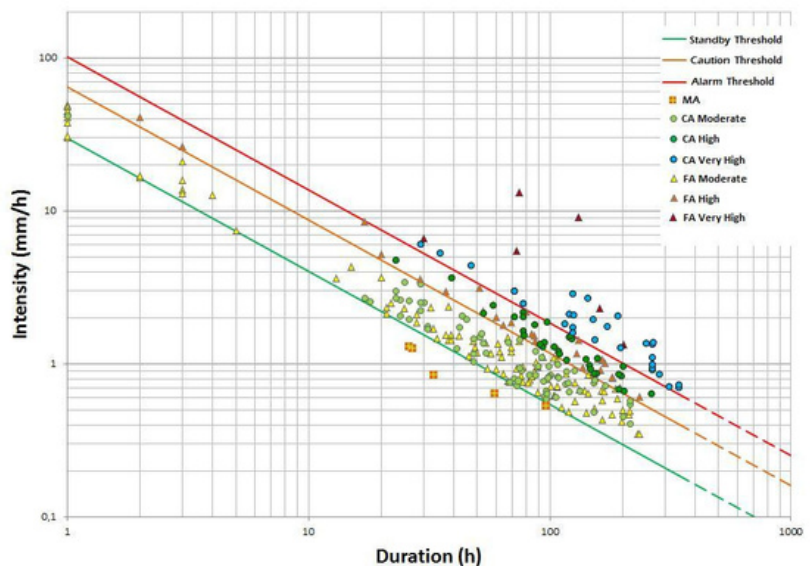
(CA: Correct Alarm, FA: False Alarm) Retrieved from https://www.mdpi.com/2076-3263/9/5/203
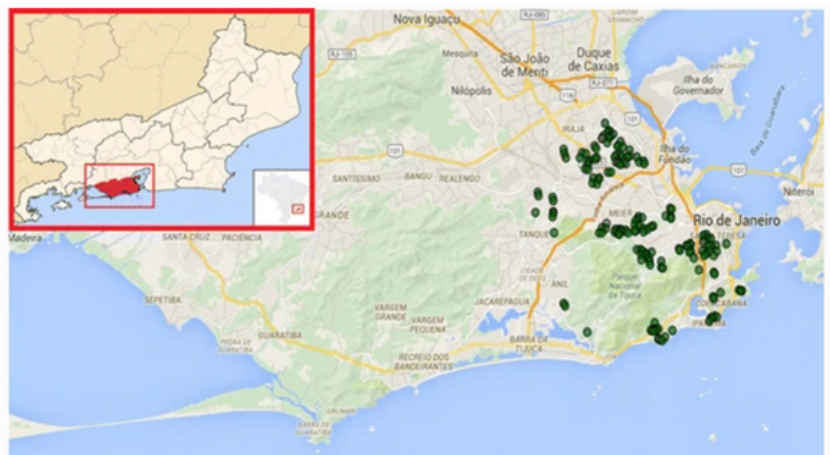
Map of Sirens in Rio de Janeiro
Prefeitura do Rio de Janeiro (2016) Sistema de Alarme Sonoro da Cidade do Rio de Janeiro, Dados pluviométricos. http://websirene.rio.rj.gov.br.

Construction
Techniques & Materials:

The favela buildings are designed to fit the needs of economically disproportionate citizens in limited space. The houses generally comprise bricks; pillars of concrete for structural support; flooring consists of beams and slabs, and the roof is usually tiles or corrugated iron. Their denisity shows them to be at least 4 stories high.

All materials for the project must be hauled on a motorcycle or foot uphill. Standard building practices for residents are renovating or adding onto pre-existing buildings. Unfinished projects will exist for 25 years; then, a resident will move in and erect a new story using what materials they have. Occasionally residents will require the use of craftsmen, with one resident from a case study mentioning that specialty workers are "required for more technical tasks - like casting slabs or placing a sheet metal roof" However, "...many build their own homes with the help of friends who lend a hand on the weekends. Sometimes they also barter — Eduardo [favela resident]" (Veysseyre, 2014).

Construction Zoning

The remarkable thing about favelas rules is there are no formal rules, with the law of mutual respect for neighbors being the standard upheld. An example of this might be keeping your house within a respectable limit or not installing a feature (window, door, roof) that would cause conflict with the existing structures.

Today I am constructing the 2nd one.

25 years ago I built the 1st floor.

My father built the ground floor 43 years ago.

Retrieved from https://www.archdaily.com/531253/case-study-the-unspoken-rules-of-favela-construction/

Recommendations:

Construction Methods for Minimizing Landslide Damage

With 22% of Rio De Janeiro's population living in favelas (IBGE, 2010), rapid urbanization has given rise to buildings being built out of necessity rather than planning (Smyth & Royle, 2000). Therefore, the implementation of newer construction techniques is needed. Furthermore, these techniques should reflect newer building integration into Rio De Janeiro's natural surrounding elements.

Excavation:

Current construction in the favelas needs foundational support systems for shifting grounds. Therefore, how slopes are altered at specific sites is essential when analyzing landslide occurrences in favelas in Rio de Janeiro. In particular, the use of "cut and fill" techniques, which involves removing soil from the rear of a site and depositing it at the front to create more level ground for construction, is prevalent in Niterói and has been linked to many landslides. Although this technique provides additional building space, the unconsolidated soil is highly vulnerable to collapse. Additionally, the construction of roads and other infrastructure projects can cause further undercutting of slopes in already unstable areas, leading to slope steepening and loading.

The severity of slope failure events can also be influenced by the angle at which the headwall is excavated. While vertical headwalls are commonly used, they are prone to collapse and can cause significant property damage. Natural downslope erosion processes, often exacerbated by rainfall events, are catalysts for such collapses. However, excavating angled terraces can reduce the likelihood of soil material damaging property by impeding the downward flow of material. Local conditions such as houses directly upslope and steep slope gradients often prevent such precautionary measures from being implemented in many areas. These factors and the directionality of the building to the slope contribute to landslides during the monsoon season.

Improved Concrete Foundations

A way to improve the structural integrity of these favelas would be to look at methods rather than materials available. More durable and resistant concrete could be achieved when mixing quicklime into the concrete rather than normal lime. In hot mixing, quicklime is added to the aggregate and the mortar; when heated, the concrete allows for chemical bonds that aren't achievable if only traditional slaked lime were used.

Future Use of Models for Risk Analysis of Landslides

Predictive Landslide Models and Simulations use GIS and many other simulative programs to help run predictive models for landslides. With the potential research of an accurate dynamic landslide simulation, a future exists where landslide crises are handled preemptively. Because of the steep slopes and material that Rio de Janeiro rests upon, the landslides of the past tend to give a sign of sorts when another occurs through scars left in the mountain, usually left in the "saddles" of the mountain. After initial landslides, these areas are more prone to erosion and displacement. One can measure the faults and obtain certain factors (slope, rock type, time of last slide, hydrological factors) to put together around when the next slide could occur and possibly gather research to determine which spots in the mountain are most susceptible to slide and when that would occur. While there are no models yet that have superior accuracy, there are multiple pieces of data and knowledge to pull from that help lead a path toward learning what areas are most vulnerable to landslides and some of the variables such simulations could use. Looking to the journal "Urban landslide hazards: incidence and causative factors in Nitero´i, Rio de Janeiro State, Brazil," surveys have taken place to evaluate the density and map the magnitude of landslides in the favela Nitero'i by directions (N, E, S, W, etc.) by creating a basic comprehensive risk assessment of a favela based on the displacement of land one can account for the amount of soil displaced based of the building techniques used.

Slope failure incidence in relation to aspect

Slope failure	N	NE	E	SE	S	SW	W	NW
No. of occurrences	–	3	–	5	13	5	2	5
%	–	9.09	–	15.15	39.39	15.15	6.06	15.15

Retrieved from Smyth, C. G., Royle, S. A. (2000). Urban landslide hazards: incidence and causative factors in Niterói, Rio de Janeiro State, Brazil. Applied Geography 20, 95–117.

Many Deterministic Models and Stochastic Hydrological/Geological Models should be used in tandem. Some potential variables that would aid the model could be used are listed :

Rainfall-Runoff Modeling, a unit hydrograph (to predict excess rainfall as surface runoff), is the factor of vegetation resistance to flow. An SCS Cover Complex Classification should also be conducted, classifying the soil use into three types. Use of land, practice or treatment, hydro-conductivity of the soil, and soil moisture content Another helpful tool is establishing a soil erosion prediction model that accurately predicts the amount of soil separation about the volume of rainwater runoff.

Construction Methods for Minimizing Landslide Damage
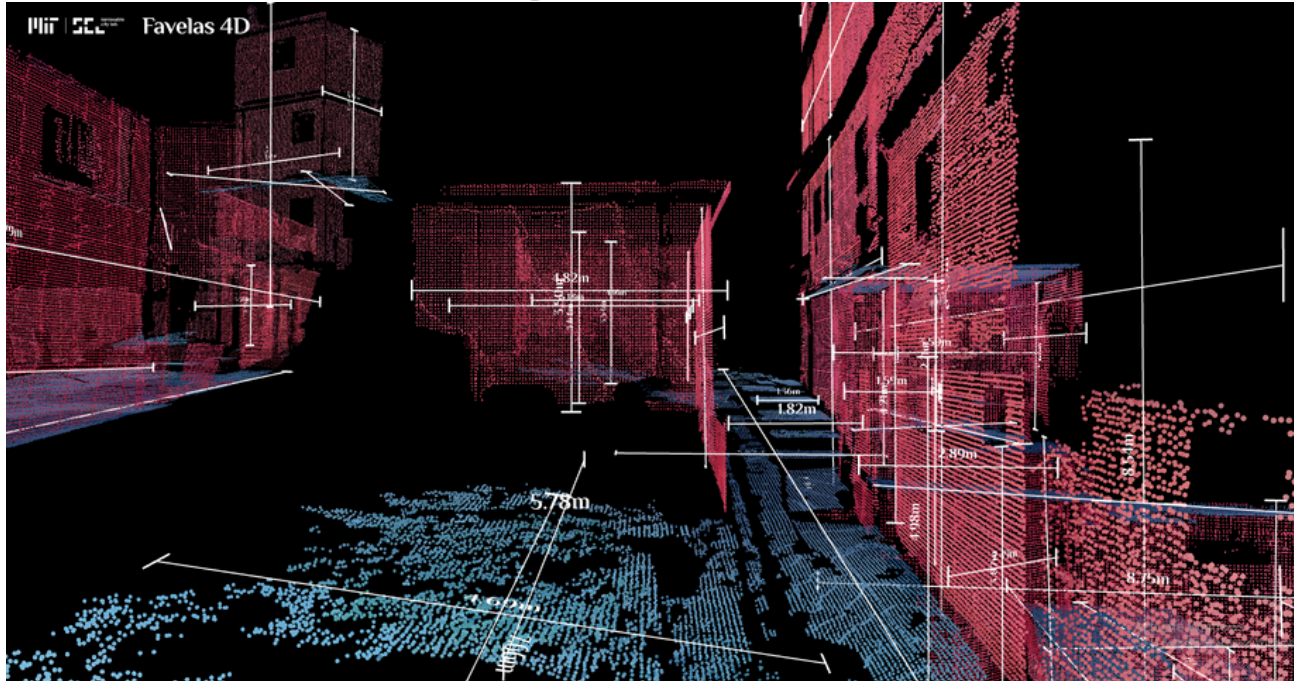
4D Laser Spatial Rendition by the Favelas 4D Project by MIT, showcasing the physical environment and their measurements. https://senseable.mit.edu/favelas/

With new technology, measurements of informal settlements can also be collected and used in dynamic landslide risk models. LiDAR remote sensing maps informal settlements by giving the approximate dimensions of the structure of certain favelas and help predict the flow of the land and water and the destruction it might have on the community. A future possibility is, with LiDAR being more common in cellular devices, more comprehensive maps can be studied to gain information on the layout of informal settlements, in turn being used better to understand the geological factors that might impact them.

Green Roofs

With the Mutirão Reflorestamento being around for so long, Rio de Janeiro needs to keep introducing more forestation to this plan. Along with restoring vegetation cover, Green Roofs should also be integrated more in the favelas. This is an initiative that started in Parque Araya by Luis

Green Roofs in the Slums of Rio de Janeiro, Retrieved from https://oppla.eu/casestudy/23397

16

Cassiano but is not funded by anyone and only is prominent in the northern zone of Rio de Janeiro, "in Parque Arará, Green Roof Favela has reached a record 15-degree-Celsius reduction in room temperature compared to the neighbor's house, which does not have a green roof" (Galuccio, 2021). If more communities were involved, this could affect the temperature of Rio in totality, reducing rainfall and mitigating landslides in the process. Green Roofs pertain to adding vegetation cover to the rooftops of favela buildings to mitigate the urban heat island effect and lower the overall temperature of the area, which eventually would lower temperatures in the surrounding areas. With lower temperatures, there would be less rainfall, indirectly countering the issue of landslides across the favelas of Rio de Janeiro. While many solutions are government based, this would require the people in the favelas to be proactive and plant canopies in their communities. While in addition to reforestation, this will not noticeably improve the effect of landslides until the future; this would require more funding and more vegetation planted on roofs. This combined effort would also educate the community on why the environment is integral to life. Rio de Janeiro has many issues, and many solutions have been proposed. Integrating the community in the process might be a fundamental way of starting the mitigation of landslides.

Reforestations
Role Against Landslides

Planting trees and vegetation can help to stabilize soil, reduce erosion, and improve drainage. This helps maintain the area's ecological balance and provides residents with access to green spaces. Reforestation is not an immediate solution for landslide

Reforestation Efforts in Rio de Janeiro have been occurring for more than 30 years. Photo retrieved from: https://oeco.org.br/noticias/prefeitura-do-rio-desmente-corte-de-50-em-mutiroes-de-reflorestamento/

mitigation, but it can be integral in minimizing landslide susceptibility. Rio de Janeiro has a plan implemented called the Mutirão Reflorestamento, which roughly translates to 'Reforestation Common by Effort,' which is a program intended for reforesting native ecosystems in Rio de Janeiro. With this being a solution for the future, it needs to be taken seriously now so the Mutirão Reflorestamento can be successful. For this to happen, the restoration project needs to be revamped and introduced in more than the eight communities it is currently involved with.

While this project has improved by adding vegetation and forestation to the surrounding communities to the Mata Atlantica biome, the only way it can help mitigate landslides would require it to be implemented on a larger scale. With said implementation, it will not take effect on landslides directly but will take some patience when searching for results.

Additional Elements to Consider

Grassroot organizations

Grassroots organizations have been essential for the support of favelas and their development. Catalyst Communities, for instance, is a leader in environmental sustainability in Rio de Janeiro's Favelas. Their programming consists of Rio on Watch (a news publication), Sustainable Favela Network (a series of sustainable initiatives at favelas), and Favela Community Land Trust (preservation and solidification of community assets) (Fowler, 2022). Partnering with such an entity would provide insight to the communities and establish a trust relation needed to succeed.

Educational Opportunities

Increasing educational opportunities through trade and vocational education has a dual benefit for favelas. You can empower citizens to address wage gaps by accessing careers with higher wages; the skills developed through these educational opportunities can also address deficiencies in their communities. Empowering citizens to access better economic opportunities they can later invest in their communities. Additional considerations, such as policy, should support educational opportunities and incentives to re-construct their homes.

Community Land Trust Model

A great example of community inclusion can be achieved through Community Land Trust Models, as it engages all stakeholders to cooperate in addressing community vulnerabilities through public-private-NGO partnerships (Fabini, 2018). Models for Favela Community Land Trust are currently being proposed for policy in Rio de Janeiro through entities like Catalyst Communities (Fowler, 2022). This would add an element of formality to community-organized initiatives, an essential element in tackling many of the sustainability problems that favelas face in Rio de Janeiro.

Appendix 1
Interviewee List

1. **Dr. Melanie Gall – ASU**

Sustainability and Disasters Mitigation Expert for Vulnerable Communities

2. **Dr. Chingwen Chen – ASU**

Landscape Architecture Expert

3. **Carissa Fowler – ASU**

ASU Student Researcher - Sustainability, Climate Change, and Disaster Adaptation/Mitigation

4. **Luciano G. Oliveira – Brazilian**

Ex-Resident of Rio de Janeiro, current resident of Arizona

Appendix 2
Meet the Team

Team Leads

John Littleton
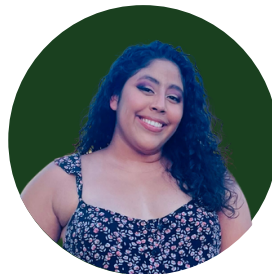
David Lugo Robles

Team Members

Kerenza Baker

Henry Dixon

Nadiuska Pulido

Ronald Summers

Appendix 3
Resources

Amaral, C., & Furtado, A. (2004). *Landslides: Evaluation and stabilization/glissement de terrain: Evaluation et stabilisation, set of 2 volumes*. Google Books. Retrieved April 24, 2023, from https://books.google.com/books?hl=en&lr=&id=DLPNBQAAQBAJ&oi=fnd&pg=PA293&dq=landslides%2Brio%2Bfavelas&ots=qsVvQZ0X6k&sig=c4YuKTd5xeAsm_O4SZsbzV9LiYw#v=onepage&q=landslides%20rio%20favelas&f=false

Ascanio R., Vanessa C., Samuele S., Tulius D N., Filippo C., and Nicola C. (2019, May 8). Landslides in the Mountain Region of Rio de Janeiro: A Proposal for the Semi-Automated Definition of Multiple Rainfall Thresholds. Retrieved Feb 12, 2023, from https://www.mdpi.com/2076-3263/9/5/203

Ashcroft, P. (2014). History of Rio de Janeiro's Military Police Part 4: Pacifying Police Units. Retrieved from Rio on Watch: https://rioonwatch.org/?p=14728

De Favelas, O. (2014, June 21). *Rio Transport System in crisis*. RioOnWatch. Retrieved April 24, 2023, from https://rioonwatch.org/?p=11271

Dias, B. (2022). *March in Rio de Janeiro's Largest Favela, Rocinha, Prefaced Highest Vote Share for Lula in the city*. Retrieved from Rio on Watch: https://rioonwatch.org/?p=72883

Chandler, D. L. (2023, January 6). Riddle solved: Why was Roman concrete so durable? MIT News | Massachusetts Institute of Technology. Retrieved April 24, 2023, from https://news.mit.edu/2023/roman-concrete-durability-lime-casts-0106

Fanibi, V. (2018). *The Diversity and Global Applicability of the Community Land Trust Model from Boston to Kenya*. Retrieved from Rio On Watch: https://rioonwatch.org/?p=45064

Fernandes, N. F., Guimarães, R. F., Gomes, R. A. T., Vieira, B. C., Montgomery, D. R., & Greenberg, H. (2004). Topographic controls of landslides in Rio de Janeiro: Field evidence and modeling. *CATENA*, *55*(2), 163–181. https://doi.org/10.1016/s0341-8162(03)00115-2

Fontoura, S.A.B. Sayao, A.S.F (2004) Landslides: Evaluation and Stabilization/Glissement de Terrain: Evaluation et Stabilization, set of 2 volumes: Proceedings of the ninth international symposium on Landslides, June 28-July 2, 2004, Rio de Janeiro, Brazil. Retrieved from

Fowler, C. (2022). Sustainable Solutions to Mitigate Disasters in Rio de Janeiro Favelas. Arizona State University, Class SOS 537.

Appendix 3
Continuation

Galuccio, M. (2021, November 3). Green roofs or air conditioning in Parque Arará? studies show the potential of green roofs in Rio's favelas [video]. RioOnWatch. Retrieved April 25, 2023, from https://rioonwatch.org/?p=64226

Green, J. N., & Skidmore, T. E. (2021). Favelas in Rio de Janeiro, Past and Present. In Brazil Five Centuries of Change.Oxford University Press. Retrieved from Brown University.

Green roofs in the slums of Rio de Janeiro, Brazil. Oppla. (2022, January 31). Retrieved April 24, 2023, from https://oppla.eu/casestudy/23397

Gonçalves, R.S. (2013). Porto Maravilha, Renovação Urbana e o uso da Noção de Risco: Uma Confluência Perversa no Morro da Providência.

Góes, L. G., Zerbinati, R. M., Tateno, A. F., Souza, A. V., Ebach, F., Corman, V. M., Moreira-Filho, C. A., Durigon, E. L., Silva Filho, L. V., & Drexler, J. F. (2019). Typical epidemiology of respiratory virus infections in a Brazilian slum. Journal of Medical Virology, 92(8), 1316–1321. https://doi.org/10.1002/jmv.25636

Hanna, A. (2019, 10). Rio de Janeiro's Landslide Mitigation Tactics, Part 1: A Technical History and Overview. Retrieved from Rio on Watch: https://rioonwatch.org/?p=54009

Hanna, A. (2019, 12). Rio's Landslide Mitigating Tactics, Part 2: Potential Improvement Via Acoustic Emissions. Retrieved from Rio on Watch: https://rioonwatch.org/?p=54143

Hanna, A. (2019). Rio's Rising Climate Vulnerability: A Decade-Long TImeline of Devastation Wrought by Landslides. Retrieved from Rio on Watch: https://rioonwatch.org/?p=54116

Hone, T., Macinko, J., Trajman, A., Palladino, R., Coeli, C. M., Saraceni, V., Rasella, D., Durovni, B., & Millett, C. (2022). Expansion of Primary Healthcare and emergency hospital admissions among the urban poor in Rio de Janeiro Brazil: A cohort analysis. The Lancet Regional Health - Americas, 15, 100363. https://doi.org/10.1016/j.lana.2022.100363

Hosek, E. (2017, March 23). The troubling state of sanitation in Rio. RioOnWatch. Retrieved April 24, 2023, from https://rioonwatch.org/?p=10892

Hungr, O., & McDougall, S. (2009). Two numerical models for landslide dynamic analysis. Computers & Geosciences, 35(5), 978–992. https://doi.org/10.1016/j.cageo.2007.12.003

IBGE - Instituto Brasileiro de Geografia e Estatística, Manual de Delimitação dos Setores do Censo 2010, Rio de Janeiro, 2010

Appendix 3
continuation

Jain, S. K. (n.d.). Introduction to hydrologic modeling - NIH Roorkee. INTRODUCTION TO HYDROLOGIC MODELING. Retrieved March 28, 2023, from http://nihroorkee.gov.in/sites/default/files/uploadfiles/Intro-to-Hydmodeling-skj.pdf

Jeantet, D. (2022, February 18). Experts say Brazil's deadly mudslides reflect poor planning in the face of climate change. PBS. Retrieved February 11, 2023, from https://www.pbs.org/newshour/amp/world/experts-say-brazils-deadly-mudslides-reflect-poor-planning-in-the-face-of-climate-change

Lab, M. I. T. S. C. (n.d.). Favelas 4D. MIT Senseable City Lab. Retrieved March 27, 2023, from https://senseable.mit.edu/favelas/

Lacerda, W. Ehrlich, M. Fontoura, S.A.B. Sayao, A.S.F (2004) Landslides: Evaluation and Stabilisation/Glissement de Terrain: Evaluation et Stabilisation, set of 2 volumes: Proceedings of the ninth international symposium on Landslides, June 28-July 2, 2004, Rio de Janeiro, Brazil. Retrieved from https://books.google.com/books?hl=en&lr=&id=DLPNBQAAQBAJ&oi=fnd&pg=PA293&dq=landslides+rio+favelas&ots=qsVvQZ0X6k&sig=c4YuKTd5xeAsm_O4SZsbzV9LiYw#v=onepage&q=landslides%20rio%20favelas&f=false

Lange, Wolfram, Simone Sandholz, and Udo Nehren. Strengthening urban resilience through nature: the potential of ecosystem-based measures for reduction of landslide risk in Rio de Janeiro. Lincoln Institute of Land Policy., 2018. Retrieved from https://www.lincolninst.edu/sites/default/files/pubfiles/lange_wp18wl1.pdf

Lepsch, I. F., & Buol, S. W. (1974). Investigations in an oxisol-ultisol toposequence in s.paulo state, Brazil. Soil Science Society of America Journal, 38(3), 491–496. https://doi.org/10.2136/sssaj1974.03615995003800030031x

Nelson, T. (2020). After 2 Deaths and in the Absence of the State, Rio's Largest and Densest Favela, Rocinha Mobilizes Against Covid-19. Retrieved from Rio on Watch: https://rioonwatch.org/?p=58638

Nuno Martins, A, Saavedra Farias, J., (2019). Inclusive sustainability within favela upgrading and incremental housing: The case of Rocinha in Rio de Janeiro. Wiley, Sustainable development DOI: 10.1002/sd.1879

Ottoni, M. V.; Ottoni Filho, T. B.; Schaap, M. G.; Lopez-Assad, M. L. R. C.; Corrêa Filho, O. C., (2018). Hydrophysical Database for Brazilian Soils (HYBRAS) and Pedotransfer Functions for Water Retention. Vadose Zone J. 17:170095. Doi: 10.2136/vz2017.05.0095

Appendix 3
Continuation

Parkin, B. (2015). Mayor Announces Eminent Domain in Vila Autódromo as MIT Reports Criticizes City Policy. Retrieved from Rio on Watch: https://rioonwatch.org/?p=20983

Passos, S. R., Borges dos Santos, M. A., Cerbino-Neto, J., Buonora, S. N., Souza, T. M. L., de Oliveira, R. V. C., Vizzoni, A., Barbosa-Lima, G., Vieira, Y. R., Silva de Lima, M., & Hökerberg, Y. H. (2017). Detection of Zika Vrus in April 2013 patient samples, Rio de Janeiro, Brazil. Emerging Infectious Diseases, 23(12), 2120–2121. https://doi.org/10.3201/eid2312.171375

Ramerini, M. (2020, April 4). The climate of Rio de Janeiro: When to go to Rio de Janeiro. Roller, Z. (2016, September 20). Rocinha's Rua 4: A mixed approach to public housing. RioOnWatch. Retrieved April 24, 2023, from https://rioonwatch.org/?p=1844

Sandholz, Lange, W., & Nehren, U. (2018). Governing green change: Ecosystem-based measures for reducing landslide risk in Rio de Janeiro. International Journal of Disaster Risk Reduction, 32, 75–86. Retrieved Feb 13, 2023, from https://doi.org/10.1016/j.ijdrr.2018.01.020

Skidmore, Thomas E. Brazil : Five Centuries of Change. Second edition., Oxford University Press, 2010

Smyth, C. G., Royle, S. A. (2000). Urban landslide hazards: incidence and causative factors in Niterói, Rio de Janeiro State, Brazil. Applied Geography 20, 95-117.

Veysseyre, S. (2014, August 3). Case study: The unspoken rules of favela construction. ArchDaily. Retrieved April 24, 2023, from https://www.archdaily.com/531253/case-study-the-unspoken-rules-of-favela-construction

"...go up the hill, it is part of the city. "

State Security Secretary Beltrame, 2009

GTD 511

Diplomacy Lab | Humanities Lab

Baker, K. J., Dixon, H., Littleton, J., Lugo
Robles, D., Pulido, N., and Summers, R.