Literature Review - Environmental Insecurity in Jamaica

By Joelle Weir

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Introduction

Slope instability puts communities based at a downward slope susceptible to sediment and rocks being displaced and causing mass movement when responding to gravity. Some popular examples of slope instability include avalanches, rockfall and landslides (Heritage-, 2000) -for the sole purpose of this review, we will use landslides to show the slope instability in Jamaica.

Landslides are predominant in the study of slope instability, in Jamaica especially, because many communities have steep typography, deep weather soils and poor slope stability. The risk increases due to the development of infrastructure in areas that are prone to slope failure as well as the rapid population growth in highly susceptible areas. (Morris & Edwards, 2008) According to the Morris' article on disaster risk reduction, "The island has experienced an increase in the frequency of natural events, primarily floods (related to inclement weather, tropical depressions, tropical storms, and hurricanes), droughts and landslides over the last 25 to 30 years."(Morris & Edwards, 2008, pg no.) Due to inadequate planning, lack of enforced legislation and lack of institutional organization (Morris & Edwards, 2008 (use More diverse range of lit to support\0), there will continue to be problems occurring from slope instability with no political push to end the cycle of destruction, especially in areas like St. Andrews and St. Thomas.

Background Information

In St. Thomas and St. Andrews (refer to a location map) the combination of x, y, z, makes the area highly prone to slope instability? (then put a bit of history of landslides in the area e. Both parishes are two of four parishes (Portland, St. Thomas, St. Mary and St. Andrew) that hosts the mountain range Blue Mountain in Jamaica and, according to Jamaica information Services, shares borders with these parishes as well as St. Catherine. (Jamaica Information Service, 2021)

Blue Mountain is 1,930 metres in the boundaries of the St. Andrews Parish.The parish itself has a coastline of 64.37 kilometres and hosts plains called the Liguanea Plains at the foothill of the Blue Mountains. (Jamaica Information Service, 2021)

According to Jamaica Information Services, St. Thomas borders St. Andrew on the west, "Portland on the north and the Caribbean Sea to the south." (Jamaica Information Service, 2021)

Parts of both Blue Mountains and John Crow Mountains are located within St. Thomas with the ridges of the Blue Mountain running from east to west across the island (Jamaica Information Service, 2021) These ridges are also a part of the Port Royal Mountain Range, which rises in some parts to 1,219.2m (4,000 feet) and stretches from above New Castle, in St. Andrew, to a location close to the sea in the Albion area, in St. Thomas. (Jamaica Information Service, 2021)- as before, try to over penden on a too few literature

Not only is there an understanding that landslides occur in areas with lots of sediment and steep slopes, the forming of Blue Mountain's typography could not occur without the occupancy of landslides. According to *The role of landslides in mountain range evolution,* "There is growing evidence that landslides are a dominant source of sediment in mountain belts and that they exert a direct geomorphic control on fluvial processes. Landslides can influence the river network in a variety of ways, from determining basin area and drainage divide positions, to setting streamwise variations in sediment load and calibre."(Korup, Densmore, et. al. , 2010)

Role of geology in conditioning the area for slope instability

History of Landslides in St. Andrew

1. Timeline of landslides occurrence in the area Regular landslides that occurs associated with hurricanes and storms) and then larger one (triggered by both rainfall and earthquake)
2.

Figure 1 Location of the parish of St. Andrew, Jamaica

History of Landslides in St. Thomas

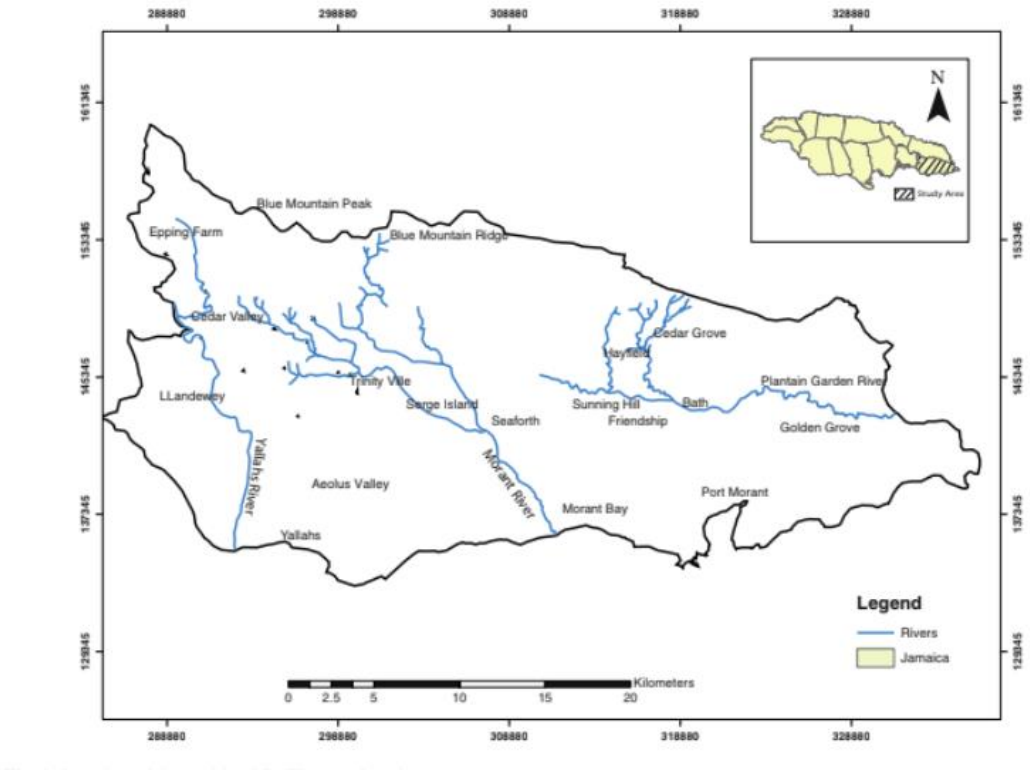

Figure 2 Location of the parish of St. Thomas, Jamaica (Miller, Brewer, et. al. 2009)

3. Timeline of landslides occurrence in the area (ok add the impact when you can)

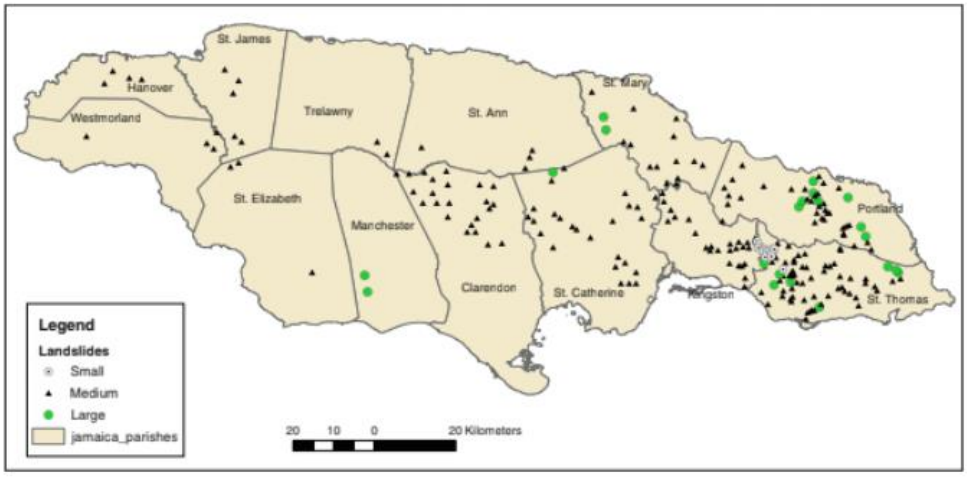

Figure 3 Geographical distribution of major landslides in Jamaica (Miller, Brewer, et. al. 2009)

Evaluation

Landslides can be evaluated and mapped through satellite imagery. According to the paper *Evaluation of the use of high resolution satellite Imagery to map slope instability in a tropical environment: ST. THOMAS, JAMAICA*, Satellite imagery and GIS process was found extremely effective in detailed field mapping of landslide prediction. (Miller & Leszczynska, 2014) According to the case study used, St. Thomas, "112 landslides that were verified in the field were used for comparison with the data derived from remote sensing. Approximately half of these landslides were pre-2000 and the other half, mapped after the heavy rainfalls in 2000. For more recent landslides (post 2000), the modelling proved to be effective, accurately identifying 91% of the landslide both in terms of the location and extent." (Miller & Leszczynska, 2014) The paper concludes that IKONOS imagery (a high-resolution satellite by GeoEye) can map out larger landslides and large terrains with steep slopes while, "In the future", SAR, RADAR and/or LIDAR should be used to enhance the landslide delineation process for "less pronounced" or smaller slopes. (Miller & Leszczynska, 2014)

Investigation

Investigating landslides require the knowledge of rainfall threshold and satellite imagery, together, to understand where these landslides occur the most and why they do. According to the St. Thomas satellite investigation, "The island of Jamaica lies in the hurricane belt which brings much rainfall, which compounds the slope instability problem . The incidence of landslides increases particularly in those areas which have a high annual rainfall for example the Blue Mountains-" [which inhabits St. Andrews and St. Thomas] (Miller & Leszczynska, 2014)

4. **Slope Instability in St. Andrews**

According to Russell's article on Landslide processes and susceptibility, "Rainfall-induced landslides are common geomorphic events on the steeper slopes of Upper St. Andrew and cause severe environmental, engineering, social and economic repercussions in the area." (Maharaj, 1993) The results yield that about 59 failures per km^2 were mapped, with the highest density within clastic sedimentary units and weathered granodiorite. (Maharaj, 1993) Slopes composed of clastic sediments are often the steepest encountered,so, when they are sometimes faulted and vertical in river valleys, St. Andrews is susceptible to the potential damage.

As well as this, it has been discovered that although there are naturally occurring steep slopes in St. Andrews, most are man made because of the misinformation and negligence by the government and industry. According to the article, road construction impacted the hillslope by cutting it, steepening the lateral and removing basal support, thus, run-off ws channeled on the surface of the road because roadside drains were not provided. "This facilitated erosion of the inner (cut) segment of the slope and deterioration of the road surface, causing failure of the roads themselves"- and bedrock with granodiorite. (sandy to gravelly textured soils that are usually non-plastic) (Maharaj, 1993)

5. **Slope Instability in St. Thomas**

St. Thomas also shares the threats of landslides to its community which can occur through the following factors: steep slopes, heavy rainfall, faulting,and the presence of sandstones, highly weathered volcanics, sandstone/shale series, limestones and hurricane season from June to November. (Miller, Brewer & Harris, 2009) The study on St. Thomas

however differs from St. Andrews because where the St. Andrew studies highlights how landslides are threats to the Jamaican community, the St. Thomas study highlights how we can harness rainfall thresholds to predict landslides and prevent them. According to Dr. Miller's article on rainfall thresholds, it's one of the most effective ways to mitigate the natural effects of landslides.(Miller, Brewer & Harris, 2009) Calculating threshold established rainfall amount/duration required for landsliding to occur. Thus, rainfall threshold is dependent on landslide data, newspaper archives, geotechnical reports, and meteorological data from, in this case, the Water Resources Authority. (WRA)

Mitigation and Management

Landslides are usually mitigated by repairing the slope stability. This is the only factor that can be controlled since the island of Jamaica is in a climate and geography prone to landslides due to the temperature being 22 degrees Calcius, a "rugged steep hills and mountains covered by deeply weathered soils." (Miller & Leszczynska, 2014)

Normally, slope repair would occur with "conventional earth-retaining structures made of steel or concrete are usually not visually pleasing or environmentally friendly. "(Schuster & Highland, 2003) Yet, the simple solution is the biotechnical approach of growing vegetation. This has less (negative) impact on the environment by creating a stronger slope less prone to causing slope instability. (Schuster & Highland, 2003) According to the article titled *Impact of Landslides and Innovative Landslide-Mitigation Measures on the Natural Environment*, Two elements of slope protection are: biotechnical stabilization and soil bioengineering stabilization, "both of which entail the use of live materials – specifically vegetation (Gray and Sotir, 1996). Biotechnical stabilization utilizes mechanical elements (structures) in combination with biological elements (plants) to prevent and arrest slope failures and erosion (Gray and Leiser, 1982)."(Schuster & Highland, 2003) This can be seen through simple systems such as geonets, anchored by soil nails, that hold in place soil seeded with grass and geocells with seeded soils in the interstices. (Schuster & Highland, 2003) Here it is vital that mechanical and biological components work together,however, with soil bioengineering stabilization " live plant parts, i.e., roots, stems and branches, serve as the main structural/mechanical elements in the slope protection system (Gray and Sotir, 1996)." (Schuster & Highland, 2003)

However, because most biotechnical solutions require a lot of money to finance the project, islands like Jamaica need to be creative with implementing solutions that don't pose a detrimental investment in the long-term as well as have a short term and cost-effective solution.

Table 6. Physical mitigation methods (Colorado Geological Survey et al., 1988).

A. Physical Mitigation Methods for Slides and Slumps
   1. Drainage
      a. Surface drainage
         1) ditches
         2) regrading
         3) surface sealing
      b. Subsurface drainage
         1) horizontal drains
         2) vertical drains/wells
         3) trench drains/interceptors, cut-off drains/counterforts
         4) drainage galleries or tunnels
         5) blanket drains
         6) electro-osmosis
         7) blasting
         8) subsurface barriers
   2. Excavation or regrading of the slope
      a. Total removal of landslide mass
      b. Regrading of the slope
      c. Excavation to unload the upper part of the landslide
      d. Excavation and replacement of the toe of the landslide with other materials
   3. Restraining structures
      a. Retaining walls
      b. Piles
      c. Buttresses and counterweight fills
      d. Tie rods and anchors

Table 6. Continued

e. Rock bolts/anchors/dowels
4. Vegetation
5. Soil hardening
   a. Chemical treatment
   b. Freezing
   c. Thermal treatment
   d. Grouting

B. Physical Mitigation Methods for Debris Flows and Debris Avalanches
1. Source-area stabilization
   a. Check dams
   b. Revegetation
2. Energy dissipation and flow control
   a. Check dams
   b. Deflection walls
   c. Debris basins
   d. Debris fences
   e. Deflection dams
   f. Channelization
3. Direct protection
   a. Impact spreading walls
   b. Stem walls
   c. Vegetation barriers

C. Physical Mitigation Methods for Rockfalls
1. Stabilization
   a. Excavation
   b. Benching
   c. Scaling and trimming
   d. Rock bolts/anchors/dowels
   e. Chains and cables
   f. Anchored mesh nets
   g. Shotcrete
   h. Buttresses
   j. Dentition
2. Protection
   a. Rock-trap ditches
   b. Catch nets and fences
   c. Catch walls
   d. Rock sheds or tunnels

❑

Table 1 Physical Mitigation Methods (Colorado Geological Survey et. al., 1988)

Impact

The physical impact of landslides wreaks havoc on Jamaica's government and national emergency fund allowance. According to the article on Natural Hazard Maps in Jamaica, the destruction of road networks and water structures alone is an estimated US $86.25 million from the time period of 1986 to 1998. (Ahmad, 2001)

For example, the flood rains from May-June 1986 caused damaged road networks that cost $16 million to repair and the displacement of 17 families cost $273, 000; Hurricane Gilbert in 1988, 60% of the island's water facilities were destroyed and cost $10 million to repay (because landslides deposited about 20, 000 m^3 of sediment into rivers) while repairs to the road network cost $19.3 million dollars (due to landslides blocking roadways in the St. Andrews province). (Ahmad, 2001)

Other physical damages include disrupting pipelines, power supply, ruining crop supply like coffee, bananas, plantains and livestock as well as community/private buildings and infrastructure.

And not only is there an economic impact from the recurring damages and the financial cost of fixing it, but the impact from the physical damages also affect the mitigation techniques that can be carried out. For example, big landslides cause roads to virtually disappear along with the possible installation of gabion slides or hard engineering techniques to be attached to steep slopes. Thus, creative solutions need to be implemented in these cases.

The socio-economic impact of landslides in local parishes amplify the push for the correct allocation of funds and diligent management. According to the Jamaica Gleaner, the Tropical storm Zeta yielded catastrophic damages in 2020 and an estimate of $1 billion is needed to repair roads, and infrastructure across several provinces in just one example. (Jamaica Gleaner, 2020)

Many occurrences of natural disasters like this require creative solutions due to lack of funding. Jamaica is a country with many slopes and terrain that does no favors to mitigate landslides.

As opposed to hard engineering, an approach that takes the medium between hard skills and soft skills is strategically enforcing better building codes instead of directly altering the geography and slope stability and creating landslide awareness as mitigation and management. The argument here may be that Jamaica doesn't have the funds to be actively regulating building codes, however, the short term often overlooks the long-term goal of saving money and creating a better and safer community overall. According to this cost-benefit analysis, "-houses that are built to code are able to withstand the effects of hurricane impacts as observed in Jamaica during Hurricane Dean and Grenada during Ivan in 2004. Similarly, stronger shelters survived the impacts of Hurricane Irene, a category 3 storm in the Bahamas." (Jerath & Sarmiento, 2012) And when conducting a cost-benefit analysis, it similarly found that retrofitting

76 houses to withstand landslides and natural disasters with soft mitigation methods cost $47,741 while rebuilding just six houses cost $82,919. (Jerath & Sarmiento, 2012)

The social impact of landslides include a culture of natural disaster awareness and education amongst children and adults alike. According to the report of Disaster Mitigation, Preparedness and Response by the Abacus for Communities, the role of active communities within the disaster management framework is extremely important and contributes to government efforts while helping to minimize loss and damage, and effectively shortening the time and cost of recovery. (Rademacher, 2010)

As well, children are an economic asset when it comes to natural disaster protection and systems to protect citizens. Emergency protocols displayed through school events create opportunities for an entire community to be educated by the youth when they inevitably share their learned information. (Morris et. al., 2008) Thus, although the perception of landslide awareness and education and awareness is often misunderstood as solely for children, however, the entire community can benefit from this as well.

Conclusion

When considering the best way to help local communities withstand the effects of natural disasters, the best way is to reach out to those communities directly. This is where socio-economic surveys are helpful. Organizations like FEMA, UNICEF, The American Red Cross, he Caribbean Disaster Emergency Management Agency (CDEMA), etc. play a huge contribution to local communities by assessing where citizens and government alike can keep themselves and their communities safe. Since the main three categories of questions are preparedness, mitigation and response, the following questions should be used to take count of how many people are 1) aware of natural disaster preparedness, 2) what to do during a disaster, and 3) how to react to the fallout after a disaster. Likewise, government agencies should make sure to 1) prepare their communities for natural disasters, 2) practice mitigation and management well in advance to decrease the social, economic and physical impact of landslides and 3) provide an effective response to their local communities.

Sample Questions:

Household Survey & Preparedness:

1) Do you know what causes landslides? (Including the Warning signs?)
2) Do you know areas in your parish generally prone to landslide hazards?
3) Do you know safe areas in our parish that are not prone to landslides?
4) Do you know how to prepare for landslides? How do you prepare for landslides?
5) Do you know what to do during landslides? What to do during landslides?
6) Do you know what to do if you are in immediate danger of a landslide? How to resolve an immediate threat of a landslide?
7) Do you know what to do after a landslide? What stages do you participate in when it comes to post-landslide response?

8) If you answered “I don’t know.” to any of these questions, do you know how you would find the answers?
9) Follow-up to 8) How?
10) Is anyone in your household trained for first aid?
11) Are any children in your household educated about the previous questions? If so, how?

Government Mitigation + Response Survey:

1) Is landslide mitigation carried out independently or jointly with private developers?
2) How is management and mitigation used in preparedness as opposed to response?
3) Is more time taken assessing a response instead of mitigation?
4) How are property owners compensated for loss of land and/or destruction of property?
5) What role do state and federal agencies play in mitigation? (financial, technical, and administrative)?
6) Are the teams to mitigate landslides interdisciplinary? (engineering, administration, funding, scientific)
7) What factors are you looking for in mitigation strategies? (ex: probability of landslide occurrences, economic loss in the event of a landslide, cost of mitigation, and economic benefit of mitigation)
8) Is there legislation for land – use planning?
9) What mitigation initiatives have been announced in the past five years that has provincial and federal leadership support? (Given reduction loss methods depend on the will of the leadership)
10) What are the conflicting measures regarding land use and development of hazard mitigation?
11) What mitigation techniques are available at a local level that promotes community involvement and is relatively cost-effective?
12) Are there routine operations of local government? (Such as the adoption and enforcement of grading and construction codes and ordinances, the development of land-use and open-space plans, elimination of nonconforming uses, limitation of the extension of public utilities, etc.) *This has the greatest potential for mitigation
13) Are there local mitigation plans/projects for parish communities to prepare in-case of emergency?
14) Are mitigation techniques communicated to planners, decision makers and emergency response personnel at the appropriate times?
15) How often have building and grading codes been updated?
16) Are there safety signs before after and during landslide events that bring awareness and provide safety guidelines for citizens of a parish?
17) What building and grading codes can be used to better mitigate landslides? (Can be cost-effective because development already occurs)
18) How often is public mitigation and community awareness used in order to mitigate potential landslide events?
19) Are warning systems put in place when visual and physical signs go undetected?
20) How often is a cost-benefit approach used to conduct mitigation?
21) How often are physical mitigation tools used and created for parishes under threat of landslide events?

Once we can ensure everyone is doing their part to better the community, only them can we address slope instability and landslides with the vigour and detail it needs to make sure our communities are safer.

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