Towards the Development of an Anti-Colonial Critique of Climate and Disaster Risk Models

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ABSTRACT

Technology mediated environmental data increasingly shapes how we understand the world, including pressing ecological issues such as disasters and climate change. However, like all data, environmental data is limited and partial. It is necessary to attend to the decisions and practices that create and use this data to understand their limits and advocate for alternatives. In this paper, we draw on postcolonial, decolonial, and anti-colonial theory and a case study of a multi-hazard disaster and climate risk assessment project conducted in Nepal to examine a potential limit of contemporary environmental data practices – the potential to extend or reinforce colonial knowledge systems and extractive relationship to land. Through our analysis, we draw attention to how environmental data practices, such as disaster risk assessment, may contribute to ongoing colonial relationships by privileging technocratic Eurocentric knowledge, conflating disaster effects with economic loss, ignoring ecological impact, and overlooking historical and ongoing power hierarchies. We build on our findings to think through opportunities to reimagine disaster and climate risk beyond probabilistic quantitative models. To do so, we propose four tactics towards an anti-colonial science of risk, as well as argue for a more thorough analysis that attends to situated practices of creating and using environmental data.

ACM Reference Format:
Shreyasha Paudel, Sabine Loos, and Robert Soden. 2021. Towards the Development of an Anti-Colonial Critique of Climate and Disaster Risk Models . In *LIMITS '23: Workshop on Computing within Limits, June 14–15, 2023.* ACM, New York, NY, USA, 12 pages.

1 INTRODUCTION

Environmental data play a central role in how we understand the world around us, including helping us make sense of pressing issues like disasters and climate change. For example, sophisticated networks of sensors collect information about land, water, atmosphere, and people's daily lives. This data is interpreted by computational models to generate trends and future projections, which are recorded and visualized in spreadsheets, maps, and dashboards. These computationally produced datasets, projections, and maps are powerful tools – they form the basis of how the public understands environmental impact and how scientific experts, advocacy groups, and policymakers envision needs and potential interventions at local, regional, and global scales [35].

Despite the importance of environmental data in planning and decision-making, we do not yet pay enough attention to the design of these tools or the practices surrounding their use [86]. Environmental data, like all data, are abstractions of the real-world and necessarily include choices regarding what is included and what is left out. In making these choices, we have a tendency to reproduce, often unknowingly, our own priorities, prejudices, and perspectives as well as those of the wider society in which we live. Political ecologists have shown how political economic structures and institutional cultures inform what counts as valid environmental data [10]. Similarly, STS and HCI scholars have demonstrated how socio-technical infrastructures such as data sources, standardization practices, hardware and software constraints, governance policies, and institutional workflows shape information practices [35]. Fortun powerfully describes this phenomenon as "informating of environmentalism" and shows how environmental information systems, such as the pollution information site, Scorecard.org, negotiate and structure power by the different ways they configure access to knowledge, manage uncertainty, and define what counts as valid knowledge and what does not [29]. Attending to these practices and understanding what information is represented, whose needs are valued, and what interventions are considered feasible is necessary to understand the limits of technologically mediated environmental data and advocate for alternatives for a more just and equitable society.

In this work, we consider how contemporary environmental data practices risk extending and reinforcing colonial relationships between Western countries and the majority world, and national governments and the indigenous communities who live in their borders. Scholars have shown how legacy of colonization has shaped the current distribution of resources, wealth, and power in the world which in turn shapes technological infrastructures [74], environmental and development goals [31, 109], economic relations [43, 109] and knowledge practices [15, 43, 109]. Others have discussed how contemporary data practices introduce new forms of extractive relations and colonialisms [11, 19, 57]. Here, we draw from indigenous scholars, scholars from the Global South, and others who argue that colonization is not over, but is an ongoing process of extractive land relations that assume continuous access to resources marked by apparatuses of domination and exclusion specific to particular place and people[52, 106]. Recent work has begun to examine how contemporary data practices and assemblages reproduce and reinforce extractive and oppressive land relations in various domains such as artificial intelligence [59], humanitarian applications [57], and environmental justice[107] .

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Our work examines the potential contribution of contemporary practices surrounding environmental information to extending or reinforcing colonial relations. We look to the specific example of an environmental data practice — a national multi-hazard disaster and climate risk assessment project recently conducted in Nepal — as one way of beginning to reckon with what is undoubtedly a much broader set of questions. The risk assessment we evaluated was funded by The World Bank and implemented by leading national and international risk modelling organizations in close collaboration with the Government of Nepal. The assessment aimed to provide a comprehensive synthesis of natural hazard risk in the country, recommendations for a disaster risk mitigation strategy, and serve as a template for similar assessments in the region. Disaster risk assessment, such as the one in Nepal, combine computational and data-driven models from the physical sciences with those from engineering and economics to obtain a probabilistic estimate of potential losses from future events. These models, commonly known as disaster risk models, were historically developed to understand the risk associated with property damage for insurers and re-insurers and are still primarily used to transfer and distribute risk [37]. Increasingly, they are being adopted by governments and developmental organizations to support critical decision-making around land-use, emergency preparedness, and response and recovery planning [44, 88].

We draw on emerging decolonial and anti-colonial theory in computer and information sciences and indigenous STS to explore the potential for disaster risk models to reinforce and encode colonial knowledge systems and extractive relationships to land. Based on this analysis, we find that this form of producing knowledge and data about the environment may contribute to ongoing coloniality through the incorporation of Eurocentric technocratic ideals into the design of the model and surrounding assessment process, reducing climate and disaster risks to economic loss, ignoring ecological impacts of disaster as well as people's situated relationship to land, and rendering both risk and Nepali social and political life more broadly as static, ahistorical entities. We build on these arguments as well as Liboiron's recent book, *Pollution is Colonialism* [52], to consider the outlines of what an anti-colonial science of disaster and climate risk might entail. We also argue that a more thorough analysis of the relationship between contemporary environmental information must go beyond the evaluation of a single report but also must carefully attend to the situated practices surrounding the design, collection, analysis and distribution of such information. Finally, we connect our analysis and arguments to ongoing conversations in the LIMITS community about the role of computational modeling [53, 64, 85], ecological limits [78, 85], and environmental justice [8].

2 RELATED WORK

2.1 Disaster Risk Management and Crisis Informatics

Disaster risk management seeks to enhance a community's capacity for disaster resilience by anticipating, resisting, responding, and recovering from disasters [101]. Much of this work includes the use of data and information system by disaster experts, policy makers, and increasingly, the public. For example, disaster practitioners use satellite and remote sensing technology for monitoring and detecting natural hazards, algorithmic models for predicting risk, Geographic Information System for mapping hazard and disaster damage, and various communication platforms for coordinating response and communicating risk [68, 101]. HCI and CSCW researchers have studied these practices under crisis informatics research which combines computing and social science perspectives to study the ways in which information and communication technology can help and constrain humans to respond to natural hazards [72]. Crisis informatics researchers draw from social sciences and information studies to address socio-technical concerns in understanding, responding, and communicating about large-scale crises and their impacts on populations such as — use of sensing and mapping technologies to understand disasters [90], use of digital communication tools for collecting information and coordinating volunteer work [96], and the evolution of digital tools and platforms as crisis infrastructures [71].

Our work builds on prior crisis informatics research that have studied information infrastructure and shown how data standards, measurement practices, and information products in disaster response legitimate some understandings of disasters while foreclosing others [87, 89, 91], shape what kind of response is made available [27, 91], and become sites of contestation and politics [40, 91]. Beyond crisis informatics, researchers have criticized disaster modeling practices for their focus on economic losses [38], limited definition of disaster risk [102], and the impossibility of precise characterization of risk [110]. More fundamentally, disaster risk assessment is an example of dominant scientific and market-driven approach to disaster response. Such a logic has been criticized by scholars for excluding indigenous perspectives [15, 52], while ignoring root causes of vulnerability to disasters shaped by social and political factors [66]. In Nepal, the focus of our case study, researchers have pointed out how a lack of institutional accountability [84], absence of local understanding of disaster risk [6], and a disaster policy guided by international humanitarian framework [45, 84] has led to significant gaps in disaster risk and recovery practices.

Critiques of crisis and disaster data point to the need to account for the socially constructed nature of risk, and draw attention to the ways that socio-political context and people's perceptions affect both the understanding of risk and the sorts of interventions that are considered [75, 91]. Increasingly, computational models, such as disaster risk models, are becoming the predominant approach to define risk. Our study examines the construction of disaster risk through the lens of anti and de-colonial theories to highlight potential colonial tendencies on how dominant environmental data practices often take an anthropocentric and resource-centric view of land and disasters. Acknowledging and attending to these tendencies can, in the words of the LIMITS CFP, "help move us closer towards computing that support diverse human and non-human lifeforms and thriving biospheres."

2.2 Computing and Colonialism

There is a growing body of research in HCI and computing-adjacent field concerned with unequal power relationships in technology use

and adoption in different contexts, including technology transfer from the Global 'North' to the Global 'South'. Such scholarships have highlighted how computing as a discipline embeds colonial relationships [2, 24, 43, 79] such as the epistemological bias in computing towards European norms, the economic and labor histories rooted in colonial histories that shape today's computing industry, and the cultural, economic and digital divide that exists in many Global South societies as a legacy of colonialism. More recently, critical scholars have also used colonialism as a framework to name and criticize newer forms of extractive and exploitative relations that have been made possible through data and information platforms such as digital colonialism [48], data colonialism [19, 79, 103], algorithmic colonialism [11, 59], and techno-colonialism [57].

Along with naming colonial relations, HCI researchers have also suggested a variety of approaches to counter contemporary forms of coloniality. For example, Irani et al. introduced the lens of postcolonial computing to examine the issues of culture and power at work in computing and ICT contexts as technologies move across geographic borders [43]. Others have said that such an approach ignores issues of race and class-based inequalities within post-colonial countries, and offered decolonial computing as an alternative that foregrounds Black and Indigenous technological histories [2, 4]. In recent years, decolonization literature within computing and data studies has called for rejecting the continuous collection of data as a resource [19], questioning colonial legacies of dominant categorization, modeling, and design practices [51, 59], and building pluriversal design and computing practices [3, 59].

Outside of the computing literature, some indigenous scholars have attempted to clarify central tenets of decolonial and anti-colonial theory, in particular emphasizing the connection between colonization and land relations [52, 106]. From this perspective, colonization is distinct from other forms of structural oppression [106]. Further, it is not limited to prior historical projects of domination of land or people, even though it is commonly associated with the European political expansion of the 15th through the 20th centuries. Instead, in this view, colonialism is ongoing and defined by the aspiration of settler and colonial projects towards unfettered access to people, land, and knowledge systems. It manifests in ways that are always specific to people, place, and their histories. Scholars working in this area note that colonial relations are deeply interwoven with scientific practice in ways that continue to impact indigenous communities and ecologies. For example, Liboiron describes how environmental practices, such as the call for recycling, is colonial because it assumes access to land for recycling centers [52]. Similarly, Gergan shows how colonial assumptions embedded in hydropower risk assessment projects exacerbates disaster risk in Sikkim and Northern India [31].

In order to further understand the colonial potential, or tendencies, of environmental data, we draw on three arguments from this literature that, together, provide a lens through which to examine the practice of disaster risk modeling in Nepal. First, we draw on indigenous theory of colonialism to examine how data practices might reproduce or enforce extractive relationship to land and people. Second, we examine how these practices are influenced by global hierarchies of power, wealth, and knowledge systems shaped by colonial mechanisms. And finally, we look at the place-based history and power relations of Nepal and South Asian region to understand how these relationships appear in specific context of disaster vulnerability in Nepal.

3 BACKGROUND: AN OVERVIEW OF DISASTER RISK MODELS

Disaster risk models are computational models that are designed to estimate the potential impacts from natural and climate hazards such as earthquake, droughts, hurricane, floods, and landslides. Modern versions of the disaster risk models can be traced to late 1980s and early 1990s when the techniques for mapping risk and measuring hazards were combined into computer-based models [37, 82]. These models were commercialized and widely adopted by insurance industry after large-scale disasters in the late 1980s and 90s such as the Hurricane Hugo, Hurricane Andrew, and the Loma Prieta Earthquake caused billions in damages [37, 82]. By the early 2010s, academic researchers, policymakers, and development planners had embraced these models driven by the reduced computational costs, widely available GIS data and open source models, as well as the heightened concerns about climate change [44]. Increasingly, the outputs from these models are used by governments and developmental organizations for public decision-making, such as evaluating the safety of public infrastructure (like dams or bridges), calibrating design standards (like building codes), designing land use policies, and developing early warning systems [88].

A typical disaster risk model consists of four main components, namely hazard, exposure, vulnerability, and loss as shown in the Figure 1. The hazard module simulates the probability of severity and extent of future natural hazards like earthquakes, flood, or hurricanes using physical models and historical data of prior events [37]. The second module is called exposure, which maps the spatial distribution of assets in the extent of the hazard and their relevant characteristics. Examples of such assets traditionally include physical infrastructure like buildings, roads, or bridges though sometimes direct population exposure is used [37]. Assets in a physical infrastructure exposure model are characterized by geographic location, age, structural properties, and economic value [12, 37], whereas population exposure typically consists of number of people. The third component, vulnerability, typically consists of a model that calculates the expected damage to an exposed asset at each hazard intensity [12]. Typically, the vulnerability component is expressed through vulnerability and fragility curves for physical infrastructure. The outputs of the hazard, exposure, and vulnerability are modified by the loss component to provide a quantifiable consequence for the damage [44]. In insurance applications, loss includes estimates of death, injuries, infrastructural damage, and economic loss due to damage or secondary disruptions [25]. In public applications, losses sometimes also include socio-economic factors [25]. In the end, these four components provide an estimate of probabilistic disaster risk, characterized as the probability distribution of potential future losses over a variety of hazard scenarios.

4 CASE STUDY AND METHODS

Our study seeks to examine the colonial tendencies of contemporary disaster risk modelling practices through a case study of a multi-hazard risk assessment project conducted in Nepal. The assessment was funded by the World Bank's Global Facility for

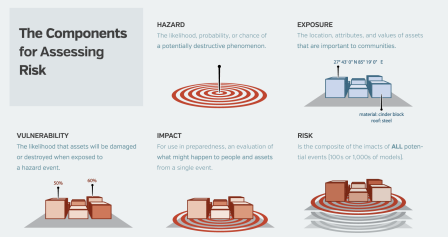

Figure 1: The components of a risk assessment model [34]

Disaster Reduction and Recovery (GFDRR), and conducted by the Asian Disaster Preparedness Center (ADPC), the Center of International Studies and Cooperation (CECI) Nepal, and the Norewegian Geotechnical Institute in close collaboration with the Government of Nepal. Additional technical support was provided by the International Institute of Applied System Analysis. The main goal of the project was to develop a synthesis report on Nepal's major hazard risks, provide recommendations for national disaster risk mitigation strategy, and serve as a template for similar assessments in the region [67].

The overall methodology for the report is presented in Figure 2. This methodology is representative of standard practices in such an assessment [32, 44]. Five different types of hazards were considered – earthquake, flood, landslide, drought, and epidemics. The assessment analyzed the exposure and vulnerability of the hazards on key sectors such as housing, health, education, transportation, agriculture, tourism, mines and quarry, power, industry, irrigation, fisheries, and trade. For each hazard, the team first collected baseline data on past hazard incidents and the estimated losses from existing reports and historical data. They then conducted hazard assessment and hazard mapping using a variety of standard scientific tools and techniques at geographic scales appropriate for each hazard. For example, the earthquake hazard assessment was carried out to divide the entire country into five zones of earthquake severity. Flood hazard mapping was conducted for seven major river basins using hydrological data, landuse data, elevation information, and river catchment information. The exposure analysis for each hazard was conducted separately, and was conducted on sectors that were selected based on expert agreement as most likely to be severely impacted. The vulnerability and risk assessment process was then combined to get an estimate of associated risk such as number of casualties or estimated economic damage for assets in each sector and for each hazard [67].

Finally, the risk assessment was followed by a macroeconomic analysis using a Catastrophe Simulation (CATSIM) model to estimate the national Gross Development Product (GDP) loss, the fiscal vulnerability gap for Nepal government, and the costs and benefits of risk mitigation options [67]. This macroeconomic analysis of GDP was done at a national level. Additionally, economic impact on individual economic sectors was also assessed using a Social Accounting Matrix (SAM) model [67]. According to the report, both CATSIM and the SAM are the most common and scientifically accepted approach for economic loss estimation of natural disasters [67]. The outcomes from the economic simulations was used to develop recommendations for risk mitigation which included a national disaster risk reduction strategy, institutional mandates, preparedness and response plans, the integration of disaster risk reduction into development planning; community-based disaster risk management (CBDRM); and public awareness, education, and training.

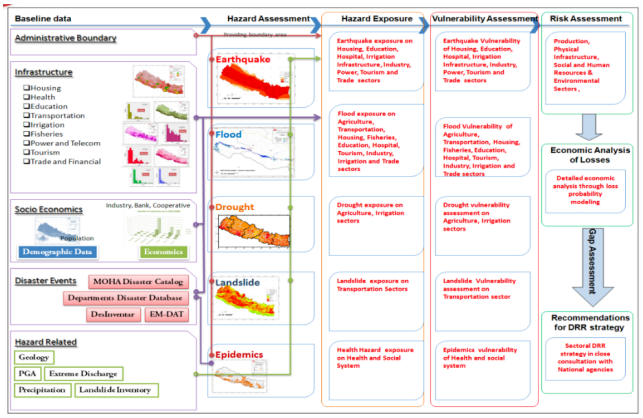

Figure 2: Overall methodology of the multi-hazard assessment project [67]

In our study, we examined the project report published at the conclusion of the project in 2010 using the three part framework that we derived from the postcolonial, decolonial, and anti-colonial literature. We paid close attention to and took notes on the language of the report, the methodology and data, and the presented results to note both stated and unstated assumptions about what constituted as risk, what constituted valid data, and who counted as stakeholders. Drawing on postcolonial, decolonial, and anti-colonial theories in STS and Information Science and Computer Science, we sought to evaluate how the assessment and the report viewed the relationships between land, people, hazards, risk, economy, and the future. We chose this particular risk assessment, because, as far as we can tell, this is the most recent national scale multi-hazard risk assessment conducted in Nepal, which was conducted in close collaboration with government agencies responsible for disaster risk management in Nepal. The assessment was considered to be robust and reflective of the best practices at the time and reflects typical regional hazard risk models that are used even today [32, 33]. Furthermore, our authoring team has significant prior research on disaster risk information in Nepal [49, 55, 73, 89, 90] to contextualize this assessment. Because the methodology used in the Nepal multi-hazard risk assessment is closely aligned with similar efforts underway in many parts of the Global South [67], an analysis of this particular report provides valuable insight into the broader state of practice of disaster risk modeling. In the following section, we identify four possible ways in which colonial perspectives (or tendencies as we term them here) are embedded in design of the model, the process through which it was carried out, and the presentation of the final report.

5 COLONIAL TENDENCIES IN CONTEMPORARY DISASTER RISK MODELLING

5.1 Embodies Eurocentric Technocratic Ideals founded on Colonial History

Nepal's multi-hazard assessment was conducted by a coalition of national and international development organizations to recommend a development planning framework for disaster risk mitigation. In doing so, the analysis promotes a dominant and scientific framework for disaster risk and decision making by central planners in the government and development organizations, and ignores the lived experience, traditional knowledge, and community expertise of local people living in disaster prone areas. By prioritizing a technocratic process and expert knowledge over situated and collaborative approaches, the assessment could reinforce colonial knowledge hierarchies and reduce local involvement.

The decision to use deterministic methods and a motivation to quantify disaster risk in the multi-hazard assessment likely stem from ingrained technocratic ideals and a belief in scientific neutrality and objectivity. The report highlights how the hazard assessment is "carried out using scientific tools" and validated "using statistical tools and methods" [67]. What counted as risk was defined by a centralized group of experts and the same methodology was used throughout the country despite significant geographic, cultural, and economic diversity across Nepal. The data used for the project was primarily quantitative and gathered from technical databases, government institutions, and international sources. When there was a lack of existing data and literature, such as vulnerability functions for earthquake, flood, and landslides, the team filled the gap by adapting literature from housing classification models developed for South and South-East Asia, or sometimes even international standards like the ATC-13 earthquake damage matrix which was originally developed for use in California [5]. The report did not mention working with local organizations, community members, or community consultations.

The technocratic motivation also influenced who the multi-hazard assessment team considered the users and stakeholders for their resulting data. For example, the report identified its primary stakeholders as the project team themselves, the primary institutional contact (Ministry of Home Affairs), and a list of beneficiary stakeholders as described below:

> "This class of [beneficiary] stakeholders includes United Nations Development program (UNDP), The International Centre for Integrated Mountain Development (ICIMOD), Central Bureau of Statistics, Ministry of Culture Tourism & Civil Aviation, Ministry of Education & Sports, Ministry of Finance, Ministry of Health and Population, Ministry of Agriculture and Cooperative, Ministry of Industry Commerce & Supplies, Ministry of Information & Communications, Ministry of Local Development, Ministry of Physical Planning & Works, Department of Electricity Development, Ministry of Irrigation etc." [67, p.3]

In the above quote, the list of stakeholders includes representatives from national government and global development organizations, which are largely centralized in Kathmandu, the capital city. Local people and communities who live in disaster prone areas are conspicuously missing. As a result, most of the recommended applications for the assessment outputs such as hazard maps, vulnerability curves, and estimated economic losses in the report are targeted at central planners and decision makers in national government and global development organizations. The recommendations in the report suggested collecting more scientific data, building institutional collaboration between government and developmental organizations, and investing in technical infrastructures such as early warning systems, GIS sensors, and more sophisticated models. While gathering data and developing technical infrastructures is important, disaster risk assessment and mitigation strategies can be strengthened and culturally contextualized if they also include traditional knowledge and practices of communities, many indigenous, who have been living and surviving in disaster prone areas of Nepal.

5.2 Measures Risk in Terms of Quantifiable Economic Losses

Like many development projects and established practices in risk assessment, the assessment and report defined disaster risk as the potential loss in national GDP. As a result, the baseline data included in the assessment incorporated data from prior hazard and vulnerability studies, risk assessment reports, disaster databases, and the national economic assets. All these datasets quantified impacts in terms of economic losses. In practice, disasters also have intangible impacts related to everyday life, place-based attachments, and cultural and community connections [94]. This focus on economic losses, while ignoring other types of disaster risk and impact, may stem from, and reinforce, colonial perspectives that reduces nation, people, and their relationships to each other as resources that are only considered from the perspective of their contribution to economic activity. It can also contribute to disaster response and mitigation efforts that widen disparities, as individuals and communities with greater assets in the first place tend to be over-represented in metrics of disaster impact that emphasize economic impact [39].

In addition, the emphasis on potential economic losses may also lead to characterization of risk that ignore the specific needs of people and communities in hazard prone regions. For example, the assessment primarily addressed "earthquakes and floods, which are the most serious risk for the fiscal position and economic growth" and ignored other hazards like droughts and landslides, which the multi-hazard assessment team considered to be negligible nationally because it only affected certain regions. While this reasoning to ignore certain risks might make sense when the goal of the assessment is to reduce disaster impacts on national-level GDP, it may not be an equitable approach for public-decision making to reduce impacts on communities who regularly and disproportionately face landslides and droughts. For example, the report cites that "moderate drought frequently occurs in all seasons" and that "all categories (moderate, severe, and extreme) droughts show increasing trend in winter season" [67]. Despite this, drought was "considered a

more regional issue affecting the Terai area" and not considered as a significant contributor to disaster risk during scenario planning. Similarly, the effect of landslides was considered "negligible at a national scale" despite the assessment finding high likelihoods of earthquake triggered landslides in hilly region as shown in Figure 3 below.

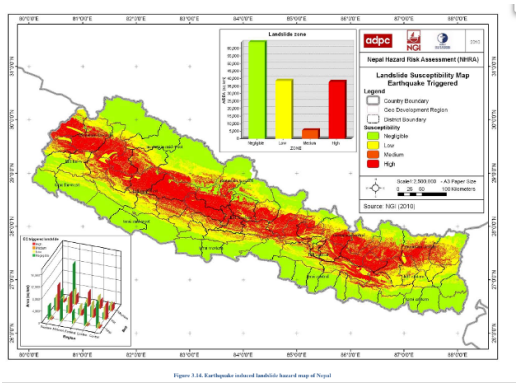

Figure 3: Landslide Susceptibility Map from the Multi-Hazard Assessment Report [67]

Lastly, economic loss was used as the only metric of risk for gap assessment and generating disaster risk reduction recommendations as shown in Figure 2. Despite considering various social and economic aspects on lives and livelihood during the hazard and exposure assessment, the use of the economic simulation model reduced these relationships to a single measure on national level GDP. Along with flattening these relationships, this methodological decision limited the ultimate scope of intended applications of this project and the report to economic cost-benefit analysis and disaster risk financing related applications. Even the recommendation for education and awareness raising programs for disaster organizations and local governments focus on risk sharing and financing options, or the ability to "identify which risks to keep, finance, or transfer" [67]. Such a limited focus and recommendation is likely to incentivize disaster preparedness and mitigation in places that have more economically quantifiable lifestyles and ignore needs of more traditional and rural forms of land relationships. For example, the assessment report suggested infrastructural development and zoning laws for urban areas as applications for the developed hazard maps but did not include any possible applications for rural areas. Our findings align with other studies which have found bias in disaster risk management and recovery towards more developed areas with higher socio-economic status [84, 94].

5.3 Ignores Ecological Impact and People's Relation to Land

The focus on economic losses also meant that the hazard assessment methodology ignored the impacts of disaster events on the environment and on biodiversity. In our reading of the report, we note two forms of such omission. First, as the flowchart in Figure 4 shows, the economic simulation model (as indicated by the red box) took only social effects and economic effects as inputs while ignoring ecological effects. The output of the economic simulation model was used for identifying gaps and generating recommendations. The report acknowledges this omission, but in our reading, we could not find any justification for ignoring ecological effects or recommendation on ways to account for such a limitation for their model.

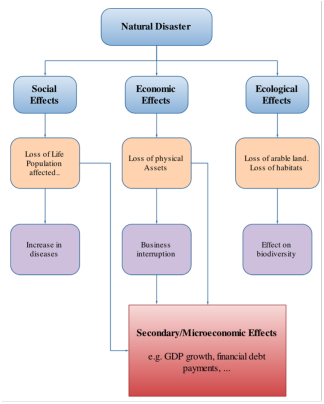

Figure 4: Flowchart showing the assessment's methodology for estimating micro-economic effects of disaster [67]

Secondly, this report mischaracterizes relations between disasters and the environment by ignoring the ways extractive economic activities harm the environment and, consequently, further exacerbate disaster impacts. For example, the assessment considered the effects of disasters on irrigation, mining, and agriculture, providing recommendations on ways to disrupt impact to these sectors when large scale disaster strikes. The unstated assumption is therefore that these sectors and their current practices should unequivocally exist and be minimally disrupted in the case of a disaster. Such an assumption ignores the environmental risks of these industries and entrenches extractive colonial relationships by foreclosing potential for alternative sustainable practices. The report did not note how ongoing practices in irrigation, mining, and agriculture might contribute to both the frequency and impact of disasters through disruption of landscapes. Studies in Nepal have linked increased flood and landslide risk to infrastructural development projects including roads, irrigation canals, and hydroelectricity projects [56, 58, 70]. Instead of treating these infrastructures as a given, a more holistic and relational approach to risk would consider the trade-offs included in having these constructions and treat disaster and crisis as an opportunity to create new configurations of human-environment relationships [41, 89].

5.4 Treats Nepal and Nepali Society as Unchanging and Ahistorical

Finally, the assessment treats Nepali society as well as the climate and disaster risk it faces, as static entities, ignoring all the ways in which both the natural environment and the social and cultural context are products of history and continuously evolving. Understanding the dynamic, temporal character of nature-society relations is necessary to be able to characterize the sources of disaster risk as well as identify meaningful opportunities for mitigation. Through

our analysis, we note three ways in which the multi-hazard assessment ignored the historical and ongoing colonial relationships in Nepal, and as a result, missed out on both root causes for disaster vulnerability as well as the potential for imagined futures and possible ways for reducing disaster risk and managing impact.

First, as critical research into disaster has repeatedly shown, disaster risk and impact are often correlated with social inequalities which are shaped by historical and ongoing oppression [91, 111], often predicated on colonial relations. Ignoring these histories means that we miss out on such causes of disaster vulnerabilities. Here, we identify two such axes of marginalization that exist due to historical colonial relationships but are not considered in the assessment as a factor that affects disaster risk – caste and internal migration due to forced displacement.

In the case of Nepal, caste hierarchy is one of the primary axes of social marginalization, and is correlated with economic precarity, social exclusion, and disaster vulnerability [1, 61, 84]. The current caste system in Nepal is attributed to the introduction of the civic code called *Muluki Ain* in 1854 which codified Hindu caste system, categorized many non-Hindu indigenous groups as 'lower caste' and prevented them from accessing education and bureaucratic positions [50, 94]. The then ruling Rana dynasty modeled the *Muluki Ain* after British common law, following their British supported visits to England and review of how the system was applied in India [50]. The assessment treated population density as a singular factor, disregarding caste demographic, erasing colonial history, and missing on an important axis of vulnerability.

Similarly, land reform and conservation policies in Nepal were historically used to dispossess many indigenous communities who "did not have land registered under their names and many of them lacked the necessary documentation (or access to the political power to produce such documentation)" [17, 69, 76]. These policies kept these groups away from positions of power [94] and forced internal migration to urban centers and Terai lowlands where many of them live in semi-permanent and temporary building structures [65]. While the assessment identified districts in Terai plains and urban areas with high population densities as places that have the highest risk of casualties, it failed to link this risk to the internal migration, social hierarchies, and economic inequalities that were behind these population and housing density patterns and can be traced to historical and ongoing colonial relationships.

The assessment also failed to consider the different ways the social and political context of the country might impact the national government's ability to effectively respond to disaster risk. At the time of the project and the publication of report, Nepal was undergoing a federal restructuring driven by demands of decentralization and an ongoing public debate over ongoing demands for caste equality, indigenous sovereignty, and ethnic governance [83]. However, the assessment team did not consider how the changed governance structure might impact disaster risk mitigation policy. The recommendations included in the document suggest collaboration with existing local authorities at zonal, district, and village development committee (VDC) levels without acknowledging that these structures would change and take a different form of governance in the next few years. As a result, the recommendations became outdated as the new constitution that came into effect in 2015 replaced the zonal and VDC system of government with a federal system with local and provincial government [16]. During our research, we were unclear how the recommendations were adopted, if they were adopted, with the changed administration. It is likely that many of the recommendations ended up losing their applicability because the assessment did not anticipate the changing governance context.

Finally, the ahistorical character of the assessment resulted in a failure to identify more meaningful opportunities for disaster risk mitigation. For example, the assessment defined Community Based Disaster Risk Management (CBDRM) to be a key strategy for disaster risk mitigation and recommended creating new CBDRM teams and networks of local volunteers. While community involvement is surely valuable, an alternative approach would have been to collaborate with ongoing social movements which seek to address structural inequalities in Nepal. For example, since the 1990s, there have been multiple identity movements in Nepal that have increased the awareness of inequality and discrimination, constructed group identities, built national and international organizational networks, and advocated for policy change at both local and national levels [50, 83]. Collaboration with existing community organizations and social movements that were already working toward reducing the types of inequity that lead to disaster vulnerability would likely be a more successful strategy, but would have required that the risk assessment process account more carefully for the dynamic character of social and political life in Nepal.

6 DISCUSSION

6.1 Tactics for an Anti-Colonial Science of Climate and Disaster Risk

Liboiron defines anti-colonial science as an "experimental otherwise" that uses "science against scientific values of universalism, separation, domination, and colonization" [52, p.154]. Anti-colonial approaches can exist in multiple forms, and are upheld by infrastructures and knowledge systems that are "sometimes arrayed with, sometimes adjacent to, and sometimes explicitly against the knowledge systems of dominant science" [52, p.133]. Here, we draw on this approach to re-imagine disaster risk modeling in ways that can counter some of the colonial implications that we identify above. We argue that an anti-colonial approach to disaster risk should move away from universal quantifiable models, and ask different kinds of questions about risk that center people's lived experiences and relations with each other and to land. Below, we propose four tactics that could orient us towards an anti-colonial approach to disaster risk. We do not present these principles as the solution to all the colonial implications listed above but instead as a reflexive starting point to undo habits of technological practices.

Anti-colonial science of risk must pay attention to the specificity of people, place, and risks. Tuck and Yang state the need to define colonization specifically by paying attention to the colonial apparatus that is assembled to order the relationships between "particular peoples, lands, the natural world, and civilization" [106]. As the colonial apparatus is specific, the anti-colonial response to it should also be specific. Unlike dominant and potentially colonial disaster risk models that assume universal definitions of risk and loss, an anti-colonial science of disaster risk would be marked by its attention to local contexts, histories, and needs. An anti-colonial

approach to risk would consider specificity in both metrics and practices and wield them to counter colonial tendencies of neutrality and universality. One way to do so would be by considering the different ways disaster risk and impact are shaped by social, political, geographic and economic vulnerabilities stemming from historical and ongoing marginalization [66, 93, 105]. We showed in subsection 5.4 that disaster vulnerabilities in Nepal correlate to existing social inequalities, which are shaped by the historical caste imposition, land-reform policies, and ongoing marginalization of indigenous communities. Beyond these inequalities, what counts as disaster risk also depends on specific geographic features and cultural practices of communities, as in the case of landslides being more common in the hilly region and posing more risks for rural agricultural communities than urban settlements [55]. An anti-colonial risk model therefore should be designed to be specific in defining the type of risk assessed, the communities they are targeting, and the purpose for measuring the risk. Another approach to increase specificity could include foregoing current hazard based risk assessment and instead starting from specific needs of the communities at risk to come up with alternate questions, metrics, and methods for risk mitigation.

Anti-colonial approaches to developing risk information could also expand beyond quantification to observing and maintaining a good relationship between land, people, and knowledge systems. In our findings, we show how the multi-hazard assessment project assumes a narrow definition of disaster risk where risk equals probability of death, infrastructure damage, or economic losses. It ignores ecological impact. This is an anthropocentric and colonial view, which assumes that nature and land are resources to be used for economic development. An anti-colonial approach instead would attend to reciprocal relationships that connect human well-being with flourishing of the environment [52, 106]. Murphy has coined the term "alterlife", which they define as "life already altered, which is also life open to alteration" to explain the multiple ways the cause and impact of chemical exposure is entangled with human and non-human life forms [63]. Climate and disaster risks are similarly entangled, they arise due to ongoing and cascading interactions of natural processes and human behavior. They also lead to interconnected and long-term consequences to land, ecology, and different life forms. Taking a relational view also allows us to correct the damage-centric narrative of disaster risk to an opportunity for creating new relations that can result in more equitable structures, infrastructures, and lifestyles. For example, Solnit describes moments of altruism, resourcefulness, and generosity that arise amid disaster's disruption [92].

An anti-colonial approach counters positivist universal views that reduce specificity and multiple relations by embracing a pluralism and multiple forms of knowledge. Escobar defines such an approach as a 'pluriverse' – 'a world where many worlds fit' where multiple forms of knowledge can exist in autonomous and radically interdependent ways without seeking to eradicate the difference through domination [26]. An example of a pluriversal approach to existing risk assessment practices would be to extend the current practice of representing probabilistic value of risk on cartographic maps to multiple representations and formulations that are adapted to local language, cultural practices, and value systems. Further, a pluriversal approach would also allow for incorporating specificity into risk assessment practices by integrating scientific and data-driven formulation of risk with alternate forms of knowledge that are more culturally situated such as oral histories, spiritual practices, and social rituals. For example, through their community mapping workshops in Langtang, Nepal, Soden and Lord identified oral histories that describe past disasters and chronic vulnerabilities that were missing from the government datasets and official narratives [89]. In a pluriversal world, the measures and metrics of disaster risk are multiple, each suited for a specific purpose. For example, a probabilistic risk assessment such as the one we analyzed would be useful for giving a high level overview of national level risk. However, it would coexist with other forms of risk assessment that would consider environmental impact, cultural contexts, historical vulnerabilities, and community needs.

Lastly, in an anti-colonial approach, the specificity, relationality, and plurality should be engaged with obligations to the communities who live in disaster prone areas and navigate these risks everyday. This means asking communities what they view as risk and how they imagine their futures. Unlike the multi-hazard risk assessment project in our case study, an assessment that showed obligation to communities and people living in disaster prone areas would include them as primary stakeholders. For example, Cadag and Gaillard suggest incorporating participatory mapping with traditional risk assessment processes to incorporate specific local knowledge as well as community context in the risk assessment process [14]. Indigenous scholar Kim TallBear calls for "standing with" researched communities to constitute knowledge "in concert with the acts and claims of those who I inquire among" [100]. This is a way of attending to obligations towards those communities and unsettle paternalistic care-based relationships that entrench colonial relationships, found in many humanitarian projects [57, 62]. In an anti-colonial worldview where multiple knowledge systems and relationships exist, grounding one's practice with obligations to relationship also allow us to navigate through the incommensurable values and enact compromises such as one encountered when conducting anti-colonial science within colonial institutions [52]. For example, attending to obligations to communities means ensuring that the community has ownership of data and narratives and refusing data platforms or collaborators which may be extractive. It can mean valuing community's guidance, feedback, and refusals, and adjusting the project even when it runs counter to established protocols. Data practices which include critical refusal [30] and indigenous data sovereignty [3, 81] provide some ways of doing so.

6.2 The Limits of Environmental Data

Our study examines the risk of current practices of environmental modeling through a case study of a multi-hazard risk assessment project in Nepal. In our findings, we list four colonial tendencies – the assessment imposed colonial technocratic ideals while ignoring local and plural forms of knowledge, encoded extractive relationships by reducing risk to economic loss, ignored ecological impacts and people's relationship to land, and ignored how disaster risk and response are shaped by historical and ongoing context. We argue that these colonial tendencies have an impact on both risk mitigation and future disaster response. Disaster vulnerability, including in Nepal, exists along the axes of existing inequalities

which were shaped by colonial histories. Many of the disaster-prone areas identified in the report are inhabited by indigenous communities. The assessment ignored these socio-cultural context and the suggested recommendations primarily focused on building technological infrastructures, instituting a national disaster strategy, and incorporating disaster risk mitigation into development priorities. Both the predicted loss and suggested recommendation do not address the root causes of disaster or envision a more just and equitable society.

However, in practice, this risk assessment report is one information source in the complex disaster management ecosystem that includes multiple forms of expertise, multiple stakeholders, diverse and sometimes conflicting institutional priorities, and spatial and temporal constraints. During our research, we were unable to trace how this assessment materially influenced disaster response in Nepal. This is not wholly unexpected, as risk assessment reports are usually meant for pre-disaster planning, while actual impact data and simulations are used for post-disaster response [36, 55]. However, we also expect that these assessments and reports would be more useful and implementable if they considered the social and governance context in the assessment process and recommendations. Studies that looked at the response after the 2015 earthquake showed that the formulation of disaster management policy had not been the priority of the country and despite the successful completion of multiple hazard assessment projects, their recommendations had not been translated to law [84]. Much of initial disaster response during the 2015 earthquake was instead driven by local communities and emergent groups [84, 89]. Beyond Nepal, research has shown that there has been an overproduction of disaster related data by academics, nongovernmental organizations, and digital volunteers which often go unused by decision-makers[93]. This is sometimes referred as a "knowledge gap", or a gap that exists between what experts know about risk and disaster and what of that knowledge makes its way into the directives of establishments presiding over the problem and the operations of people on the ground dealing with it [41].

These challenges point to a need to be cognizant of the power we assign to these individual projects. A potential issue of concern is information determinism, a form of thinking that assumes that "mere access to information will precipitate desired outcomes." [95]. Though such determinism is a trap that is most often associated with "solutionist orientations to technology" [60], it has been noted that critiques of contemporary information practices can also ascribe too much coherence and influence to information artifacts. In doing so, the critiques can distract from the wider social and political context and constraints that influences the actual impact of these artifacts on the wider world. For example, some critics of artificial intelligence have inadvertently ended up lending credibility to non-functional systems by implicitly assuming the algorithm works as marketed [77, 108]. Similar risk exists for critical researchers of environmental data as emerging technologies promise solutions to complex environmental challenges. Therefore, researchers should attend to the situated practices surrounding the collection, analysis, circulation, and use of environmental data [47]. HCI has a rich history of such research from Suchman's foundational work on situated action [98] to more recent investigations of infrastructural data practices [28, 90] and calls for attending to labor and context around data practices [22, 86]. Future studies should draw on these works to extend our analysis and examine how such colonial tendencies may shape data practices and decisions.

6.3 Relevance to LIMITS

In this paper, we have used a case study of a multi-hazard disaster risk assessment project as an example to examine the potential risks and drawbacks of colonial relationships in contemporary environmental data practices. The case study overlaps with several themes that are of interest to the LIMITS community. First, natural disasters and hazards are ecological and social issues that pose significant impact on lives, livelihood, environment, and biospheres. Like many environmental data systems, disaster risk assessment models and their predictions are used to understand the impact of disasters as well as inform the design of potential interventions. The assumptions and practices surrounding their design and use are important focus areas for the LIMITS community [64], including the focus of LIMITS 2023 on thriving biosphere.

Second, this work builds on prior work in LIMITS which has used the notion of limits to examine and visibilize hidden costs and injustices within computing technologies and digital information systems. Prior work has looked at the limits of HCD [104], hidden human cost in e-commerce and gig economy [7, 9], increased vulnerability in smart cities [13, 80], the externalized energy cost of smart-farming [97], and the limits of computational modeling [53]. Our analysis extends [53]'s discussion of epistemological struggles in environmental models by focusing on a particular limit in contemporary environmental modeling. Through our findings, we show how common practices of quantifying and building models tend to inherit and uphold colonial relations that ignore people's relationship to land, ecological impact of disasters, and long-term processes that lead to disaster vulnerabilities. Our theoretical framework and critiques of environmental data, using disaster risk modeling as an example, is applicable to topics of concern to LIMITS community such as environmental impacts, climate change adaptation, and sustainability [64].

Lastly, research published at LIMITS has explored alternative approaches and paradigms to address the ecological limits, information limits, and material limits of existing technology systems [46, 53, 85] We share this hopeful orientation and use subsection 6.1 to imagine an alternate anti-colonial approach to disaster and climate risk. This discussion builds on research in LIMITS and HCI that draw on pluriversal designs [3, 21, 53], relational thinking [20, 53], and non-anthropocentric worldviews [23, 54]. Our proposed anti-colonial tactics of specificity, relationality, and obligations can contribute to ongoing conversations in these communities on alternative approaches to environment such as eco-social change [42], eco-spirituality [18], and degrowth [99].

7 CONCLUSION

In this paper, we use the example of disaster risk assessment to consider contemporary environmental data practices through the lens of postcolonial, decolonial and anti-colonial theory. By necessity, the production of environmental data requires data-creators to abstract the complexities of the world into representations, making

choices about what is included and what is ignored along the way. These choices in turn shape the environmental imaginaries of the public and have material impact on social and political processes surrounding the management of complex processes like disasters and climate change. It is therefore necessary that we learn to be more intentional in our choices of what is abstracted and what is silenced to be able to solve the increasingly complex challenges of the Anthropocene. Our study assists with this by drawing attention to the colonial potential of contemporary environmental data practices. Drawing on postcolonial, decolonial and anti-colonial theories, we draw attention to how environmental data practices, such as disaster risk assessment, may encode extractive relationships to land, privilege technocratic Eurocentric knowledge, and invisibilize historical and ongoing power hierarchies. We build on our findings to think through opportunities to reimagine disaster and climate risk beyond probabilistic quantitative models by drawing on anti-colonial tactics and paying attention to situated practices. By drawing attention to these colonial tendencies that may manifest in creation and use of environmental data, we hope to make progress towards an anti-colonial otherwise [52].

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