“THE DAM DOMINATED THE WATER”: SOCIAL-ECOLOGICAL IMPACTS AND ENERGY INJUSTICES ASSOCIATED WITH DAM DEVELOPMENT IN THE GLOBAL SOUTH.

By

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ABSTRACT

Countries in the Global South favor hydropower because it is a low-carbon and sustainable energy source that can satisfy their energy needs and allow them to meet anticipated increases in energy demand. However, the construction of hydroelectric dams increases social and environmental inequities across multiple scales. In this dissertation, I explore the social-ecological impacts and energy injustices generated by large-scale hydroelectric dams in the Global South, focusing on dams in the Brazilian Amazon.

In *chapter one*, I conduct a meta-analysis and fuzzy-set qualitative comparative analysis (fsQCA) to understand the changes in local livelihoods in 33 hydroelectric dam projects built in the Global South. I found that natural, social, human, and financial capital are negatively impacted, whereas physical capital is positively impacted. The findings showed a relationship between lack of participation in decision-making and negative impacts on people's capital. I also found that mega-dams negatively impact people's capital regardless of the energy security status of a nation.

In *chapter two,* I examine how the construction of the Madeira hydroelectric complex in Brazil (the *Jirau* and *San Antônio* dams) has impacted the adaptive capacity of local communities in terms of food and energy security. I find that the adaptive capacity of local communities has been significantly reduced, which limits the opportunities of these communities to adapt to future climatic and anthropogenic shocks. Food security has been significantly affected and that the energy supply in the communities is unreliable. Despite living near two large hydroelectric dams, many still lack electricity access and depend on diesel generators.

In *chapters three and four,* I conduct a longitudinal qualitative case study of data collected in a community downstream from the *Belo Monte* hydroelectric dam. Data were collected at three points: during the late stage of construction (2016) and early operation (2017, 2019). *Chapter three* explores the multidimensional and multitemporal energy injustices experienced by this community. In this chapter, I use the distributional, procedural, recognition, restorative, and capabilities energy justice tenets to understand how local actors experience different injustices and how these interact over time. I found that these injustices are intertwined, causing and perpetuating the new and established structural injustices these communities have faced. In *chapter four,* I study, from a social-ecological resilience approach, the responses of individuals and households towards the effects of the construction of the Belo Monte dam. I show how individual and household responses to hydropower development occur along the spectrum from absorptive/coping to adaptation to transformation. These responses differ by gender and household characteristics.

The dissertation shows how an energy source portrayed as a solution for achieving energy transition generates immense social-ecological impacts and multidimensional and multitemporal

energy injustices perpetuating structural inequities. As energy demand and the need for a clean energy transition are increasing, we must find energy systems that look beyond just low carbon emissions to those that also address energy injustices, and provide fair and equitable processes that consider gender, ethnicity, race, and class.

Para mis padres y hermano,
quienes siempre me han apoyado y
nunca han dejado de creer en mí.

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Introduction: “The dam dominated the water”

“Because it’s crazy to see hunger going around; you think it doesn’t happen in our country, right? You know that all eyes are on this dam; everyone says: “Damn! Belo Monte is the biggest power dam in the world, one of the three largest dams, and it is here in our region. Damn! It’s too rich there”.

And here we are in this poverty!

That’s the hard reality; that’s what we’re facing here…”

-Interviewee, Fisherwoman. 2016

The most recent Intergovernmental Panel on Climate Change report (IPCC, 2022) underscores the importance of moving away from fossil fuels and toward cleaner, lower-carbon energy sources as soon as possible. Since there is considerable growth in global energy demand, which is expected to increase by 50% by 2050 (Raimi et al., 2022), nations in the Global South[1] and emerging economies see hydropower as an alternative low-carbon electricity source for providing a stable energy source for their growing populations, fuel their economies, and reduce their dependence on imported energy (Fan et al., 2022; Gürbüz, 2006; Gutierrez et al., 2019; Kelly-Richards et al., 2017; Namy, 2010; Raimi et al., 2022; Zarfl et al., 2015). Furthermore, as hydropower is the world’s top source of low-carbon electricity (IEA, 2021; IRENA, 2022), its promoters present it as a way to ensure a global energy transition or decarbonization (IHA, 2020).

Energy transition technologies, such as hydroelectric dams, have been symbolized as sources of progress, modernity, cheapness, environmental sustainability, and abundance, leading to an overestimation of their benefits and an underestimation of their drawbacks (Sovacool & Brossmann, 2014; Vanegas Cantarero, 2020). Dam supporters promote them as a pillar of these energy transition (Schneider, 2022), and as“clean” energy sources, which are often seen as environmentally benign; however, no large-scale infrastructure comes without social-ecological impacts (Bruckner et al., 2014). The literature shows that dams are not as clean as portrayed by some because they emit green gas emissions, in particular methane and carbon dioxide (Almeida et al., 2019; Flecker et al., 2022). In addition., hydroelectric dam construction is one of the primary drivers of change in the most biodiverse river basins of the world, e.g., the Amazon, Congo, and Mekong (Winemiller et al., 2016). Paradoxically, two of these basins, the Amazon and Congo, are part of the few areas in the world that still have long free-flowing rivers (Grill et al., 2019) that are essential to support productive ecosystems and provide benefits to people (Opperman et al., 2021), see Figure 1.

[1] In this dissertation, Global South refers to the Group of 77 (G-77) of the United Nations (G-77, 2022) plus China. I use the term Global South since it goes beyond geographical differentiation. It acknowledges “an entire history of colonialism, neo-imperialism, and differential economic and social change through which large inequalities in living standards, life expectancy, and access to resources are maintained.” (Dados & Connel, 2013, p. 13).

Contrarily to the sustainability and progress that energy transition technologies are supposed to generate, the construction of hydropower has increased social and environmental inequities across multiple scales (Duarte et al., 2015; Hess et al., 2016; Hodbod et al., 2019; Nguyen et al., 2017), have deepening poverty and hunger near the construction areas (Goodland, 2010; Manorom et al., 2017; Richter et al., 2010a; Yankson et al., 2018) and are affecting the livelihoods of people of nearby communities (Arantes et al., 2019, 2021; Bro et al., 2018; Calvi et al., 2019; Castro-Diaz et al., 2022; Mayer et al., 2021; Mayer, Lopez, Cavallini Johansen, et al., 2022; Mayer, Lopez, Leturcq, et al., 2022; Pinto et al., 2022). That includes resettled populations and host and downstream communities (Baird et al., 2021; Richter et al., 2010b; Scudder, 2005). These communities have faced declining livelihoods and bear most of the negative impacts of large-scale hydroelectric dams (Fan et al., 2022). For example, loss of access to natural resources (Owusu et al., 2017; Siciliano & Urban, 2017); declining health (Okuku et al., 2016); loss of social networks and family connections (Mayer, Lopez, Cavallini Johansen, et al., 2022; Mayer, Lopez, Leturcq, et al., 2022; Nguyen et al., 2017; Tilt & Gerkey, 2016), loss of cultural or religious sites (Naithani & Saha, 2019), among other impacts that also generate effects on future generations (Mwangi, 2007; Scudder, 2005).

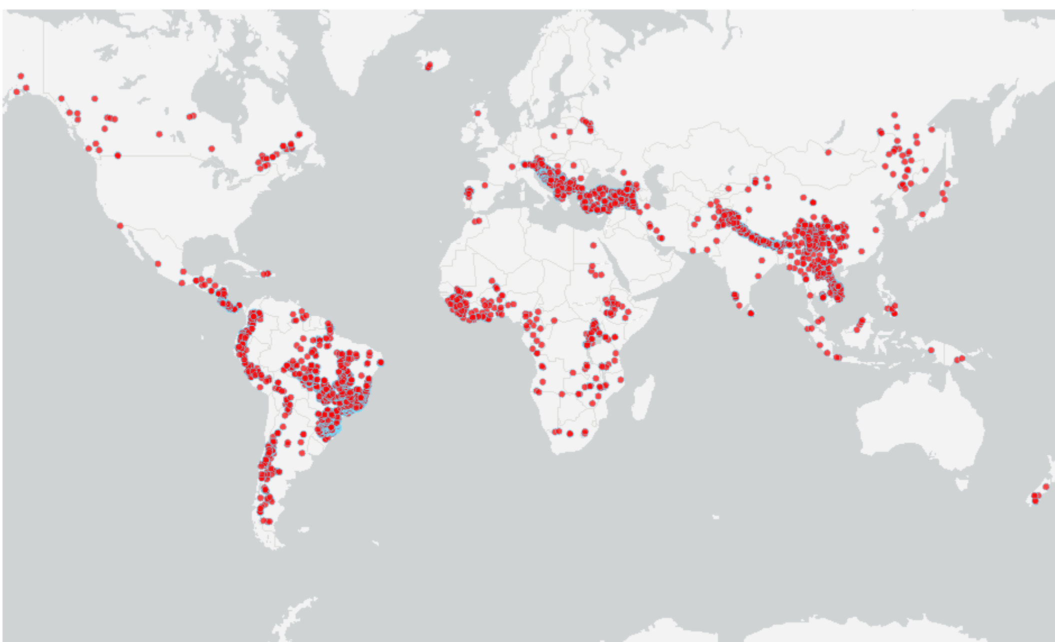

Figure 1. Global Dams planned to be constructed (GRanD et al., 2019)

Since the 1970's researchers and practitioners have suggested including affected populations in the processes of decision-making for dam construction; however, consultation and negotiation with local actors are rarely conducted in dam construction projects (Garcia et al., 2021; Hay et al., 2019; Mayer, Garcia, et al., 2022). The World Commission of Dams (WCD, 2000) recommended policy actions: national policies and local decision-making protocols that companies and governments should address before the construction of a dam, such as Environmental Impact Assessments (EIAs) and Social Impact Assessments (SIAs). SIAs and EIAs assessments focus on determining the number of people to be resettled and finding mechanisms for social and environmental impact mitigation, such as compensations (Moran et al., 2018). However, evidence shows that these are often done poorly and that people living in these territories are often not involved in these assessments (Gerlak et al., 2019). In the end, the companies and governments overlook the negative effects of dam construction and operation, disrupting local livelihoods, while they trumpet their achievement in producing electricity. I co-authored a study in which we found that large-scale dams built under democratic or autocratic regimes use very similar top-down policies that fail to consult with the populations affected and overlook the social-ecological negative impacts (Garcia et al., 2021).

In my dissertation, I explore the social impacts and energy injustices associated with dam development in communities near construction sites at different temporal and spatial scales. Considering the complexity of hydropower development, I aim to understand the underlying effects and energy injustices of dam development on the livelihoods of local communities and how these communities have responded to the associated effects. I will do that by addressing the following research goals:

1. To evaluate how the capital of local communities living near hydroelectric dams has changed because of dam construction and how their livelihoods are impacted
2. To assess the generic and specific adaptive capacity of communities affected by constructing two large-scale hydroelectric dams in the Brazilian Amazon and their contribution to food and energy security.
3. To explore the multidimensional energy injustices generated by constructing the Belo Monte hydroelectric dam in a downstream community.
4. To explore the social-ecological resilience responses of individuals and households associated with the effects generated by dam construction.

After studying dams for years, even those who were once defenders of dams concluded that they are not defensible due to their unacceptable longer-term economic and social-ecological impacts on more than half a billion dam-affected people around the globe (Scudder, 2019). Aligned with that statement, in my dissertation, I show how due to the immense energy injustices and social impacts associated with dam development, it is no longer acceptable to continue promoting dams as a "solution" for the energy transition. I argue for the need for co-designing just, effective, clean, and affordable energy systems that look beyond decarbonization and address social and environmental justice. Recent articles suggest how this can be done by co-designing the energy systems with local communities tailored to their needs and social-ecological context (Brown et al., 2022; Moran et al., in press).

As a sustainability scholar, mixed methods is the right approach because it allows the selection and integration of appropriate techniques from qualitative and quantitative approaches to investigate a research problem (Creswell, 2014; Teddlie & Tashakkori, 2015). Guba & Lincoln (1994) state that qualitative and quantitative approaches can be used with any research paradigm (Guba & Lincoln, 1994). In my research, I take a "pragmatic" position; thus, I choose my data collection and analysis methods not based on a particular epistemology but guided by my research questions and the nature of the data available and collected (Chung, 2000; Creswell, 2014; Tashakkori & Teddlie, 2009).

The social impacts of hydroelectric dams have been explored in the literature from different perspectives and disciplines. Kirchherr and Charles (2016) claim that not having a unique framework for the social impacts of dams limits the ability to accumulate knowledge, recommend policies and provide thoughtful information to different stakeholders affected by dams. In this dissertation, I want to show the risk of having a unique framework exploring the impacts of dams since it will reduce the possibility of understanding the complexity of dam development and the underlying social-ecological effects and injustices associated with it.

Table 1. A summary of this dissertation's goals and methodological approach

Goal: To understand the underlying effects and energy injustices of dam development on the livelihoods of local communities, as well as how these communities have responded to the associated effects.				
	Chapter 1	Chapter 2	Chapter 3	Chapter 4
Goal	To evaluate how the capital of local communities living near hydroelectric dams changed because of dam construction and how their livelihoods are impacted	To assess the generic and specific adaptive capacity of communities affected by constructing two large-scale hydroelectric dams in the Brazilian Amazon and their contribution to food and energy security.	To explore the injustices generated by constructing the Belo Monte hydroelectric dam in a downstream community.	To explore the responses of individuals and households associated with the effects generated by dam construction.
Theoretical Background	Social-ecological impacts of dams & Sustainable Livelihoods (Capital)	Social-ecological impacts of dams & Adaptive Capacity	Social-ecological impacts of dams & tenets approach of Energy Justice	Social-ecological impacts of dams & Social-Ecological Resilience. Considering the three core resilience capacities: coping, adaptive, and transformative capacity.

Table 1 (cont'd)

Theoretical Background	Social-ecological impacts of dams & Sustainable Livelihoods (Capital)	Social-ecological impacts of dams & Adaptive Capacity	Social-ecological impacts of dams & tenets approach of Energy Justice	Social-ecological impacts of dams & Social-Ecological Resilience. Considering the three core resilience capacities: coping, adaptive, and transformative capacity.
Study Area	Global South and Emerging economies	Communities (8) located nearby the Madeira Hydroelectric complex: Jirau and Santo Antônio. Brazil	Downstream community from the Belo Monte hydroelectric dam. Brazil	
Data Collection Methods	Qualitative Meta-Analysis of 33 hydroelectric dams	Social survey of 673 households	In-depth interviews (70) and observation	
Data Analysis	Fuzzy-set Qualitative Comparative Analysis (fsQCA)	Descriptive statistics Binary Logistic Regression Models	Interactive process for data analysis that includes data condensation, data display, and conclusions	

In this interdisciplinary dissertation, I explore the social-ecological impacts and energy injustices generated by large-scale hydroelectric dams in the Global South, focusing on dams in the Brazilian Amazon. As presented in Table 1, I used different frameworks that broadened the understanding of dam development, such as Sustainable Livelihoods, Adaptive Capacity, Energy Justice, and Social-Ecological Resilience. I use varied frameworks and methods to understand the underlying effects and energy injustices of dam development on the livelihoods of local communities and how these communities have responded to the associated impacts. Below I provide a brief overview of my dissertation chapters and how using different frameworks and methods expanded the knowledge about social effects and energy injustices associated with dam development.

Chapter 1- *Impacts on locals' livelihoods of hydropower development in the Global South*. In this chapter, I explore how the capital of local communities living near hydroelectric dams changed because of dam construction and how their livelihoods are impacted. Using a livelihoods framework and a qualitative meta-analysis allowed me to bring together the research of scholars who explored the social impacts from different approaches and methods in several regions of the world and to generate a comprehensive understanding of how the livelihoods of local actors are impacted. This paper contributes to the literature since most studies investigating the impacts of dams on people's livelihoods focus on one type of capital, one dam, or one country. I present a comparative medium-

N survey exploring the impacts of 33 large-scale hydroelectric dams on people's livelihoods, aiming to understand the negative and positive impacts dams have on people's capital. To do so, I used a qualitative meta-analysis database of peer-reviewed articles exploring the social impacts of hydroelectric dams and fuzzy-set qualitative comparative analysis (fsQCA). The results show that natural, social, human, and financial capital are negatively impacted. In contrast, physical capital is positively impacted in the form of energy production for the nation. The analysis also showed a relationship between civil society's lack of participation in decision-making and negative impacts on people's capital. This relationship had not been described in the literature.

Aside from that chapter, I have co-authored a manuscript based on the meta-analysis database. Our results show that large-scale hydroelectric dams built under democratic or autocratic regimes use top-down policies to justify the construction of the projects over the social-ecological impacts (Garcia et al., 2021). We found a persistent lack of participation in affected communities regarding resettlement processes (Garcia et al., 2021).

Three of my dissertation's chapters focus on large-scale hydroelectric dams built in the Brazilian Amazon. Brazil has the largest hydropower capacity in the world after China (IEA, 2021), where hydropower represents 67% of domestic energy consumption (IEA, 2021). The construction of dams in Brazil has been promoted to enhance economic growth while ignoring its social-ecological effects since the military dictatorship (1964-1985) (da Costa, 2014). Unfortunately, more recent hydroelectric dam projects built under democracies have also been lacking in consideration of civil society's social-ecological effects and participation (Garcia et al., 2021; Mayer, Garcia, et al., 2022).

The Amazon region has the most significant hydropower potential within the country, with 221 hydropower dams under operation and more than 200 dams planned (Flecker et al., 2022; Infoamazonia, 2022). It is noteworthy that while the energy from these hydroelectric facilities is generated in the Amazon, the main consumption centers are in the southern and coastal areas of the country, where larger cities and industries are concentrated (Hess et al. 2016). In other words, the bulk of the benefits from this energy production benefit people outside the region. I am focusing on the effects generated in local communities after constructing three large-scale hydroelectric dams in the Brazilian Amazon: Jirau and Santo Antônio in the Madeira river and Belo Monte in the Xingu river.

Jirau and Santo Antônio dams are located in the Madeira river, one of the principal tributaries of the Amazon River (Goulding et al., 2003). The Madeira complex is part of a Brazilian effort to increase energy production (Allan Silva et al., 2013), and these dams are part of the federal government's Growth Acceleration Plan (Plano de Aceleração do Crescimento PAC) (Scabin et al., 2014). The

Belo Monte Hydroelectric dam on the Xingú river in the Amazon region of Brazil is the fourth largest dam in the world, with an installed capacity of 11,233 megawatts produced by 18 turbines. However, the literature reports that the dam has not generated that potential capacity (Higgins, 2020).

Brazil continues to push hydropower development despite the high vulnerability of hydropower development to climate change, which has already been reported in the literature. In the early 2010s, there was a decrease in hydroelectricity, which was associated with a period of low rainfall (Schaeffer et al., 2018). That problem repeated in 2021 when because of the drought, Belo Monte produced only 3% of its potential (Pereira, 2021), and in August of 2022, all the turbines of Belo Monte stopped because of the low river flow.

Chapter 2- *Household food and energy security associated with hydropower development.* The literature has studied how the construction of dams impacts local communities but not the effects on their adaptive capacity. In this chapter, I assess how the construction of dams affects the adaptive capacity of eight communities near the Madeira hydroelectric complex in the Brazilian Amazon and how generic and specific adaptive capacities, among other factors, predict food and energy insecurity. I used a series of logit models based on a survey of 673 households conducted in 2020. Given the current boom of dam construction in the Global South, this study contributes to the literature by assessing the effectiveness of the programs provided by dam authorities and governments to alleviate the adverse effects of dam construction. Dam developers and governments are expected to support local populations to increase their capacities to prepare and recover from the effects associated with dam development. This promise is generally not kept. In this case study, I find that the adaptive capacity of local communities has been significantly reduced, which limits the opportunities of these communities to adapt to future climatic and anthropogenic shocks.

With my colleagues in our research group, we wrote a paper that used the same database for evaluating aspects of procedural justice in terms of the participation of affected communities in institutionalized mechanisms provided by dam authorities (e.g., public meetings) (Mayer, Garcia, et al., 2022). We analyzed how perceptions of positive and negative impacts, among other factors, predict engagement in the institutionalized mechanisms of participation. We found that perceptions of the negative and positive impacts of the dams before construction are related to participation in the meetings promoted by dam builders. Our results show frequent violations of procedural injustice tenets (Mayer, Garcia, et al., 2022) and an overall reduction in adaptive capacity.

In *chapters three and four,* I conduct a multitemporal qualitative case study of data collected in a community downstream from the *Belo Monte* hydroelectric dam. Through in-depth interviews and observations, qualitative data were collected at three points: during the late stage of construction

(2016) and early operation (2017, 2019). Both chapters add to the literature on dam development since most studies are done at one time, overlooking the temporal dynamics of the effects generated by dam construction (Kirchherr & Charles, 2016; Scudder, 2005), and downstream impacts of dams are understudied (Baird et al., 2021; Richter et al., 2010b).

Chapter 3- *Multidimensional and multitemporal energy injustices near hydropower dams* explores, from a multidimensional and multitemporal perspective, the injustices faced by the inhabitants of a community located downstream from the Belo Monte hydroelectric dam. I use the distributional, procedural, recognition, restorative, and capabilities energy justice tenets to understand how local actors experience different injustices and how these interact over time. Besides the methodological approach, a contribution to this chapter's literature is considering all the energy justice tenets in the context of dam development. I found that these injustices are intertwined, causing and perpetuating new and established structural injustices these communities have faced.

Chapter 4- *Responses to hydropower development.* Using a social-ecological resilience approach, I study the responses of individuals and households toward the effects of the construction of the Belo Monte dam. I show the importance of conducting multitemporal studies to assess the cumulative effects generated by dam development, as well as how individual and household responses to hydropower development occur along the spectrum from coping to adaptation to transformation. I found these responses differ by gender and household characteristics and change over time. In this chapter, I present how the effects of the construction of dams on this community have led individuals and households to adopt unsustainable and risky choices that could lead to the social-ecological system collapsing.

Through my dissertation, I present evidence that hydroelectric dams disrupt the livelihoods of local communities that lack political or economic power. Along the same lines, I show how dam construction perpetuates injustices in marginalized communities. In my dissertation, I argue how dam construction affects the adaptive capacity of local communities and how these communities are growing more vulnerable to current climatic and anthropogenic shocks.

The findings of this dissertation are meaningful to the current need for an energy transition since the promotion of hydroelectric dams is aligned with the energy transition narrative (Sovacool & Brossmann, 2014). Here I show how replacing fossil fuels with hydropower development is not generating structural changes since it is a centralized electricity source that brings local perturbations to those living nearby. A fundamental problem surrounding large-scale infrastructure projects, and even solar and wind large projects (considered as technologies that support energy transitions), is the lack of consultation and participation of communities living nearby the infrastructure. These projects' potential low-carbon emissions and economic benefits often hid the negative impacts on locals' lives and livelihoods, perpetuating energy injustices.

Energy transition should look beyond the change of one source to a low-carbon source (Richter et al., 2015) and consider the whole system and how it deals with local energy justice and livelihoods. A systems approach with at least three interrelated dimensions: technology, actors, and the social context (Geels, 2004). Energy systems should look beyond decarbonization; they could be decentralized energy systems appropriate to local needs (Stephens, 2019) that focus on enhancing community engagement and addressing energy injustices (Brown et al., 2022; Moran et al., in press).

Lastly, with this dissertation, I aim to bring the voice of those who have not been heard by dam authorities, governments, and academics. I invite the readers to pay attention to the voices of women and men who, despite living under unprecedented circumstances, shared their experiences with me and through me with you.

REFERENCES

Allan Silva, R., Aldo Alves Pereira, J., Antônio Coimbra Borges, L., Arantes de Barros, D., & Carlos Costa Guimarães, J. (2013). Análise Do Processo De Licenciamento Ambiental Do Complexo Hidrelétrico Do Rio Madeira. Revista Científica ANAP Brasil, 6(8), 12–28. https://doi.org/10.17271/19843240682013703

Almeida, R. M., Shi, Q., Gomes-Selman, J. M., Wu, X., Xue, Y., Angarita, H., Barros, N., Forsberg, B. R., García-Villacorta, R., & Hamilton, S. K. (2019). Reducing greenhouse gas emissions of Amazon hydropower with strategic dam planning. Nature Communications, 10(1), 1–9.

Arantes, C. C., Fitzgerald, D. B., Hoeinghaus, D. J., & Winemiller, K. O. (2019). Impacts of hydroelectric dams on fishes and fisheries in tropical rivers through the lens of functional traits. Current Opinion in Environmental Sustainability, 37, 28–40. https://doi.org/10.1016/j.cosust.2019.04.009

Arantes, C. C., Laufer, J., Pinto, M. D. da S., Moran, E. F., Lopez, M. C., Dutka-Gianelli, J., Pinto, D. M., Chaudhari, S., Pokhrel, Y., & Doria, C. R. C. (2021). Functional responses of fisheries to hydropower dams in the Amazonian Floodplain of the Madeira River. Journal of Applied Ecology, October, 1–13. https://doi.org/10.1111/1365-2664.14082

Baird, I. G., Silvano, R. A. M., Parlee, B., Poesch, M., Maclean, B., Napoleon, A., Lepine, M., & Hallwass, G. (2021). The Downstream Impacts of Hydropower Dams and Indigenous and Local Knowledge: Examples from the Peace–Athabasca, Mekong, and Amazon. Environmental Management, 67(4), 682–696. https://doi.org/10.1007/s00267-020-01418-x

Bro, A. S., Moran, E., & Calvi, M. F. (2018). Market participation in the age of big dams: The Belo Monte hydroelectric dam and its impact on rural Agrarian households. Sustainability (Switzerland), 10(5). https://doi.org/10.3390/su10051592

Brown, E., Johansen, I. C., Bortoleto, A. P., Pokhrel, Y., Chaudhari, S., Cak, A., Sulaeman, S., Castro-Diaz, L., Lopez, M. C., Mayer, A., Walgren, J., Müller, N., & Moran, E. (2022). Feasibility of hybrid in-stream generator-photovoltaic systems for Amazonian off-grid communities. PNAS Nexus, June, 1–9. https://doi.org/10.1093/pnasnexus/pgac077

Bruckner, T., Bashmakov, I. A., Mulugetta, Y., Chum, H., Navarro, A. de la V., Edmonds, J., Faaij, A., Fungtammasan, B., Garg, A., Hertwich, E., Honnery, D., Infield, D., Kainuma, M., Khennas, S., Kim, S., Nimir, H. B., Riahi, K., Strachan, N., Wiser, R., & Zhang, X. (2014). Energy Systems. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Calvi, M. F., Moran, E. F., Silva, R. F. B. da, & Batistella, M. (2019). The construction of the Belo Monte dam in the Brazilian Amazon and its consequences on regional rural labor. Land Use Policy, 90(October 2019), 104327. https://doi.org/10.1016/J.LANDUSEPOL.2019.104327

Castro-Diaz, L., Garcia, M. A., Villamayor-Tomas, S., & Lopez, M. C. (2022). Impacts on locals' livelihoods of hydropower development in the Global South. Manuscript Submitted for Publication.

Chung, K. (2000). Qualitative Data Collection techniques. In M. Grosh & P. Glewwe (Eds.), Designing household survey questionnarires for developing countries: lessons from 15 years of the Living Standards Measurement Study (Vol 2) (pp. 337–363). The World Bank.

Creswell, J. (2014). The Selection of a Research Approach. In J. Creswell (Ed.), Research Design.

Qualitative, Quantitative, and Mixed Methods Approaches (Fourth). Sage Publications.

da Costa, A. (2014). Sustainable Dam Development in Brazil. The Roles of Environmentalism, participation and Planing. In W. Scheumann & O. Hensengerth (Eds.), Evolution of Dam Policies: Evidence from the Big Hydropower States (pp. 13–53). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-23403-3

Dados, N., & Connel, R. (2013). the global south. Context, 323–340. https://doi.org/10.1177/1536504212436479

Duarte, B., Boelens, R., & Yacoub, C. (2015). Hidroeléctricas, ¿energía limpia o destrucción socioecológica? In C. Yacoub, B. Duarte, & R. Boelens (Eds.), Agua y Ecología Política: El extractivismo en la agroexportación, la minería y las hidroeléctricas en Latinoamerica. Abya-Yala.

Fan, P., Cho, M. S., Lin, Z., Ouyang, Z., Qi, J., Chen, J., & Moran, E. F. (2022). Recently constructed hydropower dams were associated with reduced economic production, population, and greenness in nearby areas. Proceedings of the National Academy of Sciences of the United States of America, 119(8). https://doi.org/10.1073/pnas.2108038119

Flecker, A. S., Shi, Q., Almeida, R. M., Angarita, H., Gomes-Selman, J. M., García-Villacorta, R., Sethi, S. A., Thomas, S. A., LeRoy Poff, N., Forsberg, B. R., Heilpern, S. A., Hamilton, S. K., Abad, J. D., Anderson, E. P., Barros, N., Bernal, I. C., Bernstein, R., Cañas, C. M., Dangles, O., … Gomes, C. P. (2022). Reducing adverse impacts of Amazon hydropower expansion. Science, 375(6582), 753–760. https://doi.org/10.1126/science.abj4017

G-77. (2022). The Group of 77. United Nations. https://www.g77.org/doc/

Garcia, M. A., Castro-Díaz, L., Villamayor-tomas, S., & Lopez, C. (2021). Are large-scale hydroelectric dams inherently undemocratic ? Global Environmental Change, 71, 1–11. https://doi.org/10.1016/j.gloenvcha.2021.102395

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. Research Policy, 33(6), 897–920. https://doi.org/https://doi.org/10.1016/j.respol.2004.01.015

Gerlak, A. K., Saguier, M., Mills-Novoa, M., Fearnside, P. M., & Albrecht, T. R. (2019). Dams, Chinese investments, and EIAs: A race to the bottom in South America? Ambio, February. https://doi.org/10.1007/s13280-018-01145-y

Goodland, R. (2010). Viewpoint - The World Bank versus the World Commission on Dams. Water Alternatives, 3(2), 384–398.

Goulding, M., Barthem, R., & Ferreira, E. (2003). The Smithsonian atlas of the Amazon.

GRanD, Esri, FAO, NOAA, & USGS. (2019). Global Dams and Reservoirs. The Global Reservoir and Dam (GRanD) Database. https://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=ef769752083b46dd8444f0d1b77defa9

Grill, G., Lehner, B., Thieme, M., Geenen, B., Tickner, D., Antonelli, F., Babu, S., Borrelli, P., Cheng, L., Crochetiere, H., Ehalt Macedo, H., Filgueiras, R., Goichot, M., Higgins, J., Hogan, Z., Lip, B., McClain, M. E., Meng, J., Mulligan, M., … Zarfl, C. (2019). Mapping the world's free-flowing rivers. Nature, 569(7755), 215–221. https://doi.org/10.1038/s41586-019-1111-9

Guba, E., & Lincoln, Y. (1994). Competing Paradigms in Qualitative Research. In Handbook of qualitative research (pp. 105–117).

https://doi.org/http://www.uncg.edu/hdf/facultystaff/Tudge/Guba%20&%20Lincoln%201994.pdf

Gürbüz, A. (2006). The Role of Hydropower in Sustainable Development. European Water, 13(14), 63–70.

Gutierrez, G. M., Kelly, S., Cousins, J. J., & Sneddon, C. (2019). What makes a megaproject? A review of global hydropower assemblages. Environment and Society: Advances in Research, 10(1), 101–121. https://doi.org/10.3167/ares.2019.100107

Hay, M., Skinner, J., & Norton, A. (2019). Dam-Induced Displacement and Resettlement : A Literature Review FutureDAMS (Issue September).

Hess, C. E. E., Costa Ribeiro, W., & Wieprecht, S. (2016). Assessing Environmental Justice in Large Hydropower Projects: The Case of São Luiz do Tapajós in Brazil. Desenvolvimento e Meio Ambiente, 37, 91–109. https://doi.org/10.5380/dma.v37i0.45273

Hodbod, J., Stevenson, E. G. J., Akall, G., Akuja, T., Angelei, I., Bedasso, E. A., Buffavand, L., Derbyshire, S., Eulenberger, I., Gownaris, N., Kamski, B., Kurewa, A., Lokuruka, M., Mulugeta, M. F., Okenwa, D., Rodgers, C., & Tebbs, E. (2019). Social-ecological change in the Omo-Turkana basin: A synthesis of current developments. Ambio, 48(10), 1099–1115. https://doi.org/10.1007/s13280-018-1139-3

IEA. (2021). Hydropower Special Market Report - Analysis and forecast to 2030. 126. https://iea.blob.core.windows.net/assets/4d2d4365-08c6-4171-9ea2-8549fabd1c8d/HydropowerSpecialMarketReport_corr.pdf.

IHA. (2020). Hydropower Status Report 2021. International Hydropower Association, 1–44. https://www.hydropower.org/publications/annual-report-2021

Infoamazonia. (2022). Improving the position of hydroelectric plants would reduce impacts on the Pan-Amazon. https://infoamazonia.org/en/2022/02/25/improving-the-position-of-hydroelectric-plants-would-reduce-impacts-on-the-pan-amazon/

IPCC. (2022). Climate Change 2022. Mitigation Climate Change. https://doi.org/10.1201/9781003264705-7

IRENA. (2022). Renewable Capacity Highlights (Issue April).

Kelly-Richards, S., Silber-Coats, N., Crootof, A., Tecklin, D., & Bauer, C. (2017). Governing the transition to renewable energy: A review of impacts and policy issues in the small hydropower boom. Energy Policy, 101(November 2016), 251–264. https://doi.org/10.1016/j.enpol.2016.11.035

Kirchherr, J., & Charles, K. J. (2016). The social impacts of dams: A new framework for scholarly analysis. Environmental Impact Assessment Review, 60, 99–114. https://doi.org/10.1016/j.eiar.2016.02.005

Manorom, K., Baird, I. G., & Shoemaker, B. (2017). The World Bank, Hydropower-based Poverty Alleviation and Indigenous Peoples: On-the-Ground Realities in the Xe Bang Fai River Basin of Laos. Forum for Development Studies, 44(2), 275–300. https://doi.org/10.1080/08039410.2016.1273850

Mayer, A., Castro-Diaz, L., Lopez, M. C., Leturcq, G., & Moran, E. F. (2021). Is hydropower worth it? Exploring amazonian resettlement, human development and environmental costs with the Belo Monte project in Brazil. Energy Research and Social Science, 78(January), 102129. https://doi.org/10.1016/j.erss.2021.102129

Mayer, A., Garcia, M. A., Castro-Diaz, L., Lopez, M. C., & Moran, E. F. (2022). Pretend participation: Procedural injustices in the Madeira hydroelectric complex. Global and Environmental Change, 75, 102524. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2022.102524

Mayer, A., Lopez, M. C., Cavallini Johansen, I., & Moran, E. (2022). Hydropower, Social Capital, Community Impacts, and Self-Rated Health in the Amazon. Rural Sociology, 87(2), 393–426. https://doi.org/10.1111/ruso.12419

Mayer, A., Lopez, M. C., Leturcq, G., & Moran, E. (2022). Changes in Social Capital Associated with the Construction of the Belo Monte Dam: Comparing a Resettled and a Host Community. Human Organization, 81(1), 22–34. https://doi.org/10.17730/1938-3525-81.1.22

Moran, E. F., Lopez, M. C., Moore, N., Müller, N., & Hyndman, D. W. (2018). Sustainable hydropower in the 21st century. Proceedings of the National Academy of Sciences, 201809426. https://doi.org/10.1073/pnas.1809426115

Moran, E. F., Lopez, M. C., Mourão, R., Erik, B., McCright, A., Walgren, J., Bortoleto, A. P., Mayer, A., Cavallini, I., Ninni, K., Castro-Diaz, L., Garcia, M. A., Lembi, R., & Mueller, N. (In press.). Advancing Convergence Research: Renewable Energy Solutions for Off-Grid Communities. PNAS

Mwangi, O. (2007). Hydropolitics, ecocide and human security in Lesotho: A case study of the Lesotho Highlands Water Project. Journal of Southern African Studies, 33(1), 3–17. https://doi.org/10.1080/03057070601136509

Naithani, S., & Saha, A. K. (2019). Changing landscape and ecotourism development in a large dam site: a case study of Tehri dam, India. Asia Pacific Journal of Tourism Research, 24(3), 193–205. https://doi.org/10.1080/10941665.2018.1557226

Namy, S. (2010). Addressing the Social Impacts of Large Hydropower Dams. The Journal of International Policy Solutions, 7, 11–17.

Nguyen, H. T., Pham, T. H., & de Bruyn, L. L. (2017). Impact of hydroelectric dam development and resettlement on the natural and social capital of rural livelihoods in bo hon village in central vietnam. Sustainability (Switzerland), 9(8), 1–15. https://doi.org/10.3390/su9081422

Okuku, E. O., Bouillon, S., Ochiewo, J. O., Munyi, F., Kiteresi, L. I., & Tole, M. (2016). The impacts of hydropower development on rural livelihood sustenance. International Journal of Water Resources Development, 32(2), 267–285. https://doi.org/10.1080/07900627.2015.1056297

Opperman, J. J., Shahbol, N., Maynard, J., Grill, G., Higgins, J., Tracey, D., & Thieme, M. (2021). Safeguarding free-flowing rivers: The global extent of free-flowing rivers in protected areas. Sustainability (Switzerland), 13(5), 1–18. https://doi.org/10.3390/su13052805

Owusu, K., Obour, P. B., & Nkansah, M. A. (2017). Downstream effects of dams on livelihoods of river-dependent communities: the case of Ghana’s Kpong Dam. Geografisk Tidsskrift - Danish Journal of Geography, 117(1), 1–10. https://doi.org/10.1080/00167223.2016.1258318

Pereira, R. (2021). Sem água, Belo Monte opera com meia turbina desde o início de agosto. CNN Brasil. https://www.cnnbrasil.com.br/business/sem-agua-belo-monte-opera-com-meia-turbina-desde-o-inicio-de-agosto/

Pinto, D. M., Pinto, V., SantAnna, I., Arantes, C. C., & Rodrigues, C. (2022). Mudanças na dinâmica pesqueira em comunidades afetadas por grandes hidrelétricas na Amazônia. Research, Society and Development, 11(6), 1–16.

https://doi.org/http://dx.doi.org/10.33448/rsd-v11i6.28775

Raimi, D., Campbell, E., Newell, R., Prest, B., Villanueva, S., & Wingenroth, J. (2022). Global Energy Outlook 2022 : Turning Points and Tension in the Energy Transition (Issue April).

Richter, B. D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., & Chow, M. (2010a). Lost in development's shadow: The downstream human consequences of dams. Water Alternatives, 3(2), 14–42.

Richter, B. D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., & Chow, M. (2010b). Lost in development's shadow: The downstream human consequences of dams. Water Alternatives, 3(2), 14–42. https://doi.org/10.1007/s11195-009-9131-2

Richter, B. D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., Chow, M., Miller, C. A., Richter, J., & O'Leary, J. (2015). Socio-energy systems design: A policy framework for energy transitions. Energy Research and Social Science, 6(2), 29–40. https://doi.org/10.1016/j.erss.2014.11.004

Scabin, F. S., Junior, N. N. P., & Cruz, J. C. da C. (2014). Judicialização de grandes empreendimentos no Brasil: uma visão sobre os impactos da instalação de usinas hidrelétricas em populações locais na Amazônia. Revista Pós Ciências Sociais, 11(22), 130–150. http://www.periodicoseletronicos.ufma.br/index.php/rpcsoc/article/view/3418

Schaeffer, R., Lucena, A. F. P., Costa, I. V. L., Vásquez, E., Viviescas, C., & Huback, V. (2018). Climate change and the energy sector in Brazil. In Climate Change Risks in Brazil. https://doi.org/10.1007/978-3-319-92881-4_6

Schneider, G. (Natel E. (2022). Why hydro is Key to the Energy Transition, Even in the Face of Drought. National Hydropower Association. https://www.hydro.org/powerhouse/article/why-hydro-is-key-to-the-energy-transition-even-in-the-face-of-drought/

Scudder. (2019). Large Dams. Long Term Impacts on Riverine Communities and Free Flowing Rivers. In Springer (Ed.), Large dams. https://doi.org/10.1596/0-8213-4028-x

Scudder, T. (2005). The Future of Large Dams: Dealing with social, environmental, institutional and political costs. Earthscan.

Siciliano, G., & Urban, F. (2017). Equity-based Natural Resource Allocation for Infrastructure Development: Evidence From Large Hydropower Dams in Africa and Asia. Ecological Economics, 134, 130–139. https://doi.org/10.1016/j.ecolecon.2016.12.034

Sovacool, B. K., & Brossmann, B. (2014). The rhetorical fantasy of energy transitions: implications for energy policy and analysis. Technology Analysis and Strategic Management, 26(7), 837–854. https://doi.org/10.1080/09537325.2014.905674

Stephens, J. C. (2019). Energy democracy: Redistributing power to the people through renewable transformation. Environment, 61(2), 4–13. https://doi.org/10.1080/00139157.2019.1564212

Tashakkori, A., & Teddlie, C. (2009). Integrating Qualitative and Quantitative Approaches to Research. In L. Bickman & D. Rog (Eds.), The SAGE Handbook of Applied Social Research Methods (pp. 283–317). Sage Publications, Inc. https://doi.org/10.4135/9781483348858.n9

Teddlie, C., & Tashakkori, A. (2015). Overview of Contemporary Issues in Mixed Methods Research. In A. Tashakkori & C. Teddlie (Eds.), SAGE Handbook of Mixed Methods in Social & Behavioral Research (2nd ed., pp. 1–42). Sage Publications, Inc. https://doi.org/10.4135/9781506335193.n1

Tilt, B., & Gerkey, D. (2016). Dams and population displacement on China's Upper Mekong River: Implications for social capital and social-ecological resilience. Global Environmental Change, 36, 153–162. https://doi.org/10.1016/j.gloenvcha.2015.11.008

Vanegas Cantarero, M. M. (2020). Of renewable energy, energy democracy, and sustainable development: A roadmap to accelerate the energy transition in developing countries. Energy Research and Social Science, 70(November 2019), 101716. https://doi.org/10.1016/j.erss.2020.101716

WCD. (2000). Dams and development: a New Framework for Decision-Making. In The report of the World Comission on Dams (Vol. 23, Issue November). https://doi.org/10.1097/GCO.0b013e3283432017

Winemiller, K. O., McIntyre, P. B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., Baird, I. G., Darwall, W., Lujan, N. K., Harrison, I., Stiassny, M. L. J., Silvano, R. A. M., Fitzgerald, D. B., Pelicice, F. M., Agostinho, A. A., Gomes, L. C., Albert, J. S., Baran, E., Petrere, M., … Saenz, L. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. Science, 351(6269), 128–129. https://doi.org/10.1126/science.aac7082

Yankson, P., Asiedu, A. B., Owusu, K., Urban, F., & Siciliano, G. (2018). The livelihood challenges of resettled communities of the Bui dam project in Ghana and the role of Chinese dam-builders. Development Policy Review, 36(October 2016), O476–O494. https://doi.org/10.1111/dpr.12259

Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L., & Tockner, K. (2015). A global boom in hydropower dam construction. Aquatic Sciences, 77(1), 161–170. https://doi.org/10.1007/s00027-014-0377-0

Chapter 1: Impacts on locals' livelihoods of hydropower development in the Global South

Introduction[2]

Hydropower is the world's leading low-carbon electricity source (IEA, 2021b). It will continue to be one of the primary energy sources, particularly in the Global South (also known as the Group of 77 and China) and emerging economies where there is a boom in dam construction (Fan et al., 2022; Moran et al., 2018; Zarfl et al., 2015). National governments and the private sector have incentivized hydroelectric dam construction, arguing it will boost economic growth and energy independence (Fan et al., 2022; Gürbüz, 2006; Namy, 2010; Smyth & Vanclay, 2017). However, research has shown that the construction of dams negatively impacts people's livelihoods and the ecosystems around them (Cernea, 1997; Cernea & Maldonado, 2018; Scudder, 2005). For instance, Fan et al. (2022) found that recently built dams in Asia, Africa, and Latin America are associated with a reduction in gross domestic product, population, and land cover near construction sites. Hydroelectric dam projects are controversial. Their advocates (i.e., dam authorities, governments, and engineering companies) argue that dams bring modernization, technological progress, national development, national prestige, control over water supplies, and energy security (Atkins, 2019; Nüsser, 2003; Nüsser & Baghel, 2017). Contrarily, dams' opponents (i.e., activists, affected populations, social justice organizations) emphasize a range of negative social-ecological and economic impacts on those living close to dams, their livelihoods, and their ecosystems, as well as their lack of participation in decision-making processes (Atkins, 2019; Garcia et al., 2021; Mayer, Garcia et al., 2022; Nüsser, 2003). Despite these arguments and the extensive literature about the social impacts of dams, there is still no comprehensive understanding of how hydroelectric dams influence changes in people's livelihoods in the Global South.

The construction of hydroelectric dams happens under contexts that include diverse social, institutional, political, and economic conditions: for instance, global pressure for a fast energy transition (IPCC, 2022); a national need to be energy independent (Fan et al., 2022; IHA, 2003; Namy, 2010; Smyth & Vanclay, 2017); a call for implementing participatory processes in dam development decision making (Garcia et al., 2021; WCD, 2000); and a higher awareness of the social-ecological impacts of dams (Arantes et al., 2019; WCD, 2000; Winemiller et al., 2016). In this study, we brought all these conditions together to understand their influence on changing people's capital in areas near dams.

Livelihoods encompass how different people make a living depending on where they live (Scoones, 2009). One way to assess livelihoods is through "capital" or "assets," which are the resources that

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support people's livelihoods; they are "combined, substituted and switched" (Scoones, 2009, p. 177) by individuals, households, and communities to make a living. In this research, we used capital, in particular natural, social, human, financial, and physical capital, as a tool to synthesize the positive and negative impacts of hydroelectric dams on people's livelihoods. Multiple authors have studied the effects of dams on livelihoods. Still, most studies focus on impacts on livelihood strategies such as fisheries (Arantes et al., 2021; Castro-Diaz et al., 2018) or agriculture (Calvi et al., 2019; Hausermann, 2018). Others focus their analyses on one type of capital and one dam. For example, Mayer, Lopez et al. (2022) studied the decrease in social capital in both resettled and host communities after the construction of the Belo Monte dam in Brazil, and Kedia (2003) assessed the health impacts (human capital) on resettled communities generated by the construction of Tehri dam in India. Few authors have looked at the concurrent changes in different types of capital. Sivongxay et al. (2017) described the changes in natural, financial, human, and physical capital near four hydroelectric dams in Laos. Yet, there is no broad understanding of how hydroelectric dams built in the Global South impact people's livelihoods and their capital.

Scholars have explored the impacts of hydroelectric dams on people's livelihoods from different perspectives and disciplines. However, these multiple methodologies and methods make the comparison across dams challenging, limiting the ability to accumulate knowledge, recommend policies, and provide thoughtful information to diverse stakeholders in the hydropower sector (Kirchherr & Charles, 2016). In this study, we are exploring how the capital of local communities living near hydroelectric dams changed because of dam construction and how their livelihoods are impacted. To do so, we selected 33 large-scale hydroelectric dams in the Global South and emerging economies (Brazil, China, and India) through a qualitative meta-analysis database of peer-reviewed articles exploring the social impacts of hydroelectric dams. Then we used fuzzy-set qualitative comparative analysis (fsQCA) to identify the conditions' pathways that explain the capital change. fsQCA has been used in the past by scholars to compare dams in the context of anti-dam movements (Kirchherr et al., 2016) and to show the deficit in participation of affected communities across different dams (Garcia et al., 2021).

This study is novel because it adds to the literature on the impacts of dams by presenting a comprehensive comparative analysis of how 33 hydroelectric dams built in multiple countries in the Global South impact positively and negatively each of the following types of capital: natural, social, human, financial, and physical. It builds off peer-reviewed cases that provide valuable information about the interaction of dam development conditions, such as the participation of civil society, the existence of international awareness of the impacts of dams, recommendations from the World Commission on Dams (WCD), the country level of energy security, and the installed capacity of each dam. We also analyzed how these interactions could generate positive or negative changes in people's capital. The results show the immense impacts caused by dam development on communities living near the construction sites and how each capital is affected differently. We shed light on the importance of considering the impacts of hydroelectric dams from a systemic approach, including positive and negative aspects, to reduce the inequalities and injustices that energy systems generate. This conversation is of great importance in the current discussion about energy transitions, which will likely increase the construction of renewable energy systems such as hydropower, even in the Global North.

Theoretical background

This study aimed to explain the changes generated by hydroelectric dams on people's livelihoods using four causal conditions of dam development associated with the changes in five types of capital: natural, social, human, financial, and physical. The first condition is the participation of civil society. The second condition is the presence of international awareness of the impacts of dams enhanced by the WCD report (2000). The third is whether the country was energy secure when the dam's construction started or had to import energy to satisfy its demand. And the fourth condition is the dam's installed capacity.

Outcomes: Capital

We consider livelihoods in terms of access and control of capital (Bebbington, 1999; Ellis, 2000; Scoones, 1998, 2009). Thus, capital, besides being the resources that support individuals', households', and communities' livelihood strategies (Bebbington, 1999; Ellis, 2000), are also the assets providing people with the capabilities to be and act (Bebbington, 1999).

In particular, we look at five types of capital: *Natural* includes natural resources humans use for survival, such as land, water, plants, and animals (Ellis, 2000; Scoones, 1998). *Social* consists of social networks, affiliations, and associations in which people participate and from which they can derive/claim support that contributes to their livelihoods (Ellis, 2000; Scoones, 1998), as well as trust and reciprocity (Flora et al., 2016) *Human* refers to the capabilities and potential of individuals and populations, such as education level and health status (Ellis, 2000; Flora et al., 2016; Scoones, 1998). *Financial* includes the stocks of cash that are accessed to purchase goods and access to credit (Ellis, 2000; Scoones, 1998). *Physical* comprises human-built infrastructure and assets brought to existence by economic production processes like tools, machines, and land improvements (Ellis, 2000; Flora et al., 2016). All these capitals interact and contribute to sustainable livelihoods (Bebbington, 1999; Flora et al., 2016) and vary by individual, household, geographical area, and other social characteristics (Bebbington, 1999; Scoones, 2009). Access and control over more capital imply greater opportunities to switch between activities to sustain livelihoods (DFID, 1999).

As mentioned in the introduction, scholars have shown how various types of capital have changed with dam construction. Bui and Schreinemachers (2011) found that even though resettlers of the Son La dam in Vietnam received "land for land" compensation, most of them did not receive arable land to support their livelihoods (i.e., they experienced a reduction of their natural capital). On the other hand, resettlers and host households benefitted from the construction of roads and access to electricity, potable water, and sewage systems (i.e., increased human and physical capital). Sayatham and Suhardiman (2015) discussed how some communities resettled by the Nam Mang 3 dam lost access to fisheries and forest products (i.e., their natural capital decreased). Despite this, they describe that other communities gained access to an unpaved road during the dry season to access markets, allowing them to earn more income from forest products (i.e., their financial and physical capital increased).

Our research was an opportunity to provide a broad perspective on the social impacts of dams on capital, not by trying to quantify the effects but by describing how they are affected differently by the construction of dams. Thus, we are exploring the effects of dams on capital and the pathways of conditions influencing the change in capital based on what researchers have found in their studies.

Causal conditions to explain changes in capital

Participation

In the context of hydroelectric dams, researchers have shown that the impacts generated by their construction depend to some degree on the participation of local actors in a fair and equitable decision-making process or procedural justice (Siciliano & Urban, 2017). Procedural justice is concerned with decision-making practices and calls for equitable procedures that engage all stakeholders (Jenkins et al., 2016). In the case of hydroelectric dams, dam authorities and governments often do not consider principles of procedural justice (Garcia et al., 2021; Mayer et al., 2021; Mayer, Garcia et al., 2022). They do not acknowledge the needs of local populations, and they repurpose control and access to natural capital resources that support local people's livelihoods, for example, forests and water, for building the project (Siciliano & Urban, 2017).

Since the 1970s, researchers, practitioners, and even WCD have suggested including affected populations in decision making for dam development to mitigate the impacts on people's livelihoods (Goulet, 2005; Hay et al., 2019). For instance, Scudder (2005) noted that involving resettlers requires not just their active participation in decision making but also the involvement of their expertise and consideration of their lifestyles. Participation should start during the assessment process because it is when the social, environmental, and economic contexts are considered. However, procedures such as consultation or negotiation with local actors are rarely conducted in dam construction projects (Hay et al., 2019). Some would argue that environmental impact assessments and social impact assessments ensure the participation of local communities, but evidence shows that these assessments are often done poorly, sometimes even by the same companies that build the dams, and people living in these territories are often not involved/consulted (Gerlak et al., 2019).

The relationship between access to capital and civil society participation works like a loop. When individuals participate in decision-making processes, their access to capital increases, and when individuals have access to a variety of capital, their participation and bargaining power also increase (Matsue et al., 2014; Radel, 2012). Thus, we expect the lack of participation (LackPAR) in decision making will decrease people's capital.

International awareness of a dam's impacts

Something that might have tamed the impacts of dam development since 1998 was the creation of WCD. The commission was seen as a response to the controversies around dam construction and its impacts (Scudder, 2001) and as a way to bring together the dam's opponents and supporters (Fujikura & Nakayama, 2009). It comprised actors from different backgrounds (civil society, governments, academia, industry) and countries (Schulz & Adams, 2019). In 2000, WCD presented a final report highlighting seven strategic priorities for sustainable dam construction and including local actors in decision-making processes. The commission elicited responses from the anti-dam movements and reactions from representatives of major dam-building nations (Sneddon & Fox, 2008). The report embraced participatory decision making in planning, designing, and operating dams (Schulz & Adams, 2019).

WCD has been very important, since it provides a way to legitimize the social movements around dams and the need for more participatory processes (Schulz & Adams, 2019; Sneddon & Fox, 2008). Despite initial support, big dam-funding agencies like the World Bank and the Asian Development Bank did not adopt WCD's guidelines. They argued that the recommendations for participatory decision making interfere with the rights of sovereign states to pursue development (Sneddon & Fox, 2008). Likewise, countries with plans for high-capacity hydropower, such as India, China, and Brazil, did not endorse the report because they felt the guidelines would limit their energy development goals (Fujikura & Nakayama, 2009). However, other funding agencies, such as the African Development Bank and the German KfW Development Bank, have followed the recommendations (Scheumann & Hensengerth, 2014; Schulz & Adams, 2019).

Lack of international awareness of hydroelectric dam impacts raised by WCD (LackINT) is the second causal condition of this research. We expected dams constructed after the commission's establishment to have better guidance to protect people's livelihoods and, therefore, have fewer negative impacts on their capital.

Energy security

Hydropower is an attractive response to climate change (Gerlak et al., 2019), because dams are advertised as an alternative source to fossil fuels to generate electricity (Namy, 2010; Oud, 2002). Hydropower development organizations claim the need for "significantly more hydropower, to be built at a much faster rate if it is to tackle climate change" (IHA, 2020, p. 8). However, this statement is debatable since, in the tropics, hydroelectric dams generate methane, carbon, and other greenhouse gases (Barros et al., 2011; Araújo et al., 2019; Scherer & Pfister, 2016), which are drivers of climate change.

The polysemic concept of energy security appears precisely in the discussions on climate change and energy (Chester, 2010). In this research, we understand that a country is energy secure when it has enough resources to meet its energy demand (Bruckner et al., 2014), with no energy supply interruptions, and when it is not dependent on other countries (Chester, 2010). A country with a vulnerable or less energy-secure system will have a high share of energy imports, making it susceptible to energy price volatility (Global Network, 2010).

Nations commonly propose energy-security policies focused on strategies to secure low-cost and reliable electricity generation and transport supplies, reducing energy imports (Global Network, 2010). We expect that less energy-secure countries (import more energy than export) will generate more negative impacts on peoples' capital. These countries' policies mainly focus on reducing energy imports by developing low-cost energy sources. Hydropower is portrayed as a low-cost energy source because, in most cases, economic benefits tend to be overestimated and social-ecological impacts and construction costs are underestimated (Moran et al., 2018; Scudder, 2005). The variable we used in the analysis was energy security (LessES) based on *net energy imports*, estimated as the percentage of energy use less production.

Installed capacity

Installed capacity is a project-specific condition that indicates the quantity of electricity measured in megawatts (MW) the dam generates. The dam size usually reflects its potential benefits (WCD, 2000), such as increasing energy access (IHA, 2020; Siciliano & Urban, 2017). This supposed installed capacity is often not achieved after the dam's construction because of climate variability, as is the case with the Belo Monte in Brazil (Stickler et al., 2013). Governments and dam authorities promote hydroelectric dams by pointing to their installed capacity rather than their effective capacity during low-water periods (Winemiller et al., 2016). A recent global study of 631 dams confirmed that the negative impacts on population, gross domestic product, and land cover are greater with the increase in installed capacity (Fan et al., 2022). Thus, we assumed that the larger the installed capacity (LargeIC) of a dam, the more negative impacts it will have on people's capital.

Research design

To explore the configurations among the causal conditions presented in Section 2.2 in relation to the changes generated by hydroelectric dams on people's capital, we used secondary sources of information and our database of a qualitative meta-analysis of peer-reviewed papers exploring the social impacts of hydroelectric dams. For data analysis, we used fsQCA.

Data collection

We conducted a qualitative meta-analysis to explore the social impacts of hydroelectric dams in the Global South. This method involves summarizing the depth and complexity of case studies according to a standard coding scheme designed by the research team. We first conducted a literature search using Google Scholar following these criteria: peer-reviewed articles (indexed) written in English, published between January 1980 and May 2019, focusing on the social impacts of large-scale hydroelectric dams (wall higher than 15 m) in the Global South. We selected 1980 as the starting date because it was the year The World Bank established the first international standard on resettlement (Vanclay, 2017). This screening yielded 129 peer-reviewed papers studying 87 dams. Then we developed a codebook and a coding protocol. The coding process involved two stages. First, all four coders collaboratively coded a selection of papers to become familiar with the codebook and the coding process. Then each coder coded a separate batch of studies using NVivo 12 software.

We used the database of the qualitative meta-analysis for information about the various types of capital and civil society's participation in dam decision-making processes. We obtained information about the dam's installed capacity in MW and the year construction began from the qualitative meta-analysis and verified with other sources such as the *Global Atlas of Environmental Justice* (EJAtlas, 2019). For each dam, we collected information on the country's net energy imports from World Bank (2015).

Data aggregation at the dam level

We selected 147 case studies from 89 articles (contact author for the dataset) representing 33 dams in 18 countries. A case study describes what was happening with one population/group in a specific period because of a dam; one paper could include more than one case study. For example, in our research, an article describing the impacts of a dam on a host community and one that is resettled was codified as two case studies. This approach allowed us to consider the heterogeneity of communities impacted by dams. For this process, we used the *collapse* command in Stata 16 software to merge the case studies' information per dam, giving us the average values of the different cases per dam. We chose these 33 dams from our meta-analysis because we had data on

them for all types of capital and the causal conditions (except for energy security).
Table 2 presents information about the 33 dams included in the analysis: name, country, year of construction, installed capacity, and if the country was a net energy importer by the time construction started.

Table 2. Dams included in the analysis

Dam	Country	Year of construction	Installed capacity (MW)	Net energy importer
A luoi	Vietnam	2007	170	No
Aswan	Egypt	1960	2100	Not Available
Ataturk	Turkey	1983	2400	Yes
Bagre	Burkina Faso	1989	16	Not Available
Bakun	Malaysia	1996	2400	No
Batang Ai	Malaysia	1982	100	No
Belo Monte	Brazil	2011	11233	Yes
Bili Bili	Indonesia	1991	19.25	No
Bui	Ghana	2009	400	Yes
Chixoy	Guatemala	1976	280.983	Yes
Cirata	Indonesia	1984	1008	No
Gilgel Gibe I	Ethiopia	1988	184	Yes
Gilgel Gibe III	Ethiopia	2006	1870	Yes
Gitaru	Kenya	1975	225	Yes
Kamburu	Kenya	1971	93	Yes
Kamchay	Cambodia	2006	193.2	Yes
Kaptai	Bangladesh	1957	230	Not Available
Kiambere	Kenya	1983	165	Yes
Kindaruma	Kenya	1968	72	Not Available
Kotmale	Sri Lanka	1979	201	Yes
Masinga	Kenya	1978	40	Yes
Nam Theun 2	Laos	2005	1075	Not Available
Ralco	Chile	1998	690	Yes
Saguling	Indonesia	1983	700	No
Sardar Sarovar	India	1987	1450	Yes
Sobradinho	Brazil	1973	1050	Yes
Son La	Vietnam	2005	2400	No
Tehri	India	1978	1000	Yes
Theun Hinboun	Laos	1994	210	Not Available
Three Gorges	China	1994	22500	No
Wonorejo	Indonesia	1992	6.2	No
Xenamnoy	Laos	2013	410	Not Available
Xepian	Laos	2013	410	Not Available

Our study has some limitations. First, our qualitative meta-analysis dataset only includes papers written in English; we acknowledge that scholars are conducting and publishing high-quality research about the social-ecological impacts of dams in other local languages, but our team did not have the proficiency to include Asian languages. Second, the 33 dams included in our analysis were selected because they were in the meta-analysis dataset and scholars have explored all five types of capital for each dam. This means that some critical dams were left out due to lack of information.

Data analysis

In fsQCA, the outcome is understood as the phenomenon to be explained, and causal conditions as the characteristics that are associated with the outcome in question. fsQCA aims to determine which combinations of factors (causal conditions) are most closely associated with the outcome. In this research, the changes in each capital (natural, social, human, financial, and physical) due to dam construction are different outcomes. The causal conditions were the same for all outcomes: civil society participation, international awareness of a dam's impacts, energy security, and installed capacity. fsQCA allows the analysis of small or intermediate *n* of purposively selected cases. It is a method that creates a bridge between qualitative and quantitative approaches to measurement because it is both case-oriented (fsQCA compares cases as representations of configurations) and variable-oriented (fsQCA pays attention to specific individual conditions) (Marx et al., 2014).

For the analysis, we calibrated both the outcomes and causal conditions, then tested the necessity and sufficiency of each causal condition for every outcome with the software fsQCA 3.0. A causal condition is necessary if it must be present for the outcome to occur, whereas a causal condition is sufficient if it can produce a specific outcome (Ragin, 2014). For the analysis of necessity, we selected a consistency threshold of 0.9 or higher, as suggested by Schneider and Wagemann (2012). For sufficiency, as Ragin (2005) recommended, we selected a consistency level of above 0.75.

Calibration

Calibration, in fsQCA, is an analytical process by which researchers transform qualitative or quantitative data into crisp or fuzzy sets (Basurto & Speer, 2012; Fiss, 2011; Schneider & Wagemann, 2012). For the outcomes, we first created indices for each capital from variables of the qualitative meta-analysis (see Table 3 and Appendix 2 for a description of each variable). The indices ranged from -7 to 5; the lower the index, the more the variables belonging to that capital decreased (Table 2). Thus, a dam with six negative variables and one positive in a specific capital will have a value of -5.

Table 3. Capital indices

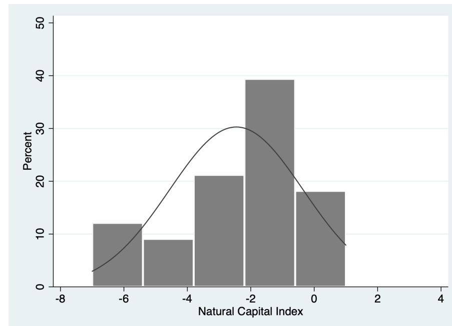
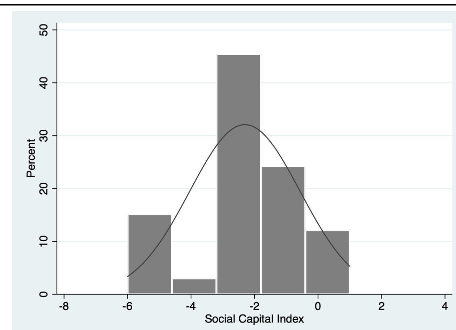
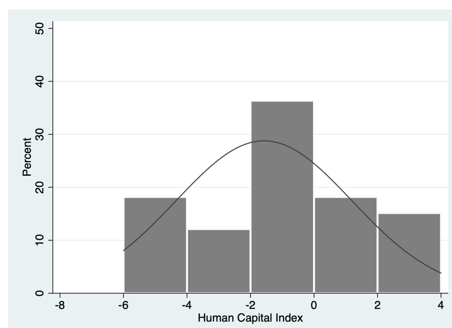
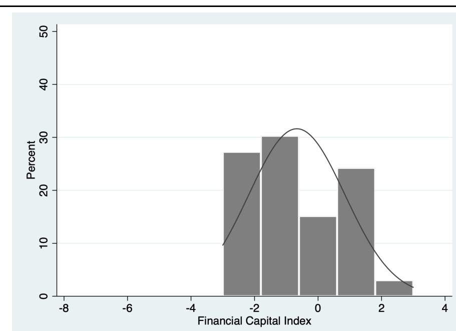
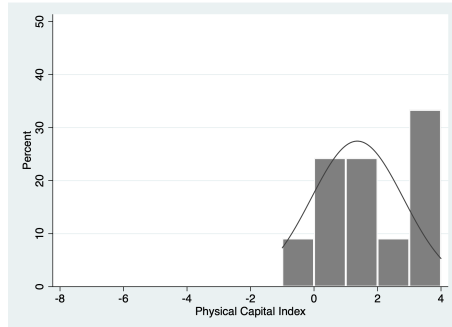
Outcome	Variable	Index distribution
Natural capital	Capital natural Soils Fish quantity Fisheries access Natural areas and products access Natural products quantity Water quality Water access Livestock amount Compensation natural capital	
Social capital	Capital social Community trust Cultural activities Friends and family connections Site neighbors Immigrants Conflict	
Human capital	Capital human Food access Food security Health Health access School Sanitation Standard of living Self-reported well-being Compensation human	
Financial capital	Capital financial Income Income inequality change Crop yield Employment Monetary compensation	

Table 3 (cont'd)

Physical capital	Capital physical Electricity access Compensation communities Physical compensations	

Then we calibrated each capital in each dam as a particular outcome based on the index value. We used direct calibration, which requires the researcher to select the values of a scale that correspond to the breakpoints of the set (Ragin, 2008). This type of calibration allows for replication and validation (Pappas & Woodside, 2021). We calibrated the index scores into a three-value scheme—0, 0.5, and 1—to indicate full non-membership, the crossover point, and full membership (see Table 3). Then, for each capital, if a dam had more positive variables than negative ones, it was calibrated as 0; if it had the same number of positive and negative variables as 0.5, and if it had more negative variables than positive, it was calibrated as 1.

Table 4. Calibration of outcomes

Value	Outcome's Calibration		Description
1	Index value ≤ -1	Full membership	Mostly negative impacts
0.5	Index value = 0	Crossover point	The same number of positive and negative impacts
0	Index value ≥ 1	Full non-membership	Mostly positive impacts

For our first condition, *Participation (*LackPAR**)**, we used a four-value scheme based on scales from non-participation to citizen control (Arnstein, 1969; Pretty, 1995; White, 2011). We used four variables from the meta-analysis for calibrating this condition: participation, consultation and information, choice, and negotiation (see Appendix 3). The calibration ranges from *No public participation* (full membership = 1) when locals could not engage in any level of participation to *Some participation occurred* (full non-membership = 0) when civil society could choose or negotiate in decision making. The calibration values between the extremes were *Poor participation occurred* (partly in membership = 0.67) when locals were consulted or participated in the decision-making process but did not have the opportunity to choose or negotiate and *Low participation occurred* (partly out membership = 0.33) when civil society was engaged in at least two levels of participation.

We calibrated *International awareness (*LackINT), the second condition, in a two-value scheme:

after the WCD report (2000) was published (full non-membership = 0) and before its publication (full membership = 1).

The third causal condition, *Energy security* (LessES), is a proxy of the country's energy security during the initial year of dam construction. We used a two-value scheme to calibrate this causal condition: Energy secure or net exporter countries (full non-membership = 0) and less energy secure or net energy importer countries (full membership = 1). A country is a net energy importer if energy use is higher than the production in a year. Countries with no information available were calibrated as the crossover point: 0.5, which in fsQCA is the value of maximum ambiguity and represents cases that are categorized as neither full membership nor full non-membership (Ragin, 2008).

For the last condition, *Installed capacity* (LargeIC), we used a four-value scheme to differentiate between the smaller dams and megadams. We assigned a value for each percentile from smaller dams (full non-membership), fairly large dams (partly out membership), large dams (partly in membership) to megadams (full membership). Table 5 contains information about the calibration of the causal conditions (See Appendix 4 for expanded information about the calibration process).

Table 5. Causal conditions calibration

Causal condition	**Value**	**Calibration**		**Source**
Participation (LackPAR)	Full membership	1	*No public participation occurred*	Qualitative meta-analysis
	Partly in membership	0.67	*Poor participation occurred*	
	Partly out membership	0.33	*Low participation occurred*	
	Full non-membership	0	*Some participation occurred*	
International awareness (LackINT)	Full membership	1	Construction started before publication of the WCD report	WCD (2000), qualitative meta-analysis, and EJAtlas (2019)
	Full non-membership	0	Construction started after publication of the WCD report	
Energy security (LessES)	Full membership	1	Less energy-secure country (net energy importer)	World Bank (2015)
	Crossover point	0.5	Country is neither a net energy importer nor a net energy exporter	
	Full non-membership	0	Energy-secure country (net energy exporter)	

Table 5 (cont'd)

Installed capacity (LargeIC)	Full membership	1	1870 MW or more mega dam	The qualitative meta-analysis and EJAtlas (2019)
	Partly in membership	0.67	1,075–1869 MW large dam	
	Partly out membership	0.33	400–1,074 MW fairly large dam	
	Full non-membership	0	Less than 400 MW smaller dam	

Results and discussion

We start by describing the distribution of the impacts on each capital reported in all 147 studies used in this research. Then we present the fsQCA configurations that explain the change in each capital for the 33 dams.

How does capital change after dam construction?

Figure 2 presents the percentage of the 174 cases that studied the impacts of hydroelectric dams in at least one variable of each capital. As shown, not all cases considered all capital; however, this was not problematic since our study was conducted at the dam level. Figure 3 shows the distribution of positive and negative impacts among those cases that considered variables of different types of capital.

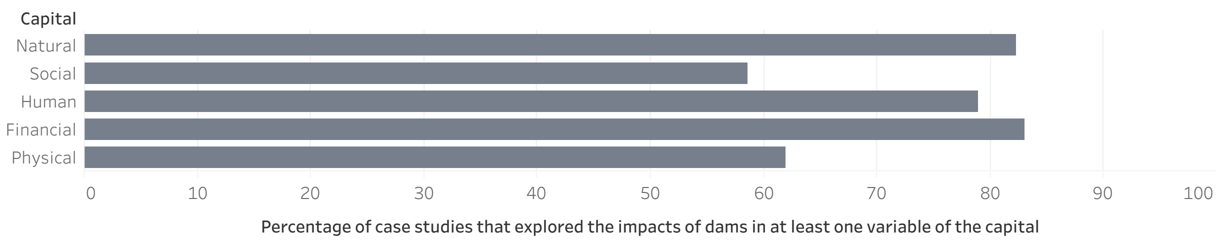


Figure 2. Percentage of cases in which the impacts of hydroelectric dams were studied in at least one variable of each type of capital

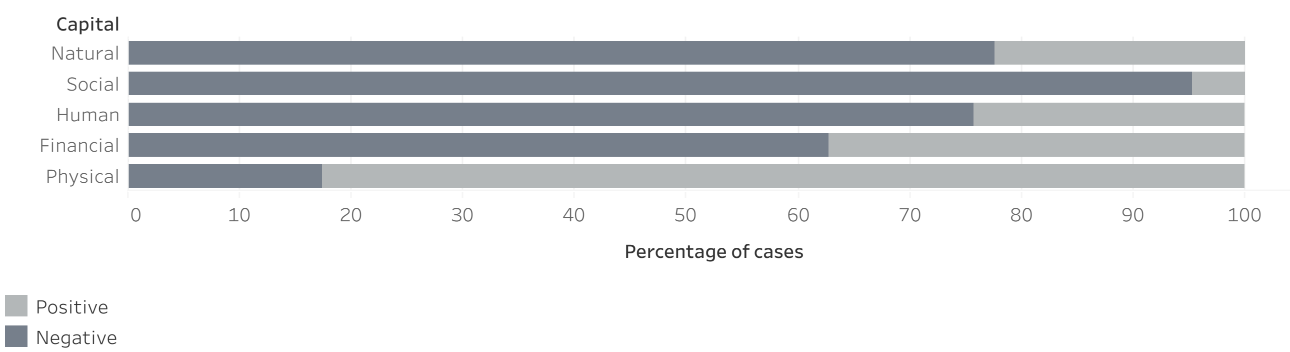


Figure 3. Distribution of capital indexes at the case-study level

Figure 2 shows that 82% of the case studies described at least once an aspect of change in natural capital; among those, it is noticeable that most of the case studies report negative impacts (Figure 3). It is very important to consider the effects of dams on natural capital because, in rural communities, this capital is the basis for supporting all the other capitals (Flora et al., 2016). Scholars reported that local actors had lost access to common-pool resources such as rivers, forests, and pasture land (Abrampah, 2017; Bisht, 2009). Another common issue was the decrease in soil quality, which was prevalent in the case of resettlers who received land of worse quality, including infertile soils compared to what they had before the resettlement, preventing them from planting quality crops and threatening their food security (Aeria, 2016; Urban et al., 2015).

Only 58% of the case studies referred to at least one variable of social capital, demonstrating that this capital was less studied in the literature (Figure 1). Still, 95% of the impacts were negative when it was reported. These impacts include the loss of traditional ceremonies due to resettlement (González-Parra & Simon, 2008; Nguyen et al., 2017) and the loss of social networks because households were often resettled in different locations than their friends and relatives (Leturcq, 2016). Among the few positive impacts on social capital, researchers have shown that, in some cases, host communities have increased their participation in associations after resettlement.

Human capital was included in 79% of the case studies; among those, 75% reported primarily negative impacts. For instance, scholars informed an increase in disease transmission (Gyau-Boakye, 2001; Kedia, 2003), hunger, malnutrition (Hall, 1994), and depression (Hausermann, 2018; Xi, 2016). However, some local communities also increased their access to health (Mishra & Kahssay, 2015), education (Fujikura & Nakayama, 2013), and sanitation services (Yoshida et al., 2013).

Aspects of financial capital are frequently mentioned in the literature. At least one aspect of this capital was described in 83% of the case studies (Figure 1), including factors like income, savings, and cash compensations provided by dam authorities. Financial capital also had both positive (37%) and negative (63%) aspects (Figure 2). For instance, resettled households experienced a decrease in their income potentiated by the loss of their natural resources, which were sources of food and cash (Bui & Schreinemachers, 2011). Furthermore, the livelihoods of displaced households were impacted negatively, not just by a drop in income but also by high housing prices in resettlement areas (Howe & Kamaruddin, 2016). In some cases, families were displaced but not resettled into new houses; some received cash compensation and were responsible for finding a new place to live. The most common type of compensation dam authorities provided to affected communities was cash, which increased financial capital in the short run. Still, if that was all people received, it certainly was not enough to restore their livelihoods (Cernea, 1997).

Finally, just 62% of the case studies made at least one reference to physical capital (Figure1). Not surprisingly, physical capital was the least negatively affected capital in these cases. Only 17% of the case studies described negative issues, whereas 82 % indicated positive aspects such as improved housing, roads, schools, health centers, and markets (Hensengerth, 2018; Jusi, 2006). These aspects not only generated benefits to the local area but were necessary for the operation of dam builders (i.e., roads). Other assets that some resettlers gained included household appliances such as televisions and refrigerators (Karimi & Taifur, 2013). Nonetheless, in most cases, resettled communities lost their houses and other physical assets due to resettlement (Faure, 2003).
Figure 4 summarizes the context of capital at the dam level. This figure reflects the distribution of positive and negative impacts after collapsing the information from all cases per dam. Among the 33 hydroelectric dams in the analysis, 27 mainly had negative impacts on natural capital, 29 on social, 22 on human, 19 on financial, and three on physical capital. On the other hand, 22 of the dams had primarily positive impacts on physical capital, which is directly related to the results presented above.

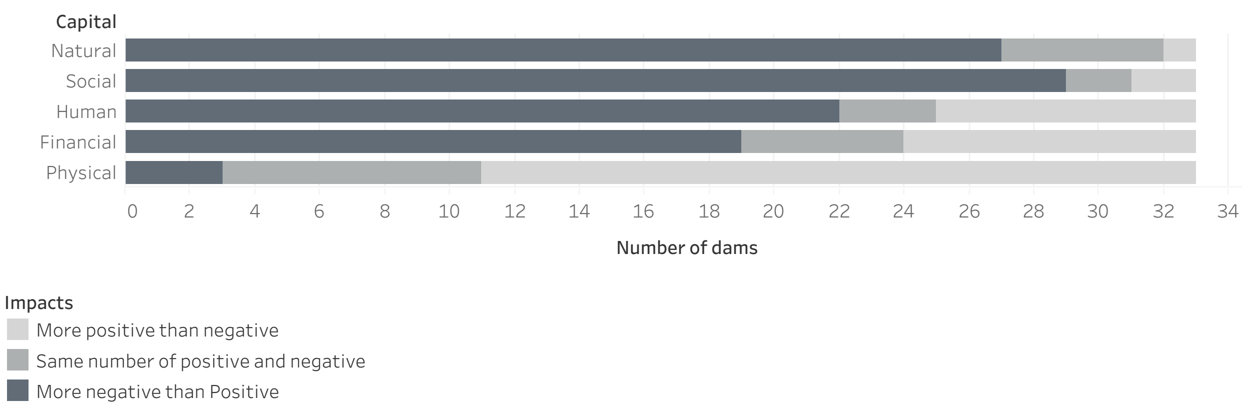


Figure 4. Distribution of positive and negative impacts across 33 large-scale dams

This section has provided an overview of the literature about the impacts of dams on people's livelihoods. It offers a broad description of how hydroelectric dams generate multidimensional impacts on people's capital. Figure 2 shows that scholars report more frequently the changes dams generate on financial, natural, and human capital, whereas impacts on physical and social capital are less often described. Figure 3 shows that dam construction generates primarily adverse impacts on social, natural, human, and financial capital and more positive impacts on physical capital. Figure 4 summarizes the information at the dam level; it shows the trend that hydroelectric dams generate more positive impacts on physical capital and negative impacts on social, natural, human, and financial capital. These results support our assumption that the construction of dams will impact people's capital differently because each capital supports different aspects of their livelihoods. In the next section, we present the fsQCA configurations, which provide a deeper understanding of the conditions that led to the changes in capital due to hydroelectric dam development.

fsQCA configurations

In this section, we describe the configurations of conditions that explain the presence of primarily negative impacts in natural, social, human, and financial capital and mostly positive impacts in physical capital. In the analysis of necessity, we found that none of the causal conditions is necessary for the presence of the outcomes. None of the causal conditions must be present for any capital to change. Results for all conditions in each outcome are presented in Appendix 5.

Table 6. Configurations of causal conditions shows 13 configurations of causal conditions or pathways that are sufficient to explain the presence of primarily negative impacts in natural, social, human, and financial capital and the presence of mostly positive impacts in physical capital (see Table 5 and Appendix 4 for extended information about the solutions). The table includes all sufficient pathways and their coverage or empirical relevance and consistency. Each pathway's raw coverage (RC) represents the proportion of dam projects explained by the pathway, including those in other pathways. The unique coverage (UC) represents the proportion of dam projects explained by that pathway. And the consistency (C) score is a value that assesses the sufficiency of each pathway. For example, the pathway LackPAR for natural capital explains that 80% RC of the dams had mostly negative impacts on this capital and are included in other pathways. LackPAR has UC of 0.15, which indicates that this pathway alone covers 15% of the dams not included in other pathways, and it has C of 0.95. High consistency suggests that the configuration is sufficient to generate the outcome in this study indicating the presence of mostly negative or positive impacts in a capital.

Table 6. Configurations of causal conditions

Causal condition	Value	Calibration		Source
Participation (LackPAR)	Full membership	1	*No public participation occurred*	Qualitative meta-analysis
	Partly in membership	0.67	*Poor participation occurred*	
	Partly out membership	0.33	*Low participation occurred*	
	Full non-membership	0	*Some participation occurred*	
International awareness (LackINT)	Full membership	1	Construction started before publication of the WCD report	WCD (2000), qualitative meta-analysis, and EJAtlas (2019)
	Full non-membership	0	Construction started after publication of the WCD report	

Table 6 (cont'd)

Energy security (LessES)	Full membership	1	Less energy-secure country (net energy importer)	World Bank (2015)
	Crossover point	0.5	Country is neither a net energy importer nor a net energy exporter	
	Full non-membership	0	Energy-secure country (net energy exporter)	
Installed capacity (LargeIC)	Full membership	1	1870 MW or more mega dam	The qualitative meta-analysis and EJAtlas (2019)
	Partly in membership	0.67	1,075–1869 MW large dam	
	Partly out membership	0.33	400–1,074 MW fairly large dam	
	Full non-membership	0	Less than 400 MW smaller dam	

Note: *, and; ~ absence of
RC, raw coverage; UC, unique coverage; C, consistency; Cases, number of cases per pathway

First, we briefly describe the solutions for each capital; then we explore in depth how different pathways explain the changes in the various types of capital. The solution for the decline of natural capital has three pathways (1, 8, and 10 in Figure 5). The first configuration indicates that dams with poor or lack of citizen participation (LackPAR) explain the presence of mostly negative impacts in this capital. Contrary to our expectations, the second configuration (LargeIC * ~ LessES) indicates that large and megadams in energy-secure countries also generate mostly negative impacts on natural capital. The last pathway shows that dams constructed with a lack of international awareness about dams' social impacts (LackINT) sufficiently explain the presence of mostly negative impacts on natural capital.

The solution for social capital has three pathways (1, 7, and 11 in Table 6) sufficient to decrease social capital. The first pathway (1) is shared with natural capital; this indicates that dams with poor or lack of civil society participation (LackPAR) explain the presence of primarily negative impacts on social capital. The other two pathways (7 and 11) show that dams built in less energy-secure countries combined with a larger installed capacity (LargeIC * LessES) or built with a lack of international awareness about the social impacts of dams (LackINT* LessES) are sufficient to explain the presence of primarily negative impacts on social capital.

For human capital, the solution has three pathways (3, 6, and 7 in Table 6). Pathways 3 and 6 show that dams built with poor or lack of civil society participation that were constructed before or after the publication of the WCD report (2000) and in energy-secure or less energy-secure countries (LackPAR* LackINT * LessES + LackPAR* ~ LackINT* ~ LessES) are sufficient for explaining the presence of primarily negative impacts on human capital. Pathway 7 shows that large dams and megadams built in less energy-secure countries (LargeIC * LessES) are sufficient for the presence of primarily negative impacts.

The solution for financial capital has two pathways (2 and 4 in Table 6). Both pathways indicate that dams with poor or lack of civil society participation and built in a context of lack of international awareness about the social impacts of dams in combination with lower large installed capacity (LackPAR * LackINT * ~ LargeIC) or built in energy-secure countries (LackPAR * LackINT *~ LessES) are sufficient for explaining the presence of primarily negative impacts on financial capital.

The final solution, which describes the presence of positive impacts on physical capital, has four pathways (5, 9, 12, and 13 in Table 6). Pathway 5 indicates that dams built with lower or lack of civil society participation built after publication of the WCD report (2000) are sufficient for the presence of primarily positive impacts on this capital (LackPAR* ~LackINT). Pathway 9 shows that large dams and megadams with some level of civil society participation are sufficient for the presence of mostly positive impacts (LargeIC * ~LackPAR). The last two configurations (12 and 13) illustrate that dams built after the WCD report (2000) in energy-secure countries (LackINT* ~ LessES) or with some level of civil society participation (LackINT * ~LackPAR) are sufficient for the presence of mostly positive impacts on physical capital.

As seen in Table 6, none of the pathways explains the change across all capital. There are three groups of configurations within all of the solutions that indicate the presence of mostly negative impacts on natural, social, human, and financial capital and mostly positive impacts on physical capital: participation of civil society and international awareness, megadams and energy security, and international awareness and energy security.

Civil society participation and international awareness

One of the most recognized contributions of the WCD report (2000) is how it acknowledges the need of participatory processes across all stages of dam construction (Schulz & Adams, 2019). Participation, as a concept, has been used by dam developers as a buzzword to indicate their projects are fulfilling the requirements. However, their "participation" processes are far from addressing procedural injustices. Mayer, Garcia, et al. (2022) have described the participation processes in dam development as "pretend participation," since the mechanisms provided by developers are completely inadequate. Table 6 shows six pathways (1–6) that include the interaction between civil society participation and international awareness to explain the changes in capital. Our results prove that poor or lack of civil society participation is related to primarily negative impacts on natural, social, human, and financial capital, and mostly positive impacts on physical capital. Thus, our results support the expectation that when individuals or local communities do not participate in decision making, most of their various types of capital will be negatively impacted. However, as described in this section, not all types of capital are affected in the same way; the lack of participation in combination with other conditions has different effects on each capital.

The first pathway, LackPAR, is sufficient to explain the presence of mostly negative impacts on natural and social capital. Its consistency for both was 0.95, which implies that this condition is highly likely to be sufficient to explain both outcomes. This pathway includes 20 dams: A luoi, Bagre, Bakun, Batang Ai, Belo Monte, Bui, Chixoy, Cirata, Gilgel Gibe III, Gitaru, Kamburu, Kamchay, Kaptai, Kiambere, Kindaruma, Masinga, Saguling, Sardar Sarovar, Sobradinho, and, Tehri. These cases show that poor or lack of civil society participation is sufficient for the presence of mostly negative impacts on natural and social capital. For example, the inhabitants of a community located downstream of Belo Monte in Brazil were not included in decision making, and they lost fish species and access to the river (Castro-Diaz et al., 2018). Resettlers did not choose to move (Randell, 2016b), and the process generated a separation from their families and acquaintances (Leturcq, 2016). Likewise, Kedia (2004) described that in the case of Tehri in India, communities were forced to resettle, and they lost their land and access to their forest. Furthermore, after relocation, they lost social cohesion and cultural practices (Naithani & Saha, 2019).

The lack of civil society participation, in combination with a lack of international awareness, is sufficient for the presence of mostly negative impacts on human capital (pathway 3) and financial capital (pathways 2 and 4). These pathways include 19 dams: Ataturk, Bakun Bagre, BatangAi, Chixoy, Cirata, Gitaru, Kamburu, Kaptai, Kiambere, Kindaruma, Masinga, Saguling, Sardar Sarovar, Sobradinho, Tehri, Theun Hinboun, Three Gorges. For example, the Bakun in Malaysia, for which construction began in 1996 (before the 2000 WCD report), did not conduct prior consultation with local indigenous communities, which violates the United Nations Declaration on Indigenous Peoples (Aeria, 2016). In other communities, the government provided information about the benefits of the dam (Siciliano & Urban, 2017). Still, there was no negotiation process. After the dam's construction, communities did not have the economic means to access their farmlands, which reduced their protein intake and food security (Choy, 2004; Siciliano & Urban, 2017).

The last group of participation conditions (pathways 5 and 6) indicates that dams lacking participation policies and built in a context of international awareness of the impacts of dams also generate mostly negative impacts on human capital and primarily positive impacts on physical capital. Five dams are included in these pathways: A luoi, Belo Monte, Bui, Gilgel Gibe III, and Kamchay. The construction of A luoi in Vietnam started in 2007, after the 2000 WCD report. The participation process of locals was poor because they did not play any role in the decision-making process. Ty et al. (2013) reported that the province and district decided to build the dam, and locals were informed they would be evicted and resettled due to the construction. Resettled communities claimed that they were concerned about their food security since there was a reduction in the satisfaction of nutritional needs. Also, the authors described how the resettlement area had a hospital building but no doctors or health workers. This reflects a typical situation; in this case, there was a positive impact on physical capital with the construction of the hospital but no access to the services, negatively impacting human capital.

Megadams and energy security

Table 6 displays the second group of configurations of causal conditions (pathways 7, 8, 9) led by installed capacity (LargeIC). The results show that megadams generate mostly negative impacts on natural, social, and human capital and positive impacts on physical capital regardless of the nation's energy security level. Our results support the assumption that the larger the dam's installed capacity, the more negative impacts it will have on people's livvelihoods, or at least in natural, social and human capital.

First, we found that the largest dams in our analysis built in less energy-secure countries (LargeIC * LessES) generate sufficient conditions for the presence of more negative impacts on social and human capital. This pathway (7) affected eight dams: Ataturk, Belo Monte, Bui, Gilgel Gibe III, Ralco, Sardar Sarovar, Sobradinho, and Tehri. A well-known case among these dams is Sobradinho, a dam with 1050 MW of installed capacity, built during the 1970s under a Brazilian military dictatorship and in a context when Brazil depended on energy imports. The dam was conceived to respond to the country's growing urban and electricity requirements and to reduce petroleum imports (Hall, 1994). Hall (1994) reported that 4150 km^2 were flooded for its construction, and around 120,000 people were displaced without a resettlement program. Additionally, because of the lack of planning and processes of expropriation used, local actors suffered from psychological stress and widespread hunger and malnutrition, which reflect negative impacts on human capital. Cernea and Maldonado (2018) described the case of Sobradinho as a social disaster that acted as a stimulus for generating radical changes, such as the implementation of the World Bank's first international standard on resettlement in 1980 (see also Mathur, 2011; Vanclay, 2017).

Megadams in energy-secure countries generate negative impacts on natural capital (LargeIC * ~LessES), as in the cases of Bakun, Cirata, Saguling, Son La, and Three Gorges. All these dams are located in Asia and financed by Asian agencies such as the China Export-Import Bank, the Overseas Economic Cooperation Funds of Japan, the Asian Development Bank, and the China Development Bank. This pathway (8) does not support our assumption that countries with less share of energy imports will generate fewer negative impacts on peoples' capital. Still, it would be essential to investigate where the energy produced by these dams will end up going, because it will likely go to another country. Here we are showing cases of Asian hydroelectric megadams built in energy-secure countries that caused mostly negative impacts on natural capital.

For example, Saguling was built in an energy-secure country and negatively impacted natural capital. It was constructed in 1983 in Indonesia, the largest energy producer in Southeast Asia (IEA, 2021a), to increase the reliability of the electricity system, reserve petroleum, and improve the irrigation system, among others (Nakayama, 1998). In the case of natural capital, farmers lost more than 4713 ha of productive farmland (Nakayama, 1998), fish species declined (Sunardi et al., 2013), and pollution levels increased due to the population increase in the resettlement areas (Manatunge et al., 2009).

Another case presented in this pathway is the Three Gorges Dam, the largest dam in the world, which has displaced the largest number of people, around 1.13 million (Wang et al., 2013; Wilmsen, 2016). Its construction began in 1994 in the Yangtze River (China). This dam was expected to generate 10% of the electricity demand of China (Salazar, 2000) and reduce flooding and control navigation (Yan, 2010). Scholars have reported a variety of impacts generated by this megadam. To mention some, the loss of land for farming (Heggelund, 2006; Wilmsen & van Hulten, 2017); lower quality of soils after resettlement (Tan et al., 2005); loss of aquatic mammals like river dolphins, and loss of riparian areas (Beck et al., 2012).

The third configuration (pathway 9) within this group indicates that large dams and megadams with some level of civil society participation are sufficient for the presence of mostly positive impacts on physical capital (LargeIC * ~LackPAR). This pathway includes six dams: Nam Theun2, Ralco, Aswan, Son La, Xenamnoy, and Xepian. The Aswan High Dam, with 2100 MW of installed capacity, was built in the 1960s in Egypt. It had some level of civil society participation since, before the resettlement process, the government held meetings with community delegates (Weist, 1995). For its construction, new roads were built, which increased local actors' access to urban facilities such as health centers, police stations, transportation systems, markets, and schools (Weist, 1995).

International awareness and energy security

The last group of configurations (pathways 10, 11, 12, and 13) reflects the effects of international awareness about the social-ecological impacts of large-scale hydroelectric dams in local communities. The pathways show that the effect of international awareness in protecting peoples' livelihoods maintains despite the context of energy security. Our results support the assumption that dams built after publication of the 2000 WCD report, in a context with more international awareness about the social impacts of dams, have better protocols to protect people's livelihoods and, therefore, fewer negative impacts on capital.

Pathways 10 and 11 (LackINT + LackINT*LessES) indicate that dams built before the WCD report in less energy-secure countries generate mostly negative impacts on natural and social capital. These pathways support our assumption that dams built without international awareness about the social impacts of dams in less energy-secure countries generate more negative impacts on capital. Twenty hydroelectric dams are included in these pathways: Aswan, Ataturk, Bagre, Bakun, BatangAi, Bili Bili, Chixoy, Cirata, Gilgel Gibe I, Gitaru, Kamburu, Kaptai, Kiambere, Kindaruma, Kotmale, Masinga, Saguling, Sardar Sarovar, Sobradinho, and Tehri. For example, Gitaru dam was constructed in 1975 in Kenya while the country depended on energy imports for its supply. Gitaru has an installed capacity of 225 MW, and as a result of its construction, areas were flooded, which mainly generated negative impacts on natural and social capital. For instance, after the dam's construction, there was a decrease in arable land and crop yields, forcing landowners to built irrigation systems, generating an increase in their production cost. Contrarily, in areas located downstream from the dam, the flooding of the reservoir increased the drying of floodplains and decreased riverine forests and access to gathering activities (Okuku et al., 2016). Okuku et al. (2016) also reported social disintegration in the communities impacted by the dam's construction due to the lack of roads and an increase in conflicts between different groups.

Finally, dams built before the the WCD report in a fairly energy-secure country or with better participation policies (LackINT*~LessES + LackINT*~LackPAR) generated mostly positive impacts on physical capital. Pathways 12 and 13 include ten hydroelectric dams: Aswan, Bakun, Batang Ai, Bili Bili, Cirata, Gilgel Gibe I, Kotmale, Saguling, Three Gorges, and Wonorejo. To illustrate, during the resettlement process for Wonorejo dam in Indonesia, built under a context of energy security, families whose houses were going to be flooded received support from local authorities to negotiate cash compensation. After resettlement, families reported their houses were larger than before, and public facilities, such as roads, were better than those in their previous settlements (Sisinggih et al., 2013).

Conclusions

The social impacts of hydroelectric dams have been studied from different perspectives. On one side, dam advocates highlight positive impacts, whereas dam opponents present negative ones. In this study, we explored hydroelectric dams' positive and negative impacts on capital specifically supporting the livelihoods of communities living near construction sites. In our research, we complemented the literature on the social impacts of dams by presenting a comparative analysis of 33 large-scale hydroelectric dams. So far, most of the literature focuses on one or multiple dams in one country, and among those, the majority evaluate the social impacts of dams focusing on one type of capital. Therefore, the results of our analysis bring into the literature a comprehensive and global view of the social impacts of dams by assessing multiple types of capital across dams in Africa, Asia, and Latin America.

First, we describe the impacts on people's capital. Then we explored the configurations of dam development conditions that explain the changes in the capital: civil society participation, international awareness of the social-ecological impacts of dams, installed capacity, and nations' energy security.

The analysis showed that financial, human, and natural capital impacts are frequently studied. In contrast, the literature should further explore social and physical issues. Our results suggest that peoples' capital are impacted differently by the construction of hydroelectric dams. Natural, social, human, and financial capital are negatively impacted, whereas physical capital is often positively impacted, mainly because dam construction companies need better infrastructure like roads to build the dams and to conduct their operations successfully. Other infrastructure, such as hospitals and schools, are often promised during negotiations at the regional level. In many cases, these are built in host communities or are part of the new resettlements created for people displaced by the construction. However, it is worth mentioning that physical capital does not ensure the provision of services. As found in our qualitative meta-analysis, the construction of a school or a health center does not guarantee the presence of individuals with the skills to provide the services, such as teachers or health practitioners.

The literature, including the studies in our qualitative meta-analysis, portrayed persistent procedural justice problems in dam development. However, they did not explain how this injustice related to the dam's impact on people's livelihoods. Usually, scholars noted the urgent need to include affected populations in decision making to reduce impacts on their livelihoods (Goulet, 2005; Hay et al., 2019) without portraying a comprehensive understanding of this relationship. Our medium-N study indicates how the lack of participation of civil society in decision-making processes influences negative impacts on all but physical capital. This result is critical, since our study demonstrates that participation of local communities in decision making is meaningful because they have the right to make decisions about their own livelihoods. Their active participation, power, and recognition will mitigate and reduce the negative impacts of energy development in their lives. Thus, to pursue equitable and just processes in energy development projects, we need people's participation in decision making.

Some countries have initiatives like consultation when projects such as dams are planned and being constructed, especially in indigenous lands; however, even with those procedures, dams continue to be built without real input from stakeholders. When a dam is to be built, governments need to improve the design and implementation of environmental and social impact assessments. One way to do that is by assessing the livelihoods of populations living near the construction area and include their voices (upstream, downstream, population that will be resettled, and host communities) in the assessments. Governments and dam builders need to understand that the impacts of dams are multidimensional, and that all populations living near dams are affected in one way or another and for a long period of time. In this paper, we demonstrate that dams cause diverse positive and negative effects on people's capital. Allowing people's participation in all steps of the project could provide the knowledge and tools to ensure at least the restoration of local livelihoods to the conditions before the dam's construction.

All dams included in our analysis have a large installed capacity, a characteristic used by governments to promote the potential benefits of a dam for the nation while overlooking the potential local social-ecological and economic impacts. We presented how the construction of megadams in less energy-secure countries negatively impact social and human capital while causing positive effects on physical capital. We also described how megadams built in energy-secure countries generate negative impacts on natural capital. This is consistent with the results found by Fan et al. (2022), showing how large-scale dams negatively impact land cover near construction. However, in our case, this capital also included the loss of quality land, fisheries, and the effects on people when they lost those ecosystems, among other impacts on natural capital. In sum, regardless of the energy security status of a nation, the larger the dam's installed capacity, the more negative impacts the dam will have on people's capital, except for physical, since more investment is needed to improve the region's infrastructure.

Our results do not support our expectations regarding energy security. We found that regardless of the energy-security status of a country, dams generate negative impacts in all capital except physical, which reflects the influence of governments and dam authorities in endorsing dam construction due to its benefits at national and global scales. These results also suggest that governments and dam construction companies are continually overlooking the impacts at the local level. The increased global energy demand and the urgent need for energy transitions are pressuring nations to invest in low-carbon energy sources. In the Global South and emerging economies, hydropower is presented as a clean energy source that will meet nations' energy needs while reducing dependence on fossil fuels.

Considering the immense impacts of megadams and the need for the energy security of Global South nations and emerging economies, it is necessary to rethink dams and other energy systems. We believe strategies that consider local populations' social, ecological, and economic characteristics, such as decentralized microgrids (Brown et al., 2022), are needed for everyone to thrive in the future.

Despite the controversies generated by the publication of the WCD report (2000), and the lack of adoption of its recommendations and guidelines by some agencies and governments, our results show that dams built after the the report generated fewer negative impacts on people's capital. Our results indicate the importance of the role played by WCD in raising international awareness about the social-ecological impacts of dams despite a country's energy-security status. WCD also helped affected communities to legitimize their concerns (Sneddon & Fox, 2008) for protecting their livelihoods through the environmental justice movement. Well-organized social movements strengthen the mobilization against large dams by providing locals a political voice (Shah et al., 2021). More common efforts should be made among academics, activists, and civil society organizations to shed light on the social impacts of dams.

Our analysis showed that none of the conditions we explored is necessary to explain changes in all types of capital but that different pathways explain changes in some. This shows how complex it is to assess changes in people's livelihoods, since each capital supports different aspects of livelihoods, but also that people and communities intertwine their capital to live. In the same argument, future research needs to explore how hydroelectric dams' impacts on one capital are related to other capital over time. For instance, negative impacts on natural capital, such as the reduction in land fertility or land scarcity, could generate negative impacts on human capital like food insecurity. Studying this requires longitudinal research, and not only in one period of time because the impacts and responses to dam development are dynamic; they depend on social-ecological and economic contexts and change over time (Castro-Diaz et al., Draft; Kirchherr & Charles, 2016; Scudder, 2005).

As energy demand and the need for a clean energy transition are increasing, we must find energy systems that will consider the positive and negative impacts at different geographical and temporal scales. Our comprehensive study demonstrates that large-scale hydroelectric dams affect the livelihoods of those living near construction sites and therefore enhance injustices in communities that lack the political power to make decisions about the projects.

REFERENCES

Abrampah, D. A. M. (2017). Strangers on their own land: Examining community identity and social memory of relocated communities in the area of the Bui Dam in west-central Ghana. *Human Organization*, 76(4), 291–303. http://ezproxy.msu.edu/login?url=https://search.proquest.com/docview/1979465178?accountid=12598

Aeria, A. (2016). Economic development via dam building: The role of the state government in the Sarawak Corridor of Renewable Energy and the impact on environment and local communities. *Southeast Asian Studies*, 5(3), 373–412. https://doi.org/10.20495/seas.5.3_373

Arantes, C. C., Fitzgerald, D. B., Hoeinghaus, D. J., & Winemiller, K. O. (2019). Impacts of hydroelectric dams on fishes and fisheries in tropical rivers through the lens of functional traits. *Current Opinion in Environmental Sustainability*, 37, 28–40. https://doi.org/10.1016/j.cosust.2019.04.009

Arantes, C. C., Laufer, J., da Silva Pinto, M. D., Moran, E. F., Lopez, M. C., Dutka-Gianelli, J., Mendonça Pinto, D., Chaudhari, S., Pokhrel, Y., & Doria, C. R. C. (2021). Functional responses of fisheries to hydropower dams in the Amazonian floodplain of the Madeira River. *Journal of Applied Ecology*, 59(3), 680–692. https://doi.org/10.1111/1365-2664.14082

Araújo, K. R. De, Sawakuchi, H. O., Bertassoli, D. J., Da Silva, K. D., Vieira, T. B., Ward, N. D., & Pereira, T. S. (2019). Carbon dioxide (CO2) concentrations and emission in the newly constructed Belo Monte hydropower complex in the Xingu River, Amazonia. *Biogeosciences*, 16(18), 3527–3542. https://doi.org/10.5194/bg-16-3527-2019

Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Planning Association*, 35(4), 216–224. https://doi.org/10.1080/01944366908977225

Atkins, E. (2019). *Contesting hydropower in the Brazilian Amazon*. Routledge.

Barros, N., Cole, J. J., Tranvik, L. J., Prairie, Y. T., Bastviken, D., Huszar, V. L. M., Del Giorgio, P., & Roland, F. (2011). Carbon emission from hydroelectric reservoirs linked to reservoir age and latitude. *Nature Geoscience*, 4(9), 593–596. https://doi.org/10.1038/ngeo1211

Basurto, X., & Speer, J. (2012). Structuring the calibration of qualitative data as sets for qualitative comparative analysis (QCA). *Field Methods*, 24(2), 155–174. https://doi.org/10.1177/1525822X11433998

Bebbington, A. (1999). Capitals and capabilities: A framework for analyzing peasant viability, rural livelihoods and poverty. *World Development*, 27(12), 2021–2044. https://doi.org/10.1016/S0305-750X(99)00104-7

Beck, M. W., Claassen, A. H., & Hundt, P. J. (2012). Environmental and livelihood impacts of dams: Common lessons across development gradients that challenge sustainability. *International Journal of River Basin Management*, 10(1), 73–92.

Bisht, T. C. (2009). Development-induced displacement and women: The case of the Tehri Dam, India. *Asia Pacific Journal of Anthropology*, 10(4), 301–317. https://doi.org/10.1080/14442210903271312

Brown, E., Cavallini Johansen, I., Bortoleto, A. P., Pokhrel, Y., Chaudhari, S., Cak, A., Sulaeman, S., Castro-Diaz, L., Lopez, M. C., Mayer, A., Walgren, J., Müller, N., & Moran, E. (2022). Feasibility of hybrid in-stream generator-photovoltaic systems for Amazonian off-grid communities. *PNAS Nexus*, 1(3) in progress, pgac077. https://doi.org/10.1093/pnasnexus/pgac077.

Bruckner, T., Bashmakov, I. A., Mulugetta, Y., Chum, H., Vega Navarro, A. de la, Edmonds, J., Faaij A., Fungtammasan, B., Garg, A., Hertwich, E., Honnery, D., Infield, D., Kainuma, M., Khennas, S., Kim, S., Nimir, H. B., Riahi, K., Strachan, N., Wiser, R., & Zhang, X. (2014). Energy systems. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), *Climate change 2014: Mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Bui, T. M. H., & Schreinemachers, P. (2011). Resettling farm households in northwestern Vietnam: Livelihood change and adaptation. *International Journal of Water Resources Development*, 27(4), 769–785. https://doi.org/10.1080/07900627.2011.593116

Calvi, M. F., Moran, E. F., Bicudo da Silva, R. F., & Batistella, M. (2019). The construction of the Belo Monte Dam in the Brazilian Amazon and its consequences on regional rural labor. *Land Use Policy*, 90, Article 104327. https://doi.org/10.1016/J.LANDUSEPOL.2019.104327

Castro-Diaz, L., Lopez, M. C., Moore, S., Radonic, L., & Hodbod, J. (Draft). Multidimensional energy injustices and dams: The case of a fishers' community. "Available from L. Castro-Diaz, castrodi@msu.edu."

Castro-Diaz, L., Lopez, M. C., & Moran, E. (2018). Gender-differentiated impacts of the Belo Monte hydroelectric dam on downstream fishers in the Brazilian Amazon. *Human Ecology*, 46(3), 411–422. https://doi.org/10.1007/s10745-018-9992-z

Cernea, M. (1997). The risk and reconstruction model for resettling displaced populations. *World Development*, 25(10), 1569–1587. https://doi.org/10.1016/S0305-750X(97)00054-5

Cernea, M., & Maldonado, J. (2018). Challenging the prevailing paradigm of displacement and resettlement: Its evolution, and constructive ways of improving it. In M. M. Cernea & J. K. Maldonado (Eds.), *Challenging the prevailing paradigm of displacement and resettlement:Risks, impoverishment, legacies, solutions* (pp. 1–42). Routledge.

Chester, L. (2010). Conceptualising energy security and making explicit its polysemic nature. *Energy Policy*, 38(2), 887–895. https://doi.org/10.1016/j.enpol.2009.10.039

Choy, Y. K. (2004). Sustainable development and the social and cultural impact of a dam-induced development strategy: The Bakun Experience. *Pacific Affairs*, 77(1), 50–68. Retrieved from https://www.jstor.org/stable/40022274

DFID (Department for International Development, UK). (1999). Sustainable livelihoods guidance sheets. Retrieved from https://www.livelihoodscentre.org/documents/114097690/114438878/Sustainable+livelihoods+guidance+sheets.pdf/594e5ea6-99a9-2a4e-f288-cbb4ae4bea8b?t=1569512091877

EJAtlas. (2019). *Global Atlas of Environmental Justice*. Environmental Justice Atlas. https://ejatlas.org/

Ellis, F. (2000). Concepts, definitions and framework. In F. Ellis (Ed.), *Rural livelihoods and diversity in developing countries* (pp. 3–51). Oxford University Press.

Fan, P., Cho, M. S., Lin, Z., Ouyang, Z., Qi, J., Chen, J., & Moran, E. F. (2022). Recently constructed hydropower dams were associated with reduced economic production, population, and greenness in nearby areas. *Proceedings of the National Academy of Sciences of the United States of America*, 119(8), Article e2108038119. https://doi.org/10.1073/pnas.2108038119

Faure, A. (2003). Improving public information about large hydroelectric dams: Case studies in

France and West Africa. *Natural Resources Forum*, 27(1), 32–41. https://doi.org/10.1111/1477-8947.00038

Fiss, P. C. (2011). Building better causal theories: A fuzzy set approach to typologies in organization research. *Academy of Management Journal*, 54(2), 393–420. https://doi.org/10.5465/AMJ.2011.60263120

Flora, C., Flora, J. L., & Gasteyer, S. P. (2016). *Rural communities: Legacy + change* (5th ed.). Routledge. https://doi.org/10.4324/9780429494697-2

Fujikura, R., & Nakayama, M. (2009). Lessons learned from the World Commission on Dams. *International Environmental Agreements: Politics, Law and Economics*, 9(2), 173–190. https://doi.org/10.1007/s10784-009-9093-y

Fujikura, R., & Nakayama, M. (2013). The long-term impacts of resettlement programmes resulting from dam construction projects in Indonesia, Japan, Laos, Sri Lanka and Turkey: A comparison of land-for-land and cash compensation schemes. *International Journal of Water Resources Development*, 29(1), 4–13. https://doi.org/10.1080/07900627.2012.741032

Garcia, M. A., Castro-Díaz, L., Villamayor-Tomas, S., & Lopez, M. C. (2021). Are large-scale hydroelectric dams inherently undemocratic? *Global Environmental Change*, 71, 1–11. https://doi.org/10.1016/j.gloenvcha.2021.102395

Gerlak, A. K., Saguier, M., Mills-Novoa, M., Fearnside, P. M., & Albrecht, T. R. (2019). Dams, Chinese investments, and EIAs: A race to the bottom in South America? *Ambio*, 49, 156–164. https://doi.org/10.1007/s13280-018-01145-y

Global Network (Global Network on Energy for Sustainable Development) (2010). *Policy brief: Achieving energy security in developing countries*. Retrieved from http://gbio.webhostusp.sti.usp.br/sites/default/files/anexospaginas/1560168145_9.pdf.

González-Parra, C., & Simon, J. (2008). All that glitters is not gold: Resettlement, vulnerability and social exclusion in the Pehuenche community Ayin Mapu, Chile. *American Behavioral Scientist*, 51(12), 1774–1789. https://doi.org/10.1177/0002764208318930

Goulet, D. (2005). Global governance, dam conflicts, and participation. *Human Rights Quarterly*, 27(3), 881–907. https://doi.org/10.1353/hrq.2005.0036

Gürbüz, A. (2006). The Role of Hydropower in Sustainable Development. *European Water*, *13*(14), 63–70.

Gyau-Boakye, P. (2001). Environmental impacts of the Akosombo Dam and effects of climate change on the lake levels. *Environment, Development and Sustainability*, 3(1), 17–29. https://doi.org/10.1023/A:1011402116047

Hall, A. (1994). Grassroots action for resettlement planning: Brazil and beyond. *World Development*, 22(12), 1793–1809. https://doi.org/10.1016/0305-750X(94)90174-0

Hausermann, H. (2018). 'Ghana must progress, but we are really suffering': Bui Dam, antipolitics development, and the livelihood implications for rural people. *Society and Natural Resources*, 31(6), 633–648. https://doi.org/10.1080/08941920.2017.1422062

Hay, M., Skinner, J., & Norton, A. (2019). *Dam-induced displacement and resettlement : A literature review*. FutureDAMS Working Paper 004. Manchester: The University of Manchester. Retrieved from https://hummedia.manchester.ac.uk/institutes/gdi/publications/workingpapers/futuredams/futuredams-working-paper-004-hay-skinner-notron.pdf.

Heggelund, G. (2006). Resettlement programmes and environmental capacity in the Three Gorges

Dam project. *Development and Change*, 37(1), 179–199. https://doi.org/10.1111/j.0012-155X.2006.00474.x

Hensengerth, O. (2018). South-South technology transfer: Who benefits? A case study of the Chinese-built Bui Dam in Ghana. *Energy Policy*, 114, 499–507. https://doi.org/10.1016/j.enpol.2017.12.039

Howe, B. M., & Kamaruddin, N. (2016). Good governance and human security in Malaysia: Sarawak's hydroelectric conundrum. *Contemporary Southeast Asia*, 38(1), 81–105. https://doi.org/10.1355/cs38-1d

IEA (International Energy Agency). (2021a). *E4. Country profile: Energy efficiency Indonesia*. Retrieved from https://www.iea.org/articles/e4-country-profile-energy-efficiency-indonesia.

IEA (International Energy Agency). (2021b). *Hydropower special market report: Analysis and forecast to 2030*. Retrieved from https://iea.blob.core.windows.net/assets/4d2d4365-08c6-4171-9ea2-8549fabd1c8d/HydropowerSpecialMarketReport_corr.pdf.

IHA (International Hydropower Association). (2020). *Hydropower status report 2021*. Retrieved from https://www.hydropower.org/publications/annual-report-2021.

IPCC (Intergovernmental Panel on Climate Change). (2022). *Climate change 2022: Mitigation of climate change*. Contribution of Working Group III to the Sixth Assessment. https://www.ipcc.ch/report/ar6/wg3/.

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science*, 11, 174–182. https://doi.org/dx.doi.org/10.1016/j.erss.2015.10.004

Jusi, S. (2006). The Asian Development Bank and the case study of the Theun-Hinboun hydropower project in Lao PDR. *Water Policy*, 8(5), 371–394. https://doi.org/10.2166/wp.2006.043

Karimi, S., & Taifur, W. D. (2013). Resettlement and development: A survey of two of Indonesia's Koto Panjang resettlement villages. *International Journal of Water Resources Development*, 29(1), 35–49. https://doi.org/10.1080/07900627.2012.739539

Kedia, S. (2003). Assessing and mitigating the health impacts of involuntary resettlement: The Tehri Hydroelectric Dam project. *Advances in Science and Technology of Water Resources*, 23(2), 65–68.

Kedia, S. (2004). Changing food production strategies among Garhwali resettlers in the Himalayas. *Ecology of Food and Nutrition*, 43(6),421–442. https://doi.org/10.1080/03670240490500271

Kirchherr, J., & Charles, K. J. (2016). The social impact of dams: A new framework for scholarly analysis. *Environmental Impact Assessment Review* 60, 99–114. https://doi.org/10.1016/j.eiar.2016.02.005

Kirchherr, J., Charles, K. C. & Walton, M. J. (2016). Multi-causal pathways of public opposition to dam projects in Asia: A fuzzy set qualitative comparative analysis (FsQCA). *Global Environmental Change*, 41, 33–45. https://doi.org/10.1016/j.gloenvcha.2016.08.001

Leturcq, G. (2016). Differences and similarities in impacts of hydroeletric dams between north and south of Brazil. *Ambiente e Sociedade*, 19(2), 265–286. https://doi.org/10.1590/1809-4422ASOC0254R1V1922016

Manatunge, J., Takesada, N., Miyata, S., & Herath, L. (2009). Livelihood rebuilding of dam-affected communities: Case studies from Sri Lanka and Indonesia. *International Journal of Water Resources Development*, 25(3), 479–489. https://doi.org/10.1080/07900620902957928

Marx, A., Rihoux, B., & Ragin, C. (2014). The origins, development, and application of qualitative comparative analysis: the first 25 years. *European Political Science Review*, 6(1), 115–142. https://doi.org/10.1017/S1755773912000318

Mathur, H. M. (2011). An interview with Professor Michael M. Cernea. *Resettlement News*, 23/24, 1–4. https://www.brookings.edu/wp-content/uploads/2016/06/Resettlement-News_2011_MCernea.pdf

Matsue, N., Daw, T., & Garrett, L. (2014). Women fish traders on the Kenyan coast: Livelihoods, bargaining power, and participation in management. *Coastal Management*, 42(6), 531–554. https://doi.org/10.1080/08920753.2014.964819

Mayer, A., Castro-Diaz, L., Lopez, M. C., Leturcq, G., & Moran, E. F. (2021). Is hydropower worth it? Exploring Amazonian resettlement, human development and environmental costs with the Belo Monte project in Brazil. *Energy Research and Social Science*, 78(January), Article 102129. https://doi.org/10.1016/j.erss.2021.102129

Mayer, A., Garcia, M. A., Castro-Diaz, L., Lopez, M. C., and Moran, E. F. (2022). Pretend participation: Procedural injustices in the Madeira Hydroelectric Complex. *Global and Environmental Change*, 75, Article 102524. https://doi.org/10.1016/j.gloenvcha.2022.102524.

Mayer, A., Lopez, M. C., Leturcq, G., & Moran, E. (2022). Changes in social capital associated with the construction of the Belo Monte Dam: Comparing a resettled and a host community. *Human Organization*, 81(1), 22–34. https://doi.org/10.17730/1938-3525-81.1.22

Mayer, A., Lopez, M. C., & Moran, E. F. (2022). Uncompensated losses and damaged livelihoods: Restorative and distributional injustices in Brazilian hydropower. *Energy Policy*, 167(August), Article 113048. https://doi.org/10.1016/j.enpol.2022.113048

Mishra, S., & Kahssay, A. (2015). A hydroelectric project and its impact on development indicators in Ethiopia. *Forum for Development Studies*, 42(3), 489–505. https://doi.org/10.1080/08039410.2015.1053729

Moran, E. F., Lopez, M. C., Moore, N. J., Müller, N., & Hyndman, D. W. (2018). Sustainable hydropower in the 21st century. *Proceedings of the National Academy of Sciences of the United States of America*, 115(47), 11891–11898. https://doi.org/10.1073/pnas.1809426115

Naithani, S., & Saha, A. K. (2019). Changing landscape and ecotourism development in a large dam site: A case study of Tehri Dam, India. *Asia Pacific Journal of Tourism Research*, 24(3), 193–205. https://doi.org/10.1080/10941665.2018.1557226

Nakayama, M. (1998). Post-Project review of environmental impact assessment for Saguling Dam for involuntary resettlement. *International Journal of Water Resources Development*, 14(2), 217–229. https://doi.org/10.1080/07900629849411

Namy, S. (2010). Addressing the social impacts of large hydropower dams. *The Journal of International Policy Solutions*, 7, 11–17.

Nguyen, H. T., Pham, T. H., & Lobry de Bruyn, L. (2017). Impact of hydroelectric dam development and resettlement on the natural and social capital of rural livelihoods in Bo Hon Village in central Vietnam. *Sustainability*, 9(8), 1–15. https://doi.org/10.3390/su9081422

Nüsser, M. (2003). Political ecology of large dams: A critical review. *Petermanns Geographische Mitteilungen*, 147(1), 20–31. Retrieved from https://www.sai.uni-heidelberg.de/geo/pdfs/Nuesser_2003_PoliticalEcologyOfLargeDams_PGM_147(1)_20-27.pdf.

Nüsser, M., & Baghel, Ravi. (2017). The emergence of technological hydroscapes in the Anthropocene: Socio-Hydrology and development paradigms of large dams. In B. Warf (Ed.), *Handbook on Geographies of Technology* (287–301). Edward Edgar. https://doi.org/10.4337/9781785361166.00029

Okuku, E. O, Bouillon, S., Odhiambo Ochiewo, J., Munyi, F., Kiteresi, L. I., & Tole, M.. (2016). The impacts of hydropower development on rural livelihood sustenance. *International Journal of Water Resources Development*, 32(2), 267–285. https://doi.org/10.1080/07900627.2015.1056297

Oud, E. (2002). The evolving context for hydropower development. *Energy Policy*, 30(14), 1215–1223. https://doi.org/10.1016/S0301-4215(02)00082-4

Pappas, I. O., & Woodside, A. G. (2021). Fuzzy-Set qualitative comparative analysis (FsQCA): Guidelines for research practice in information systems and marketing. *International Journal of Information Management*, 58(June), Article 102310. https://doi.org/10.1016/j.ijinfomgt.2021.102310

Pretty, J. N. (1995). Participatory learning for sustainable agriculture. *World Development*, 23(8), 1247–1263. https://doi.org/10.1016/0305-750X(95)00046-F

Radel, C. (2012). Gendered livelihoods and the politics of socio-environmental identity: Women's participation in conservation projects in Calakmul, Mexico. *Gender, Place and Culture*, 19(1), 61–82. https://doi.org/10.1080/0966369X.2011.617905

Ragin, C. (2005). *From fuzzy sets to crisp truth tables*. Retrieved from http://www.compasss.org/wpseries/Ragin2004.pdf.

Ragin, C. (2008). *Redesinging social inquiry: Fuzzy sets and beyond*. University of Chicago Press.

Ragin, C. (2014). *The comparative method: Moving beyond qualitative and quantitative strategies* (2nd ed.). University of California Press.

Randell, H. (2016). Structure and agency in development-induced forced migration: The case of Brazil's Belo Monte Dam. *Population and Environment*, 37(3), 265–287. https://doi.org/10.1007/s11111-015-0245-4

Salazar, J. G. (2000). Damming the child of the ocean: The Three Gorges project. *Journal of Environment and Development*, 9(2), 160–174. https://doi.org/10.1177/107049650000900204

Sayatham, M., & Suhardiman, D. (2015). Hydropower resettlement and livelihood adaptation: The Nam Mang 3 project in Laos. *Water Resources and Rural Development*, 5, 17–30. https://doi.org/10.1016/j.wrr.2015.01.001

Scherer, L., & Pfister, S. (2016). Hydropower's biogenic carbon footprint. *PLoS ONE*, 11(9), 1–11. https://doi.org/10.1371/journal.pone.0161947

Scheumann, W., & Hensengerth, O. (2014). *Evolution of dam policies: Evidence from the big hydropower states*. https://doi.org/10.1007/978-3-642-23403-3

Schneider, C., & Wagemann, C. (2012). Data analysis technique meets set-theoretic approach. In C. Q. Schneider & C. Wagemann (Eds.), *Set-theoretic methods for the social sciences: A guide to qualitative comparative analysis* (275–312). Cambridge University Press. https://doi.org/10.1017/cbo9781139004244.016

Schulz, C., & Adams, W. M. (2019). Debating dams: The World Commission on Dams 20 years on. *Wiley Interdisciplinary Reviews: Water*, 6(5), 1–19. https://doi.org/10.1002/wat2.1369

Scoones, I. (1998). Sustainable rural livelihoods a framework for analysis. *Analysis*, 72, 1–22. https://doi.org/10.1057/palgrave.development.1110037

Scoones, I. (2009). Livelihoods perspectives and rural development. *Journal of Peasant Studies*, 36(1), 171–196. https://doi.org/10.1080/03066150902820503

Scudder, T. (2001). The World Commission on Dams and the need for a new development paradigm. *International Journal of Water Resources Development*, 17(3), 329–341. https://doi.org/10.1080/07900620120065110

Scudder, T. (2005). *The future of large dams: Dealing with social, environmental, institutional and political costs*. Earthscan.

Shah, E., Vos, J., Veldwisch, G. J., Boelens, R., & Duarte-Abadía, B. (2021). Environmental justice movements in globalising networks: a critical discussion on social resistance against large dams. *Journal of Peasant Studies*, *48*(5), 1008–1032. https://doi.org/10.1080/03066150.2019.1669566

Siciliano, G., & Urban, F. (2017). Equity-based natural resource allocation for infrastructure development: Evidence from large hydropower dams in Africa and Asia. *Ecological Economics*, 134, 130–139. https://doi.org/10.1016/j.ecolecon.2016.12.034

Sisinggih, D., Wahyuni, S., & Juwono, P. T. (2013). The resettlement programme of the Wonorejo Dam project in Tulungagung, Indonesia: The perceptions of former residents." *International Journal of Water Resources Development*, 29(1), 14–24. https://doi.org/10.1080/07900627.2012.743432

Sivongxay, A., Greiner, R., & Garnett, S. T. (2017). Livelihood impacts of hydropower projects on downstream communities in central laos and mitigation measures. *Water Resources and Rural Development* (46–55). https://doi.org/10.1016/j.wrr.2017.03.001

Smyth, E., & Vanclay, F. (2017). Land acquisition, resettlement and livelihoods. In R. Therivel & G. Wood (Eds.), *Methods of environmental and social impact assessment* (546–576). https://doi.org/10.4324/9781315626932

Sneddon, C., & Fox, C. (2008). Struggles over dams as struggles for justice: The World Commission on Dams (WCD) and anti-dam campaigns in Thailand and Mozambique. *Society and Natural Resources*, 21(7), 625–640. https://doi.org/10.1080/08941920701744231

Stickler, C. M., Coe, M. T., Costa, M. H., Nepstad, D. C., McGrath, D. G., Dias, L. C. P., Rodrigues, H. O., & Soares-Filho, B. S. (2013). Dependence of hydropower generation on forests in the Amazon Basin at local to regional scales. *Proceedings of the National Academy of Sciences of the United States of America*, 110(23), 9601–9606. https://doi.org/10.1073/pnas.1215331110

Sunardi, B. G., Manatunge, J., & Pratiwi, F. D. (2013). Livelihood status of resettlers affected by the Saguling Dam project, 25 years after inundation. *International Journal of Water Resources Development*, 29(1), 25–34. https://doi.org/10.1080/07900627.2012.738593

Tan, Y., Hugo, G., & Potter, L. (2005). Rural women, displacement and the Three Gorges project. *Development and Change*, 36(4), 711–734. https://doi.org/10.1111/j.0012-155X.2005.00431.x

Ty, P. H., Van Westen, A. C. M., & Zoomers, A. (2013). Compensation and resettlement policies after compulsory land acquisition for hydropower development in Vietnam: Policy and practice. *Land*, 2(4), 678–704. https://doi.org/10.3390/land2040678

Urban, F., Nordensvard, J., Siciliano, G., & Li, B. (2015). Chinese overseas hydropower dams and social sustainability: The Bui Dam in Ghana and the Kamchay Dam in Cambodia. *Asia and the Pacific Policy Studies*, 2(3), 573–589. https://doi.org/10.1002/app5.103

Vanclay, F. (2017). Project-Induced displacement and resettlement: From impoverishment risks to an opportunity for development? *Impact Assessment and Project Appraisal*, 35(1), 3–21. https://doi.org/10.1080/14615517.2017.1278671

Wang, P., Wolf, S. A., Lassoie, J. P., & Dong, S. (2013). Compensation policy for displacement caused by dam construction in China: An institutional analysis. *Geoforum*, 48(August), 1–9. https://doi.org/10.1016/j.geoforum.2013.04.009

WCD (World Commission on Dams). (2000). *Dams and development: A new framework for decision-making*. *The report of the World Comission on Dams*. Earthscan. Retrieved from https://archive.internationalrivers.org/sites/default/files/attached-files/world_commission_on_dams_final_report.pdf. Accessed Month Day, Year.

Weist, K. M. (1995). Development refugees: Africans, Indians and the big dams. *Journal of Refugee Studies*, 8(2), 163–184. https://doi.org/10.1093/jrs/8.2.163

White, S. (2011). Depoliticizing development: The uses and abuses of participation. *Development in Practice*, 6(1), 142–155. https://doi.org/10.1080/0961452961000157564

Wilmsen, B. (2016). After the deluge: A longitudinal study of resettlement at the Three Gorges Dam, China. *World Development*, 84, 41–54. https://doi.org/10.1016/j.worlddev.2016.04.003

Wilmsen, B., & van Hulten, A. (2017). Following resettled people over time: The value of longitudinal data collection for understanding the livelihood impacts of the Three Gorges Dam, China. *Impact Assessment and Project Appraisal*, 35(1), 94–105. https://doi.org/10.1080/14615517.2016.1271542

Winemiller, K. O., McIntyre, P. B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., Baird, I. G., Darwall, W., Lujan, N. K., Harrison, I., Stiassny. M. L. J., Silvano, R. A. M., Fitzgerald, D. B., Pelicice, F. M., Agostinho, A. A., Gomes, L. C., Albert, J. S., Baran, E., Petrere, M. Jr., . . . Sáenz, L. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. *Science*, 351(6269), 128–129. https://doi.org/10.1126/science.aac7082

World Bank. (2015). Energy imports, net (% of energy use). Retrieved from https://data.worldbank.org/indicator/EG.IMP.CONS.ZS.

Xi, J. (2016). Types of integration and depressive symptoms: A latent class analysis on the resettled population for the Three Gorges Dam project, China. *Social Science & Medicine*, 157, 78–86. https://doi.org/10.1016/j.socscimed.2016.03.045

Yan, D. (2010). Documenting Three Gorges migrants: Gendered voices of (dis)placement and citizenship in rediscovering the Yangtze River and Bingai. *WSQ: Women's Studies Quarterly*, 38(1-2), 27–47. https://doi.org/10.1353/wsq.0.0225

Yoshida, H., Agnes, R. D., Solle, M., & Jayadi, M. (2013). A long-term evaluation of families affected by the Bili-Bili Dam development resettlement project in South Sulawesi, Indonesia. *International Journal of Water Resources Development*, 29(1), 50–58. https://doi.org/10.1080/07900627.2012.738495

Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L., & Tockner, K. (2015). A global boom in hydropower dam construction. *Aquatic Sciences*, 77(1), 161–170. https://doi.org/10.1007/s00027-014-0377-0

APPENDIX 1 VARIABLES FROM THE QUALITATIVE META-ANALYSIS INCLUDED FOR CREATING THE INDICES OF EACH CAPITAL

Table 7. Variables from meta-analysis

Outcome	Variable (code)	Description
Natural capital	Capital natural	If authors described that natural capital has changed. For instance, fish stocks, land owned, crops cultivated, etc. (Alisson et al., 2006)
	Soils	How soil quality changed after dam construction
	Fish quantity	How fish quantity/levels changed after dam construction
	Fisheries access	If access to fisheries changed after dam construction (distance, physical barriers, loss of equipment, etc.)
	Natural areas and products access	If access to natural areas and products changed after dam construction (distance, physical barriers, loss of equipment, etc.). Do not code when authors refer to fisheries
	Natural products quantity	How forest products changed post resettlement and or compensation. Do not code when authors are referring to fisheries
	Water quality	How water quality has changed after dam construction
	Water access	If access to water changed after dam construction (distance, physical barriers, loss of equipment, etc.)
	Livestock amount	Whether the number of livestock that people own changed after dam construction
	Compensation natural capital	If impacted communities received any type of compensation (Natural capital)
Social capital	Capital social	If authors say, social capital has changed membership in organizations and groups, social and professional networks. (Allison & Ellis, 2001; Meizen-Dick et al., 2014)
	Community trust	Whether trust among community members changed post-resettlement or compensation
	Cultural activities	Whether cultural and community activities changed after dam construction
	Social connections	Whether connections with relatives and friends changed after dam construction
	Site neighbors	If resettled were able to continue living close to old neighbors
	Immigrants	If exists competition between the affected and immigrants
	Conflict	If authors mention that conflict was present between the impacted population and dam builders/government during the resettlement or compensation process. Conflict is understood here as a serious disagreement or argument.
Human capital	Capital human	If authors say, human capital has changed. Human Capital includes people's capabilities in terms of their health, labor, knowledge, and skills (Alisson et al., 2006).
	Food access	Change of food access (for example, if they used to plant their food but now must buy food from a store, etc.) after dam construction. Food access is defined by the ability of individuals to obtain adequate resources, including traditional entitlements, to acquire appropriate foods for a nutritious diet. (FAO, 2006).

Table 7 (cont'd)

	Food security	Food security after dam construction. Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2006).
	Health	Health status after dam construction. It includes mental health.
	Health access	Whether the access to health services changed after dam construction.
	School	Whether the access to schools that people had changed after dam construction.
	Sanitation	Whether the access to sanitation services had changed after dam construction.
	Standard of living	If the authors said their standard of living changed post-resettlement and compensation.
	Self-reported well-being	How the resettled and compensated feel about with well-being related to outlook (author's definition of well-being, not of coders. It could change paper by paper).
	Compensation human	If impacted communities received any type of compensation (Human capital).
Financial capital	Capital financial	If authors say, financial capital has changed. Savings, credit, and inflows.
	Income	If income changed after dam construction (can include words like changes in economic/financial security).
	Income inequality change	Whether income inequality changed after construction.
	Crop yield	How much crop yield changed after dam construction.
	Post-employment	Whether access to employment changed after dam construction.
	Monetary compensation	Whether impacted communities received any monetary or cash compensation.
Physical capital	Capital physical	If authors say, physical capital has changed. It includes agricultural and business equipment, houses, consumer durables, vehicles and transportation, water supply and sanitation facilities, and communications infrastructure (Allison & Ellis, 2001; Meizen-Dick et al., 2014).
	Electricity access	Whether local actors had access to electricity after the construction of the dam.
	Compensation communities	If compensation is given to the community or municipality by the dam builders (e.g., roads, access to energy, schools, health centers).
	Physical compensations	Whether individuals, households, or communities received any physical compensation.

APPENDIX 2 PARTICIPATION VARIABLES

Table 8. Variables from the qualitative meta-analysis used to calibrate the causal condition lackpar

Variable (Code)	**Definition**
Participation	If affected were involved in compensation planning and process. It was used when the authors didn't give details about how the affected participated.
Consultation and information	"Being asked an opinion in specific matters without guarantee of influencing decisions" (Agarwal, 2001)
Choice	This code was for whether the resettled were given the choice of how/where to resettle. Or the population affected were given the choice of how/what they would be compensated with.
Negotiation	Whether the affected were able to negotiate with the dam's authorities.

APPENDIX 3 UNCALIBRATED DATA AND CALIBRATION

This dataset includes the original values of the outcomes and casual conditions. The rows present each of the 33 large-scale hydroelectric dams in the analysis. The columns have information about the four causal conditions and the outcomes. The first column is the country where the dam is built. The second column indicates the year of construction of the dam. The third column is the installed capacity (MW) of each dam. The fourth column is
the country's net energy imports for each dam from the World Bank. We used an annual dataset compiled by the IEA that includes information about Net energy imports (https://data.worldbank.org/indicator/EG.IMP.CONS.ZS). The following four columns include the variables from the qualitative meta-analysis used to calibrate the causal condition LackPAR. These values are the result of the aggregation of the cases of study that had information about these aspects per dam. The last five columns include the index values of each of the outcomes for each dam

Table 9. Uncalibrated data

					Participation				Capitals (Outcomes)				
Dam	Country	Year construction started	Installed Capacity (MW)	Energy use - production	Participation	Consultation	Choice	Negotiation	Natural	Social	Financial	Human	Physical
A luoi	Vietnam	2007	170	-38.83980641	-1	-1	-1	-1	-2	-3	-2	-1	2
Aswan	Egypt	1960	2100	Not Available		1			-1	-3	0	2	1
Ataturk	Turkey	1983	2400	45.95050607		1		-1	-1	-1	-1	-2	1
Bagre	Burkina Faso	1989	16	Not Available	0	-1			-4	-1	-1	-1	-1
Bakun	Malaysia	1996	2400	-83.24364766		1	-1	-1	-7	-4	-1	-5	3
Batang Ai	Malaysia	1982	100	-49.31028492		-1		-1	-4	-3	-1	-2	3
Belo Monte	Brazil	2011	11233	7.712621471	-1	-1	1	-1	-5	-3	-1	0	3
Bili Bili	Indonesia	1991	19.25	-76.99152577			1		-2	-1	1	4	3
Bui	Ghana	2009	400	44.88279699			-1	-1	-7	-5	-1	-4	3
Chixoy	Guatemala	1976	280.983	26.94083325		-1		-1	-3	-2	-2	-4	-1
Cirata	Indonesia	1984	1008	-110.6680161	-1				0	-1	-1	1	0
Gilgel Gibe I	Ethiopia	1988	184	3.386065284			1		-2	-1	0	-1	1
Gilgel Gibe III	Ethiopia	2006	1870	4.247062388			-1	-1	0	-5	1	-1	2
Gitaru	Kenya	1975	225	20.15332632	-1	-1			-3	-3	-3	-6	0
Kamburu	Kenya	1971	93	21.53846764	-1	-1			-3	-3	-3	-6	0
Kamchay	Cambodia	2006	193.2	29.68407142	-1	-1		-1	-7	-2	0	2	1
Kaptai	Bangladesh	1957	230	Not Available		-1			-2	-2	-1	1	1
Kiambere	Kenya	1983	165	16.08785925	-1	-1			-3	-3	-3	-6	0
Kindaruma	Kenya	1968	72	Not Available	-1	-1			-3	-3	-3	-6	0
Kotmale	Sri Lanka	1979	201	28.8030184	1	1	1	-1	-2	-3	1	3	3
Masinga	Kenya	1978	40	20.87260689	-1	-1			-3	-3	-3	-6	0
Nam Theun 2	Laos	2005	1075	Not Available		1		1	-1	0	1	1	4
Ralco	Chile	1998	690	65.58378467			1	1	1	-6	-1	-2	3

Table 9 (cont'd)

Saguling	Indonesia	1983	700	-91.37061388	-1				-2	0	-2	0	3
Sardar Sarovar	India	1987	1450	5.947143571		-1	-1		-2	-2	1	-2	2
Sobradinho	Brazil	1973	1050	37.4962405	-1		-1		-3	-1	0	-3	-1
Son La	Vietnam	2005	2400	-47.2893012	1	1		-1	-2	1	3	0	3
Tehri	India	1978	1000	7.484055027				-1	-6	-5	1	-3	1
Theun Hinboun	Laos	1994	210	Not Available	-1	-1			-1	-2	-1	-1	3
Three Gorges	China	1994	22500	-1.369907835	-1	1	1	-1	-1	-5	-2	-2	1
Wonorejo	Indonesia	1992	6.2	-73.71249021				1	0	1	0	2	1
Xenamnoy	Laos	2013	410	Not Available	1	1		-1	0	-1	1	-2	0
Xepian	Laos	2013	410	Not Available	1	1		-1	0	-1	1	-2	0

Table 10. Data after calibration

Dam	LackPAR	LackINT	LargeIC	LessES	Natural	Social	Human	Financial	Physical
A luoi	1	0	0	0	1	1	1	1	0
Aswan	0.33	1	1	0.5	1	1	0	0.5	0
Ataturk	0.67	1	1	1	1	1	1	1	0
Bagre	1	1	0	0.5	1	1	1	1	1
Bakun	1	1	1	0	1	1	1	1	0
Batang Ai	1	1	0	0	1	1	1	1	0
Belo Monte	1	0	1	1	1	1	0.5	1	0
Bili Bili	0.33	1	0	0	1	1	0	0	0
Bui	1	0	0.67	1	1	1	1	1	0
Chixoy	1	1	0.33	1	1	1	1	1	1
Cirata	1	1	0.67	0	0.5	1	0	1	0.5
Gilgel Gibe I	0.33	1	0.33	1	1	1	1	0.5	0
Gilgel Gibe III	1	0	1	1	0.5	1	1	0	0
Gitaru	1	1	0.33	1	1	1	1	1	0.5
Kamburu	1	1	0	1	1	1	1	1	0.5
Kamchay	1	0	0.33	1	1	1	0	0.5	0
Kaptai	1	1	0.33	0.5	1	1	0	1	0
Kiambere	1	1	0	1	1	1	1	1	0.5
Kindaruma	1	1	0	0.5	1	1	1	1	0.5
Kotmale	0	1	0.33	1	1	1	0	0	0
Masinga	1	1	0	1	1	1	1	1	0.5
Nam Theun 2	0	0	1	0.5	1	0.5	0	0	0
Ralco	0	0	0.67	1	0	1	1	1	0
Saguling	1	1	0.67	0	1	0.5	0.5	1	0
Sardar Sarovar	1	1	1	1	1	1	1	0	0
Sobradinho	1	1	0.67	1	1	1	1	0.5	1
Son La	0.33	0	1	0	1	0	0.5	0	0
Tehri	1	1	0.67	1	1	1	1	0	0
Theun Hinboun	1	1	0.33	0.5	1	1	1	1	0
Three Gorges	0.67	1	1	0	1	1	1	1	0
Wonorejo	0.33	1	0	0	0.5	0	0	0.5	0
Xenamnoy	0.33	0	0.67	0.5	0.5	1	1	0	0.5
Xepian	0.33	0	0.67	0.5	0.5	1	1	0	0.5

APPENDIX 4 FSQCA

Here we present fsQCA process after the calibration. First, we tested whether a causal condition individually is necessary for the presence of the outcomes. Typically, causal conditions are necessary if their consistency score for necessity is above 0.9. Table 4 shows that none condition is necessary for the outcomes to occur.

Table 11. Analysis of necessary conditions for the presence of Natural, Social, Human, Financial and absence of Physical Capital

Outcome		LackPAR	LackINT	LessES	LargeIC
Natural	Consistency	0.8	0.74	0.62	0.5
	Coverage	0.95	0.95	0.92	0.89
Social	Consistency	0.78	0.71	0.66	0.5
	Coverage	0.95	0.93	1	0.89
Human	Consistency	0.83	0.7	0.68	0.5
	Coverage	0.79	0.71	0.8	0.71
Financial	Consistency	0.89	0.79	0.6	0.44
	Coverage	0.78	0.73	0.65	0.57
~Physical	Consistency	0.71	0.65	0.59	0.58
	Coverage	0.75	0.73	0.77	0.9

Then we ran the analysis of sufficiency for the presence of natural, social, human, financial, and absence of physical Capital. In the fsqca software, we created a truth table for each outcome. The following tables present the pathways that are sufficient or have consistency above 0.75.

Table 12. Presence of natural capital

Presence of Natural Capital (Mostly Negative impacts) (0.66 and 1)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	n	raw consist.	PRI consist.
1	1	1	0	1	5	1	1
1	1	1	1	1	4	1	1
0	1	1	0	1	2	1	1
0	0	0	1	1	1	1	1
1	0	0	0	1	1	1	1
1	1	0	0	1	1	1	1
1	0	1	0	1	1	1	1
1	1	0	1	1	4	0.9575	0.951429
0	1	0	0	1	2	0.873134	0.797619
1	0	1	1	1	3	0.863388	0.8
0	0	1	1	0	1	0.691244	0.42735
0	0	0	0	0	0		
0	0	1	0	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		
1	0	0	1	0	0		

Table 13. Presence of social capital

Presence of Social Capital (Mostly Negative impacts) (0.66 and 1)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	n	raw consist.	PRI consist.
1	1	1	0	1	5	1	1
1	1	1	1	1	4	1	1
1	0	1	1	1	3	1	1
0	1	1	0	1	2	1	1
1	0	0	0	1	1	1	1
1	0	1	0	1	1	1	1
0	0	1	1	1	1	1	1
1	1	0	1	1	4	0.9575	0.951429
1	1	0	0	1	1	0.923611	0.917293
0	0	0	1	0	1	0.691244	0.598802
0	1	0	0	0	2	0.5	0.5
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Table 14. Presence of human capital

Presence of Human Capital (Mostly Negative impacts) (0.66 and 1)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	n	raw consist.	PRI consist.
1	0	0	0	1	1	1	1
1	1	1	0	1	5	0.931787	0.931787
1	1	1	1	1	4	0.867735	0.867735
1	0	1	1	1	3	0.773224	0.737342
0	0	1	1	1	1	0.769585	0.769585
0	0	0	1	0	1	0.691244	0.598802
1	1	0	0	0	1	0.655093	0.626566
1	1	0	1	0	4	0.625	0.571429
1	0	1	0	0	1	0.596386	0.596386
0	1	1	0	0	2	0.5	0.5
0	1	0	0	0	2	0	0
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Table 15. Presence of financial capital

Presence of Financial Capital (Mostly Negative impacts) (0.66 and 1)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	n	raw consist.	PRI consist.
1	1	0	1	1	4	1	1
1	1	1	0	1	5	0.95498	0.950525
1	1	0	0	1	1	0.923611	0.917293
1	1	1	1	0	4	0.631263	0.519582
1	0	0	0	0	1	0.60241	0.60241
1	0	1	1	0	3	0.546448	0.501502
1	0	1	0	0	1	0.5	0.284483
0	1	0	0	0	2	0.373134	0
0	1	1	0	0	2	0.373134	0
0	0	1	1	0	1	0.308756	0.308756
0	0	0	1	0	1	0	0
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Table 16. Absence of physical capital

Absence of Physical Capital (Mostly Positive impacts) (0.33 and 0)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	n	raw consist.	PRI consist.
1	0	1	1	1	3	1	1
0	1	0	0	1	2	1	1
0	1	1	0	1	2	1	1
1	0	0	0	1	1	1	1
1	0	1	0	1	1	1	1
0	0	0	1	1	1	1	1
0	0	1	1	1	1	1	1
1	1	0	1	1	4	0.9575	0.951429
1	1	0	0	1	1	0.884259	0.856734
1	1	1	1	1	4	0.799599	0.785408
1	1	1	0	0	5	0.567531	0.343685
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Then, there is a process of logical minimization of the pathways from the truth table. Table 5 presents the intermediate solutions for each outcome. For each outcome, it presents the solution formula, solution consistency, solution coverage, pathways, raw coverage of the pathway (RC), unique coverage of the pathway (UC), consistency of the pathway (C), and the dams included in each pathway.

Table 17. Results of the fsQCA. Intermediate solution

Capital	Solution Formula	Solution Consistency	Solution Coverage	Pathways	RC	UC	C	Dams (Cases)
Natural	LackPAR+ LackINT + LargeIC * ~LessES --> negative impacts in natural capital	0.95	0.98	LackPAR	0.8	0.15	0.95	Aluoi (1,1), Bagre (1,1), Bakun (1,1), BatangAi (1,1),BeloMonte (1,1), Bui (1,1), Chixoy (1,1), Cirata (1,0.5), GilgelGibeIII (1,0.5), Gitaru (1,1), Kamburu (1,1), Kamchay (1,1), Kaptai (1,1),Kiambere (1,1), Kindaruma (1,1), Masinga (1,1),Saguling (1,1), SardarSarovar (1,1), Sobradinho (1,1),Tehri (1,1)
				LackINT	0.75	0.11	0.95	Aswan(1,1), Ataturk (1,1), Bagre (1,1), Bakun (1,1),BatangAi (1,1), BiliBili (1,1), Chixoy (1,1), Cirata (1,0.5), GilgelGibeI (1,1), Gitaru (1,1), Kamburu (1,1), Kaptai (1,1), Kiambere (1,1), Kindaruma (1,1), Kotmale (1,1), Masinga (1,1), Saguling (1,1), SardarSarovar (1,1), Sobradinho (1,1),Tehri (1,1)
				LargeIC* ~ LessES	0.23	0.05	0.97	Bakun (1,1), SonLa (1,1), ThreeGorges (1,1), Cirata (0.67,0.5), Saguling (0.67,1)
Social	LackPAR+ LargeIC* LessES+ LackINT* LessES --> negative impacts in social capital	0.905	0.959	LackPAR	0.78	0.28	0.95	Aluoi (1,1), Bagre (1,1), Bakun (1,1), BatangAi (1,1),BeloMonte (1,1), Bui (1,1), Chixoy (1,1), Cirata (1,1), GilgelGibeIII (1,1), Gitaru (1,1), Kamburu (1,1), Kamchay (1,1), Kaptai (1,1), Kiambere (1,1), Kindaruma (1,1), Masinga (1,1), Saguling (1,0.5), SardarSarovar (1,1), Sobradinho (1,1),Tehri (1,1)
				LackINT* LessES	0.45	0.044	1	Ataturk (1,1), Chixoy (1,1), GilgelGibeI (1,1), Gitaru (1,1), Kamburu (1,1), Kiambere (1,1), Kotmale (1,1),Masinga (1,1), SardarSarovar (1,1), Sobradinho (1,1),Tehri (1,1)
				LargeIC* LessES	0.366	0.05	1	Ataturk (1,1), BeloMonte (1,1), GilgelGibeIII (1,1), SardarSarovar (1,1), Bui (0.67,1), Ralco (0.67,1), Sobradinho (0.67,1), Tehri (0.67,1)

Table 17 (cont'd)

Human	LackPAR* ~ LackINT* ~LessES+ LackPAR* LackINT * LessES+ LargeIC * LessES--> mostly negative impacts	0.68	0.857	LargeIC* LessES	0.361	0.14	0.77	Ataturk (1,1), BeloMonte (1,0.5), GilgelGibeIII (1,1), SardarSarovar (1,1), Bui (0.67,1), Ralco (0.67,1), Sobradinho (0.67,1), Tehri (0.67,1)
				LackPAR* ~ LackINT* ~LessES	0.08	0.05 6	1	Aluoi (1,1)
				LackPAR* LackINT* LessES	0.446	0.26 2	0.926	Chixoy (1,1), Gitaru (1,1), Kamburu (1,1), Kiambere (1,1), Masinga (1,1), SardarSarovar (1,1), Sobradinho (1,1), Tehri (1,1), Ataturk (0.67,1)
Financial	LackPAR* LackINT* ~LessES+ LackPAR* LackINT * ~LargeIC- -> negative impacts in financial capital	0.63	0.95	LackPAR* LackINT*~ LessES	0.34	0.15 5	0.95	Bakun (1,1), BatangAi (1,1), Cirata (1,1), Saguling (1,1), ThreeGorges (0.67,1)
				LackPAR* LackINT* ~LargeIC	0.48	0.29	0.93	Bagre (1,1), BatangAi (1,1), Kamburu (1,1), Kiambere (1,1), Kindaruma (1,1), Masinga (1,1), Chixoy (0.67,1), Gitaru (0.67,1), Kaptai (0.67,1), TheunHinboun (0.67,1)
~Physical	LackPAR* ~ LackINT+ LargeIC* ~LackPAR + LackINT* ~LessES+ LackINT* ~LackPAR	0.73	0.93	LackPAR* ~ LackINT	0.23	0.19	1	Aluoi (1,1), BeloMonte (1,1), Bui (1,1), GilgelGibeIII (1,1), Kamchay (1,1)
				LackINT* ~LackPAR	0.16	0.03	1	Kotmale (1,1), Aswan (0.67,1), BiliBili (0.67,1), GilgelGibeI (0.67,1), Wonorejo (0.67,1)
				LackINT* ~LessES	0.32	0.24	0.89	Bakun (1,1), BatangAi (1,1), BiliBili (1,1), Cirata (1,0.5), Saguling (1,1), ThreeGorges (1,1), Wonorejo (1,1)
				LargeIC * ~LackPAR	0.205	0.09	0.94	NamTheun2 (1,1), Ralco (0.67,1), Aswan (0.67,1), SonLa (0.67,1), Xenamnoy (0.67,0.5), Xepian (0.67,0.5)

APPENDIX 5 FSQCA FOR THE ABSENCE OF ALL CAPITAL AND THE PRESENCE OF PHYSICAL

Table 18. Necessary conditions for the absence of all capital and presence of physical capital

Outcome		LackPAR	LackINT	LessES	LargeIC
~Natural	Consistency	0.56	0.28	0.71	0.76
	Coverage	0.08	0.04	0.12	0.16
~Social	Consistency	0.38	0.5	0.166	0.666
	Coverage	0.047	0.06	0.02	0.119
~Human	Consistency	0.56	0.68	0.54	0.42
	Coverage	0.21	0.28	0.3	0.2
~Financial	Consistency	0.54	0.52	0.69	0.65
	Coverage	0.25	0.26	0.479	0.37
Physical	Consistency	0.95	0.85	0.4	0.85
	Coverage	0.27	0.26	0.16	0.3

Analysis of sufficiency for the absence of natural, social, human, financial, and presence of physical Capital. In the fsqca software, we created a truth table for each outcome. The following tables present the pathways that are sufficient or have consistency above 0.75.

Table 19. Absence of Natural capital

Absence of Natural Capital (Mostly Positive impacts) (0.33 and 0)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	**n**	raw consist.	PRI consist.
0	0	1	1	1	1	0.769585	0.57265
0	0	0	1	0	1	0.460829	0
1	0	0	0	0	1	0.39759	0
1	0	1	0	0	1	0.39759	0
0	1	0	0	0	2	0.373134	0
1	0	1	1	0	3	0.31694	0
1	1	0	0	0	1	0.152778	0
1	1	0	1	0	4	0.125	0
1	1	1	0	0	5	0	0
1	1	1	1	0	4	0	0
0	1	1	0	0	2	0	0
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Table 20. Absence of Social Capital

Absence of Social Capital (Mostly Positive impacts) (0.33 and 0)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	n	raw consist.	PRI consist.
0	1	0	0	1	2	1	1
0	1	1	0	0	2	0.5	0.5
0	0	0	1	0	1	0.460829	0.299401
1	1	0	1	0	4	0.4575	0.38
1	1	0	0	0	1	0.421296	0.373434
1	0	1	0	0	1	0.403614	0.403614
0	0	1	1	0	1	0.230415	0.230415
1	0	1	1	0	3	0.226776	0.10443
1	1	1	1	0	4	0.132265	0.132265
1	1	1	0	0	5	0.0682128	0.0682128
1	0	0	0	0	1	0	0
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Table 21. Absence of human capital

Absence of Human Capital (Mostly Positive impacts) (0.33 and 0)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	**n**	raw consist.	PRI consist.
0	1	0	0	1	2	1	1
0	1	1	0	0	2	0.5	0.5
0	0	0	1	0	1	0.460829	0.299401
1	1	0	1	0	4	0.4575	0.38
1	1	0	0	0	1	0.421296	0.373434
1	0	1	0	0	1	0.403614	0.403614
0	0	1	1	0	1	0.230415	0.230415
1	0	1	1	0	3	0.226776	0.10443
1	1	1	1	0	4	0.132265	0.132265
1	1	1	0	0	5	0.0682128	0.0682128
1	0	0	0	0	1	0	0
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Table 22. Absence of financial capital

Absence of Financial Capital (Mostly Positive impacts) (0.33 and 0)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	**n**	raw consist.	PRI consist.
0	0	0	1	1	1	1	1
0	1	0	0	1	2	0.873134	0.797619
0	1	1	0	1	2	0.873134	0.797619
1	0	1	0	0	1	0.698795	0.568965
0	0	1	1	0	1	0.691244	0.691244
1	1	1	1	0	4	0.567134	0.436031
1	0	1	1	0	3	0.543716	0.498499
1	0	0	0	0	1	0.39759	0.39759
1	1	0	0	0	1	0.152778	0.0827068
1	1	1	0	0	5	0.135061	0.0494753
1	1	0	1	0	4	0.0825	0
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Table 23. Presence of physical capital

Presence of Physical Capital (Mostly Negative impacts) (0.66 and 1)							
LackPAR	LackINT	LessES	LargeIC	Sufficient	n	raw consist.	PRI consist.
1	1	1	0	0	5	0.545703	0.310559
0	0	0	1	0	1	0.460829	0
0	0	1	1	0	1	0.460829	0
1	0	0	0	0	1	0.39759	0
1	0	1	0	0	1	0.39759	0
1	1	0	0	0	1	0.30787	0.143266
1	1	1	1	0	4	0.266533	0.214592
1	0	1	1	0	3	0.180328	0
1	1	0	1	0	4	0.125	0
0	1	0	0	0	2	0	0
0	1	1	0	0	2	0	0
0	0	0	0	0	0		
0	0	1	0	0	0		
1	0	0	1	0	0		
0	1	0	1	0	0		
0	1	1	1	0	0		

Chapter 2: Household food and energy security associated with hydropower development

Introduction

One of the United Nations' Sustainable Development Goals is to "Ensure access to affordable, reliable, sustainable, and modern energy for all" by 2030(United Nations, 2015). However, more than 759 million people still have no reliable, safe, and efficient electricity access (SEforALL, 2021). Hydropower is an appealing energy generation option because it allows nations in the Global South and emerging economies to be energy-independent and to produce ostensibly clean energy (Fan et al., 2022; Gürbüz, 2006; Namy, 2010; Smyth & Vanclay, 2017). However, the construction of hydroelectric dams is one of the significant drivers of change in the most biodiverse river basins of the world: the Amazon, Congo, and Mekong (Winemiller et al., 2016). Hydroelectric dams have negative impacts not only on rivers but on the whole social-ecological system where dams are built. For instance, the construction generates displacement of human populations with little or no consultation (Trussart et al., 2002; von Sperling, 2012); increases the rates of deforestation (Alho et al., 2015; Winemiller et al., 2016); reduces fish production and fish diversity (Baran & Myschowoda, 2009; Orr et al., 2012), among other numerous negative impacts.

In 1997, the World Commission on Dams (WCD) was created to discuss the controversial issues associated with large dams (WCD, 2000), finding that large dams have caused irreversible damage to the environment, displaced populations, and affected other populations relying on the river. Bird and Wallace (2001) mentioned that dam builders' efforts to respond to the impacts of dams "lack attention to anticipating and avoiding impacts, the poor quality and uncertainty of predictions, the difficulty of coping with all impacts, and the only partial implementation and success of mitigation measures" (Bird & Wallace, 2001, p. 58). The WCD report was presented in 2000 and contained seven strategic priorities for sustainable dam construction and 26 guidelines to support decision-making processes considering technical, financial, economic, social, and environmental aspects (WCD, 2000). Some of these recommendations and guidelines, particularly those under the strategic priority "*Recognizing entitlements and benefit sharing,*" aim to mitigate dams' negative impacts and guarantee that affected populations could also benefit from them. Unfortunately, many countries most deeply engaged in building dams, such as China and Brazil, did not accept these recommendations. More recent efforts have been made to portray the social-ecological impacts of dam development worldwide, for example, the Atlas of Environmental Justice (EJAtlas, 2022), organizations such as International Rivers (International Rivers, 2022), and regional initiatives led by academics and practitioners of the Amazon Basin (Amazon Dams Network, 2022).

Then, it is not surprising that the dam development literature published, even after the WCD, shows that the food security of communities living near hydroelectric dams has been threatened. For example, because of the construction of the Tehri dam in India, the Belo Monte dam, and the Madeira hydroelectric complex in Brazil, local communities have lost access to forests and rivers that were essential for their livelihoods and from which they were getting their primary sources of protein (Arantes et al., 2021; Castro-Diaz et al., 2018; Kedia, 2004). The loss of natural resource access has escalated into a change in people's diets (Agostinho et al., 2008; Stenberg, 2006) and has created a higher dependency on markets for food provision rather than on their crops (Urban et al., 2015; Wiejaczka et al., 2018; Wilmsen et al., 2011; Yankson et al., 2018). To make things worse, the literature also reports an increase in prices due to inflation, adding another challenge to the food security of the households leaving nearby dams (Calvi et al., 2019; Castro-Diaz, Lopez, et al., 2022; Moran, 2016).

Even though dams are often promoted as good for the nation, among other things, because they will generate energy that the country needs, it has been reported that most of the electricity produced by large-scale dams goes to distant industries and urban centers (Hess et al., 2016; Mayer, Lopez, & Moran, 2022). At the same time, nearby communities still lack access to reliable and clean electricity sources (Fearnside, 1999), leaving them, in some cases, still dependent on wood, kerosene lamps, or expensive and polluting diesel generators (Brown et al., 2022; Fearnside, 1999; Legese et al., 2018). When they have access to electricity from the grid, the prices are often unaffordable, and the energy is unreliable (Obour et al., 2016).

The literature on climate change and climate hazards reveals that to effectively respond to the negative impacts generated by these types of shocks, local populations need to increase their capacities to prepare and recover from the effects of these shocks. For the case of dams, and in particular, for the case of communities that already had suffered the shock of the construction of a dam, it is crucial to know if communities have adaptive capacity vis a vis other possible shocks. We understand adaptive capacity as "the conditions that enable people to anticipate and respond to change, to minimize the consequences, to recover, and take advantage of new opportunities" (Cinner et al., 2018, p. 119). Then, in this study, we assess the adaptive capacities of local communities living nearby two large-scale hydroelectric dams in the Madeira Basin in the Brazilian Amazon a few years after the construction of the dams and how the adaptive capacities impact food and energy security.

Scholars differentiate adaptive capacity into generic and specific dimensions (Eakin et al., 2014; Lemos et al., 2016). Generic adaptive capacity refers to the manifestation of the ability to respond to and manage more general social, economic, political, and ecological stressors (Lemos et al., 2016).

For example, a generic adaptive capacity is a household's income level (Lemos et al., 2016); the higher the income, the more likely the household will respond to change. In contrast, specific adaptive capacity is the ability to respond to particular hazards (Lemos et al., 2016), such as the threats caused by hydropower development. To illustrate, knowledge about the threats of a particular hazard increase the likelihood of households adapting to it (L. Smith & Frankenberger, 2018; Williams et al., 2015). Thus, the mitigation plans and shared information provided by dam authorities before dam construction should enhance these specific adaptive capacities and increase the likelihood of households preparing and adapting to the effects of dam development.

There is a relationship between generic and specific adaptive capacity since a minimum of generic adaptive capacity is needed to support specific adaptive capacities (Lemos et al., 2016). There is a synergy since the positive combination of both can enhance long-term adaptation (Lemos et al., 2013). Also, if specific adaptive capacities are low, systems can be trapped in undesirable states, such as poverty and rigidity traps (Lemos et al., 2013).

The strategic priority of the WCD: *Recognizing entitlements and benefits* was conducive to improving the specific adaptive capacities of people living close to dam construction. Even though the recommendations of the WCD were not followed, dam builders have established mechanisms that aim to reduce the social-ecological impacts generated by hydroelectric dams, such as Environmental Impact Assessments (EIAs) and Social Impact Assessments (SIAs). However, these are done poorly, and people living in these territories are often not involved in creating and applying these assessments (Gerlak et al., 2019). Compensation strategies are usually considered in Environmental Impact Assessments (EIAs) and Social Impact Assessments (SIAs). However, EIAs and SIAs only include communities that will be resettled due to their location in the areas that will be flooded (Martínez & Castillo, 2016), leaving other affected communities, such as downstream and host communities, without compensation or much consideration of how they might be affected. In some cases, not all displaced communities are compensated (Mathur, 2011). In other cases, individuals not considered in the compensation programs have organized litigation processes, which require collective action and capital, with the support of public prosecutor's offices that allowed them to get compensation (Fundo Brasil, 2022). Unfortunately, legal actions take time; the actions often take place in the early stages of the projects and, if considered, will be evaluated when the projects are already under construction and in operation (Scabin et al., 2014).

These compensation mechanisms have been described as necessary for supporting individuals' and households' coping and adaptation after resettlement (Cernea, 1997). As presented in Chapter 1, participation in the decisions before dams are built, and access to information about the projects are other conditions that allow communities to reduce the negative impacts on their livelihoods.

However, to our knowledge, there are no studies investigating the contributions of generic and specific adaptive capacity in alleviating the effects of hydropower dam development on food and energy security.

This study assesses the generic and specific adaptive capacity of communities affected by the construction of two large-scale hydroelectric dams in the Brazilian Amazon and their contribution to food and energy security. We look at financial status, access to natural resources, the household's health status, and the respondent's education level for generic adaptive capacities. For specific adaptive capacities, we investigate access to information about the dam, participation in the decision-making processes, and access to compensation. We surveyed eight communities near the Santo Antônio and Jirau dams seven years after the completion of the dams. We hypothesize that households with higher generic and specific adaptive capacity after the dam's construction have higher food and energy security and are less vulnerable to new shocks. Understanding the adaptive capacity of communities after the construction of a dam is vital since it shows us how vulnerable these are to confront climate shocks like El Niño or other anthropogenic activities like the construction of new dams or other infrastructure projects under consideration in the Amazon region.

Theoretical Background

Adaptive Capacity in the context of dam development

Resilience is a concept that has many interpretations and can be applied at different levels (Anderies, 2014); like sustainability, it is a polysemic concept meaning that it can be used differently by individuals and fields. In this study, we understand resilience as an emergent property of systems (Berkes et al., 2008); particularly, social-ecological resilience explores individuals', households,' and communities' capacity to absorb, adapt, and transform into new stages in the face of dynamic change (Béné et al., 2012; Folke, 2016; Folke et al., 2010). One of the key attributes of resilience is adaptive capacity (Béné et al., 2012; L. Smith & Frankenberger, 2018), which reflects learning and flexibility to try solutions in response to shocks (Walker et al., 2002). Adaptive capacity is not static; it is context-specific, its determinants are interrelated (Smit & Wandel, 2006), and governance, institutions, and management influence it (Engle, 2011). A system will be more resilient if it has a higher adaptive capacity (Engle, 2011), which implies a combination of generic and specific capacities.

Adaptive capacity can be explored at an individual, household, or collective level (Eakin et al., 2014; Nelson et al., 2007). In this study, we are exploring adaptive capacity at the household level. Adaptive capacity is classified into two categories: generic adaptive capacity and specific adaptive capacity. Generic adaptive capacity includes the capacities needed for addressing general social, ecological, economic, and political stressors (Eakin et al., 2014; Lemos et al., 2016). These capacities include income, education, health, and physical and social assets (Lemos et al., 2016), which are linked to the five capital of sustainable livelihoods: natural, social, human, financial, and physical (Mortreux & Barnett, 2017; Thapa et al., 2016). These capitals are the basis for households to respond to stress and manage risk (Bebbington, 1999), and as shown in the first paper of this dissertation based on a meta-analysis looking at 33 large dams built in the Global South, natural, social, human and financial capital are negatively impacted by dam construction. Then, if a population has lower levels of formal education and lacks health services, their generic capacities are low (Eakin et al., 2014). For our analysis, we included capacities related to financial capital (household financial status), natural capital (access to natural resources), and human capital (health status of the members in the household and the education level of the respondent).

Specific capacities are needed to address particular hazards (Eakin et al., 2014). For example, in the case of climate hazards, these could include climate-related knowledge and skills, emergency response plans, access to external income, and access to alternative sources of water, had been proven to be essential (Lemos et al., 2016; Thapa et al., 2016). In this study, we include specific capacities that dam builders were supposed to provide to all populations living nearby dams, like information about the dam, facilitating the participation of locals in the decision-making process, and providing compensation. In this study, we are not including adaptive capacities that reflect the agency of individuals and households to respond to a shock, like collective action initiatives and litigation, among others.

Knowledge/Information about dam construction

In the context of energy systems, one of the energy justice principles is transparency and accountability. It argues that "all people should have access to high-quality information about energy and the environment and fair, transparent, and accountable forms of energy decision-making" (Sovacool et al., 2017, p. 687). Knowledge is a determinant of adaptive capacity, requiring access to information and interpretation (Williams et al., 2015). Having information helps locals make sense of changes, take a position concerning those changes and respond to them in ways that serve their interests (L. Smith & Frankenberger, 2018; Williams et al., 2015).

Unfortunately, local communities have limited access to information about dam projects before and after the construction. For instance, resettled communities of the Ilisu dam in Turkey were not informed about the resettlement process, which generated misconceptions (Morvaridi, 2004). Furthermore, the assessment studies were published in English, with limited access to information for locals (Morvaridi, 2004). Another example in which dam developers did not provide information to affected communities was Sobradinho in Brazil. Communities were not informed about the impoundment of the reservoir, the water started to rise, and locals had to be displaced immediately by military trucks to lands unsuitable for resettlement (Cernea & Maldonado, 2018). Locals could also access information about dam development through the media. However, a content analysis of news articles published over two decades in Brazil found that media usually covers information about dams provided by dam authorities and promotes the economic benefits while overlooking the social-ecological effects of dam construction (Mourão et al., 2022).

Participation in decision-making

Participation in decision-making involves a process that allows the development of successful initiatives associated with increased mobilization of stakeholder ownership of policies and projects (Pretty, 1995). It is a dynamic process and a political issue (White, 2011); therefore, different stakeholders will participate in various stages of the process and with different levels of participation (Cornwall, 2008). The active participation of communities affected by dam development before the project's construction has been suggested by researchers, practitioners, and the WCD (Goulet, 2005; Hay et al., 2019; WCD, 2000). Access to a fair institutional decision-making process (Schlosberg, 2007) is essential for achieving energy justice. However, consultation or negotiation with local actors are rarely conducted in dam construction projects (Garcia et al., 2021; Mayer, Garcia, et al., 2022), and as shown in Chapter 1, the lack of participation is related to negative impacts on the livelihoods of people living nearby construction sites.

Compensation

Compensation strategies are essential for supporting individuals' and households' coping and adaptation after resettlement (Cernea, 1997). These strategies can be used to restore the adverse effects and injustices associated with the construction of an energy project. However, dam projects have poorly implemented compensation (Cernea, 2008) because these are not tailored to the social and economic context and needs, so they are often inadequate. In sum, affected populations end up under-compensated, if compensated at all (Cernea, 2003; Nakayama et al., 1999; Vanclay, 2017).

Hydropower and household food security

In this study, we adopt the FAO et al. (2022) definition of food security. Food security refers to a situation "when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO et al., 2022, p. 202). There are four dimensions of food security that build upon each other. *Availability* refers to the physical presence of food. *Access,* if food is available, then whether people have physical and economic access to that food. *Utilization*, if the food was available, and people could access it whether they are maximizing the consumption to adequate nutrition. *Stability* ensures that food security is sustainable (FAO et al., 2022).

One of the groups affected by dams that have been studied is resettled communities, and researchers have found that this group is at risk of increased food insecurity because of the shock dams impose on them (Cernea, 1997, 2000). Cernea (1997, 2000) found that resettled communities have suffered chronic undernourishment caused by a reduction in crop availability and drops in income. In cases when communities are resettled from rural to urban areas, their food security is disrupted since they rely more on the market for food provision than on their crops, as occurred before resettlement (Urban et al., 2015; Wiejaczka et al., 2018; Wilmsen et al., 2011; Yankson et al., 2018). Such is the case of communities resettled by the Tehri dam in India, who lost access to forest products that were the basis of their diet (Kedia, 2004). Furthermore, accessing animal products was challenging due to the high prices, reducing their protein intake (Kedia, 2004).

Scholars working with other communities (no resettled) have found that dam construction had affected locals' food security regarding availability and access. The food security of riverine communities has been threatened by hydropower development mainly because of its impacts on fisheries. The blockage of fish migration, loss of fishing areas, and loss of fish species has impacted the food security of communities that depend on fish for their livelihoods (Arantes et al., 2021; Castro-Diaz et al., 2018).

In addition to food insecurity, scholars have shown that the construction of hydroelectric dams generates steep inflation in nearby areas (Calvi et al., 2019; Moran, 2016), which increases the challenges of families accessing food, as presented in Chapters 3 and 4. Added to inflation, the literature reports reduced staple food production in the areas near the construction sites, mainly generated by the high migration of workers from the farm sector to work on the dam (Moran, 2016; Yankson et al., 2018). Reducing food intake is one of the main coping strategies used by households after a shock (Lemos et al., 2016), such as the construction of dams, indicating reduced adaptive capacity (Lemos et al., 2016).

Hydropower and household energy security

There are different understandings of the concept of energy security. It differs by country, and temporal and spatial scale, among other variables immersed in a complex social, political, environmental, and economic context (Chester, 2010; Jakstas, 2020; Sovacool & Brown, 2010). For instance, a country could be classified as energy secure globally if it can meet its energy demand without interruptions and dependence on other countries (Bruckner et al., 2014; Chester, 2010). At a household and individual level, energy security can be understood as sufficient and affordable energy of the type and quantity necessary for a healthy life (Jakstas, 2020). Regardless of the context, energy security can be understood as "the way of equitably providing available, affordable, reliable, efficient, environmentally benign, proactively governed, and socially acceptable energy services to end-users" (Goldthau & Sovacool, 2012, p. 235). Based on this definition, energy security has four interconnected dimensions: availability, reliability, affordability, and sustainability (Sovacool, 2011; Sovacool & Brown, 2010). *Availability* is a "sufficient and interrupted supply" (Sovacool, 2011, p. 9). *Reliability* is the system's efficiency; one aspect of this dimension is ensuring that consumers receive energy tailored to their needs. *Affordability* refers to equitable and stable prices in energy services, including high levels of electricity access. And *sustainability* calls attention to the sustainable use of the environment and its protection for the benefit of future generations (Sovacool, 2011; Sovacool & Brown, 2010).

Communities living near hydroelectric dam projects have faced different dimensions of energy insecurity. For instance, there is no electricity available for them in some cases. To illustrate, fifteen years after the construction of the Xepian–Xenamnoy dam complex in Laos, communities that were resettled still lacked access to electricity (Green & Baird, 2016). In the Brazilian Amazon, for instance, the Tucuruí dam, built in 1984, generated electricity consumed by industry, while locals relied on kerosene lamps for their lighting (Fearnside, 1999). More recently, the electricity of Belo Monte, a mega-dam in the Xingu River, is sent to the country's larger cities (Hess et al. 2016). In contrast, as presented in Chapter 3, locals lack access to a reliable and affordable electricity source, with the Tucurui dam rather than Belo Monte as its source. If they have electricity, local people pay many times more per kWh than urban dwellers in Sao Paulo or Rio.

Scholars have also reported the high electricity prices in communities near construction sites. For instance, communities living nearby the Kamchay dam in Cambodia get electricity from Vietnam, and the service is unaffordable (Siciliano et al., 2016). Or, after the construction of the Bui dam in Ghana, resettled communities got access to electricity. However, they reported that their economic burdens increased after receiving high-priced electricity bills (Obour et al., 2016).

Our study focuses on understanding how generic capacities of households, such as financial status, access to natural resources, health status of the household, and education level. Also, exploring specific adaptive capacities, such as information about the dam, participation in the decision-making process, and compensation that households have after the construction of the dams influence food and energy security.

Madeira hydroelectric complex

After China, Brazil has the world's largest hydropower capacity (IEA, 2021). With 221 hydropower dams in operation and more than 200 planned, the Amazon region has the most significant hydropower potential in the country (Flecker et al., 2022; Infoamazonia, 2022). This high dependence on hydropower comes from a powerful political discourse on energy independence promoted since the military dictatorship in the 60s to 80s, which has continued in the following democratic governments.

The Madeira hydroelectric complex comprises two large-scale hydroelectric dams: Jirau and Santo Antônio, in the Madeira river, one of the principal tributaries of the Amazon River (Goulding et al., 2003). The Madeira complex is part of a Brazilian effort to increase energy production (Allan Silva et al., 2013), and these dams are part of the federal government's Growth Acceleration Plan (Plano de Aceleração do Crescimento PAC) (Scabin et al., 2014). The construction of Jirau and Santo Antônio started in 2008 and finished in 2013, both dams are located close to each other, but their construction concessions were given to different consortia (Fearnside, 2014).

The Jirau dam has an installed capacity of 3750 MW (Fearnside, 2014); and a reservoir area of 361 km^2. The Santo Antônio dam has an installed capacity of 3150 MW (Fearnside, 2014) and has a reservoir area of 271km^2. According to Mayer et al. (2022), these dams were one of the first "run-of-river dams" that require a smaller reservoir than traditional dams. Because of that, these are supposed to generate lesser adverse effects on downstream communities (Almeida et al., 2020). However, the dams were built 120 km apart, which formed a large reservoir between the two (see Figure 5).

Jirau and Santo Antônio dams are controversial due to the social-ecological impacts they have caused and because their construction began before their EIAs were completed (Fearnside, 2014; Scabin et al., 2014). Despite the size of the projects and the fact that both dams are located close by, dam authorities only held four public meetings in the area (Fonseca et al., 2013) and in locations that were not easily accessible (Novoa Garzon, 2008). It is also reported that armed security was present in these meetings, which could contribute to a space where local actors did not feel safe sharing their thoughts and concerns (Gugliano & Luiz, 2019). Added to the lack of a fair process of participation, Gugliano and Luiz (2019) reported issues with information transparency since the EIAs were not publicly available.

After constructing these dams, many scholars have studied their impacts and disturbances in the social-ecological system. Dams have altered the water's pH, turbidity, and transparency of the river (Cella-Ribeiro et al., 2017). Scholars also found a decline in fish catches of more than 30%, particularly in migratory fish, due to the loss of river connectivity (Arantes et al., 2021). Income from fishing has also decreased (Arantes et al., 2021; Doria et al., 2021), which has increased overfishing (Doria et al., 2021).

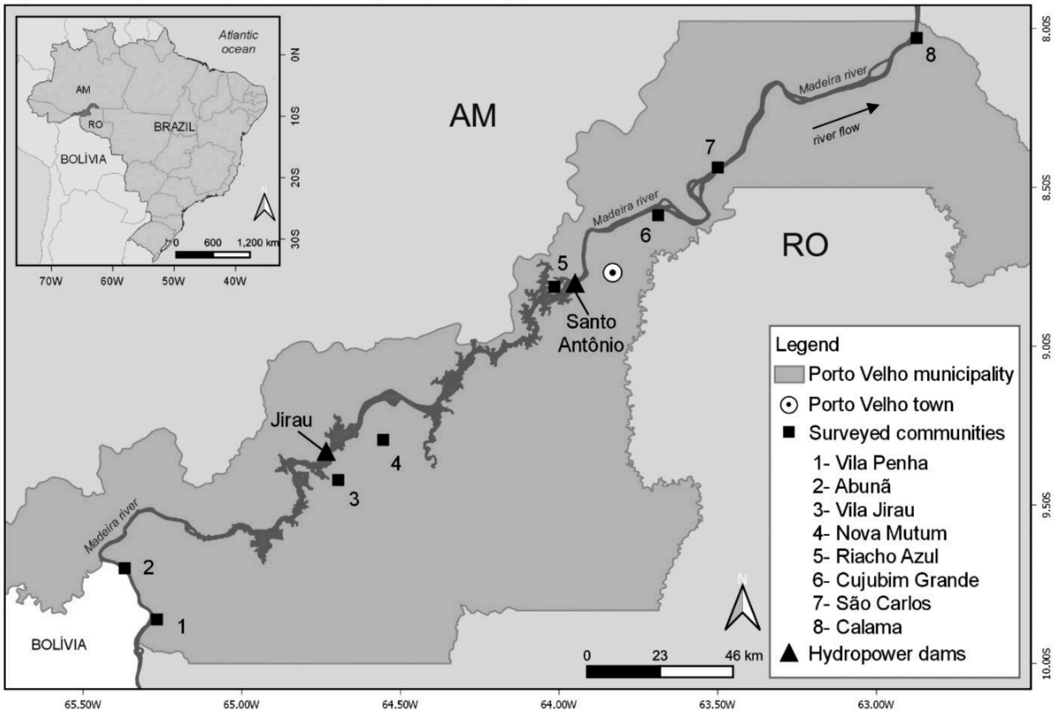


Figure 5. Location of Jirau and Santo Antônio Dam and surveyed communities (Mayer, Lopez, cavallini johansen, et al., 2022. p. 403)

Araujo and Moret (2016) reported that communities resettled by the Jirau dam were unsatisfied with the resettlement and began to leave the houses provided by the dam authorities. They said that families were relocated far from the river and, therefore, forced to change their means of making a living (Araujo & Moret, 2016). Likewise, communities resettled for the construction of Santo Antônio, whose livelihoods depended on fisheries, were relocated to a settlement where they could not fish or find new jobs (Cavalcanti et al., 2020). Mayer et al. (2022) found that compensation given to affected communities was insufficient and that eight years after the dams' construction, the income, and livelihoods of affected communities had not been restored. Those who got compensation received different forms of compensation like a house, land, cash, or a credit card (Cavalcanti et al., 2020; Moraes Ribeiro, 2013; Passos & Praxedes, 2013). Furthermore, compensation is given to those with the title over the land (Araujo & Moret, 2016), which generates a burden for many locals since, in the Amazon region, riverine people usually lack titles over their land (Boanada Fuchs, 2015). Other locals received boats, fishing gear, and agricultural inputs as compensation (Mayer, Lopez, & Moran, 2022)

Methods

Data Collection

This study is part of a research project funded by the National Science Foundation (NSF) under the INFEWS program. Within the project, we designed and collected a survey in eight communities near the Santo Antônio and Jirau hydroelectric dams. Three communities are located downstream from the dams (Calama, São Carlos, and Cujubim grande); two communities are upstream from the dams (Abunã, Vila Penha); and the last three communities also upstream from the dams were resettled during the dam constructions (Nova Mutum, and Riacho Azul, Vila Jirau). The last one was informal, by people who refused to go to the other two. Furthermore, two communities may be resettled in the future (Abuna and Vila Penha) because the flooding from the dam has been more extensive than predicted (Li et al., 2020).

The survey was collected between August 2019 and March 2020, it was done using tablets (Samsung Galaxy with GPS capability), and data were entered directly into Qualtrics. It included 500 possible questions, but responders answered between 300-400 questions since many were nested. The survey took up to 1.5 hours, and between 3 and 5 % of households refused to answer it. The sampling used a geospatial sampling strategy. We used a satellite image to observe the settlements, and with visibility of the roofs of the houses, each house was enumerated. From there, a proportional random sample was conducted. Enumerators were given a list of randomly selected houses to survey and a list of alternative houses that they could use if, after visiting up to five times a house, they could not locate its residents. The total sample was 673 households.

Before the data collection, all enumerators participated in a two-week training to learn the sampling protocol, how to use the tablets, and the survey details. This training also served to rephrase some of the questions of the survey. Then the team did pilots in communities similar to the ones where the survey would be collected. During data collection, enumerators administered the surveys in pairs. One of the enumerators asked the questions while the other took notes. Each team arrived at a house, introduced themselves, presented the study's objectives, and asked permission to conduct the survey using consent to guarantee the confidentiality of the information. This study was exempt under 45 CFR 46.104(d) 2ii (STUDY00002997: Survey INFEWS).

Dependent Variables

Household Food Security

Data included questions to address two of the four dimensions of food security: Food Availability and Food Access after the construction of the dams. We did not include the other two because we did not have that information in our survey. We asked respondents if their ability to get the food they needed for themselves or others in their household increased, stayed the same, or decreased due to the dam's construction. We also asked if food prices decreased, stayed the same, or increased. Figure 6 presents the distribution of these variables. Eight percent of the respondents stated food availability increased, 46.3% that it stayed the same, and 45.8% of respondents reported that food availability decreased. Few respondents (1.4 %) indicated that food price was lower, 18.2% that the prices stayed the same, whereas 80.4% reported increased food prices.

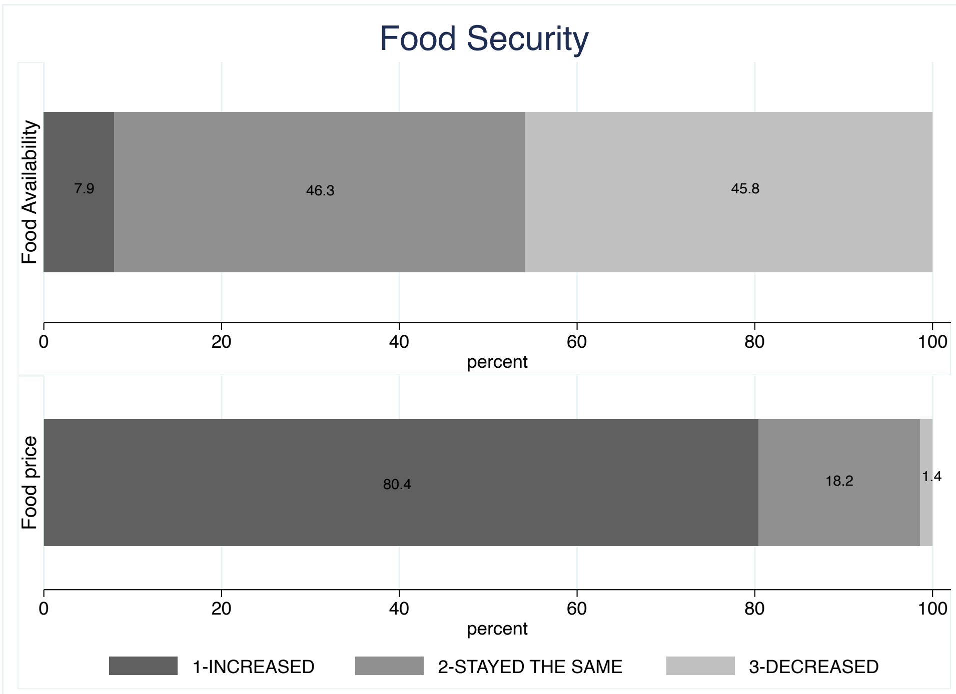


Figure 6. Distribution of dependent variables for household food security

Household Energy Security

The survey also included questions to assess energy security at the household level. We asked respondents if their primary source of electricity came from a transmission line or was generated by diesel generators-- a common source of energy in regions in the Amazon not connected to the grid. We also asked if their ability to access electricity has increased, stayed the same, or decreased after the construction of the dams. Lastly, we asked if the price of electricity decreased, stayed the same, or increased. Figure 7 presents the distribution of these variables. Sixty-four percent (63.9%) of the respondents indicated that their primary source of electricity is the transmission grid, while 36.1% still rely on diesel generators. Eighteen percent (18%) indicated that the access to electricity decreased, 52.2% reported that the access stayed the same, and 29.8% reported that the access increased. A minority of respondents (4.8%) said that the price of electricity was lower than before the construction of the dams; 11.3% reported the price stayed the same, whereas 83.9% indicated that the cost of electricity had increased.

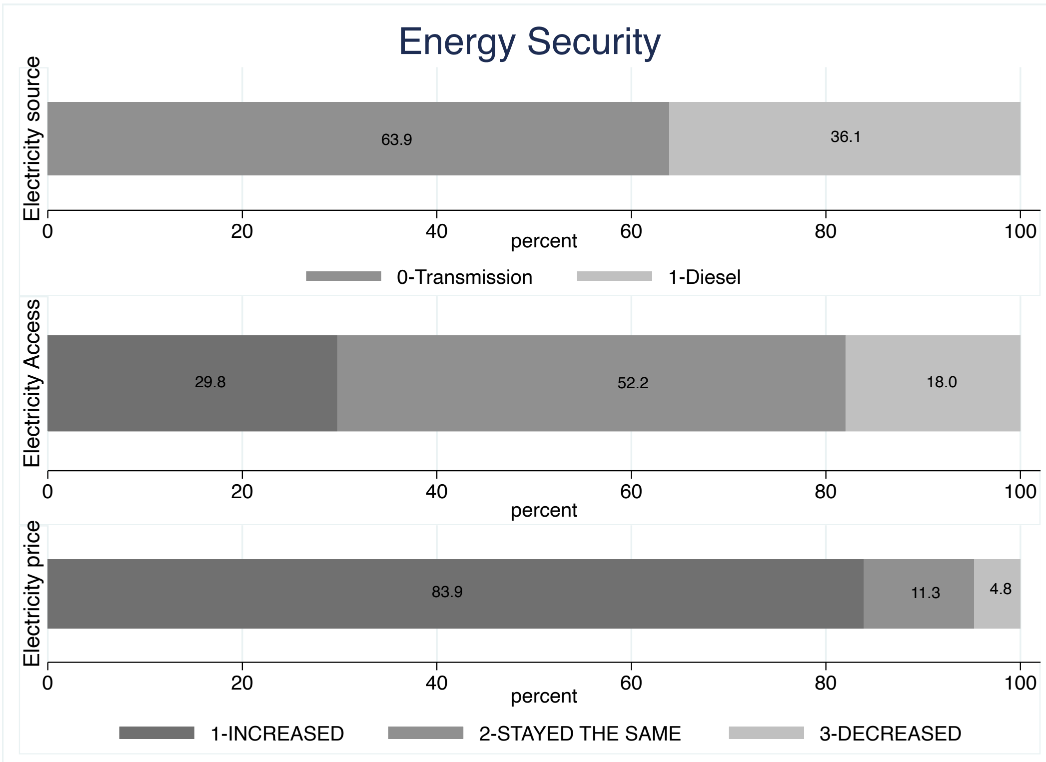


Figure 7. Distribution of dependent variables for household energy security

Independent Variables

We explore how generic and specific household capacities impact food and energy security. For that reason, we created two groups of variables: some looking at generic household capacities and others looking at specific ones. Table 25 presents descriptive statistics for the variables included in this analysis.

Generic adaptive capacity

To assess generic adaptive capacity, we included four household variables as proxies for capital likely to mitigate and respond to a broad range of hazards (Bacon et al., 2017).

We asked respondents *Overall, would you say you or your household's* ***financial situation*** *remained the same, worsened, or improved (due to the construction of the dam(s))?* Then, we expect that households with a decreased financial situation will have lower energy and food security levels because they cannot afford these things. Forty-two percent (42.5%) of the respondents indicated their household situation decreased after the construction of the dams.

Fishing in this region is one of the prominent livelihood activities and sources of income (cite). We asked: *Has **the ability to access the river** to fish remained the same, gotten worse, or improved (due to the building of the dam(s))?* Access to natural resources in this area, particularly the river, means access to protein for many households. Thus, we expect households that lose access to the river to have lower food security levels. On the other hand, we expect that those households that lose access to the river will have a higher energy security level since some will be in the resettlement areas and connected to the transmission line. More than fifty percent (52.5%) of the respondents indicated that their ability to access the river decreased due to the construction of the dams.

We asked *households: Overall, has your **health** or the health of others in your household remained the same, gotten worse, or improved (due to the building of the dam(s))?* Forty-one percent (41%) of the respondents indicated that their overall health status decreased due to the construction of the dams. Health and human capital are generic capacities that support the ability to deal with shocks (Eakin et al., 2014; Lemos et al., 2016; L. Smith & Frankenberger, 2018). Thus, we expect households with decreased health to have lower food security and no changes in energy security levels.

The last variable included in generic adaptive capacity is the respondent's level of education. Education is a capacity that allows individuals, households, and communities to respond to general stressors (Eakin et al., 2014). We asked respondents; *What is the highest level of education that you completed?* The categories of this variable go from (1) no formal education, (2) primary education, (3) secondary education, and (4) technical or university. Thus, we expect households with higher education levels will have higher levels of food security and energy security.

Specific adaptive capacity

To assess generic adaptive capacity, we included three household variables. We included the capacities needed to address and effectively respond to a particular threat (Eakin et al., 2014), such as one from hydropower development. Access to compensation is the first specific adaptive capacity included in our analysis. As mentioned above, dam development compensation aims to restore the losses generated by dam construction, mainly to restore people's livelihoods (Cernea, 2008; Kanbur, 2003). Therefore, one could assume they should also positively impact people's adaptive capacities. We asked: *Did you or anyone in your household receive any type of compensation/mitigation because of the dam*?

Households could receive several different forms of compensation and combinations of different types of compensation, including housing, cash, credit, and agricultural inputs. These measurements are supposed to be explicitly designed for the adverse effects of dam construction in the nearby area. Therefore, we expect households that got compensation to have higher food and energy security levels than those impacted but non-compensated. Eighty-five percent (85%) of the respondents indicated they did not get any compensation due to the dams.

We also asked respondents *Prior to the construction of the dam, did you hear about how people and/or communities would be affected positively or negatively by the dams?* Knowledge is a determinant of adaptive capacity, requiring access to information and interpretation (Williams et al., 2015). Knowledge helps locals make sense of changes, take a position concerning those changes and respond to them in ways that serve their interests (L. Smith & Frankenberger, 2018; Williams et al., 2015). Thus, knowing dam development's positive or negative effects before construction will help locals prepare. It will be reflected in higher food and energy security levels. More than half of the respondents (53.7%) indicated having prior knowledge, either positive or negative, about the effects of the dams.

The last variable we included for assessing specific adaptive capacity was participation. We asked: *Before the construction of the dam, did you attend any meetings (one or more) regarding the dam?* People involved in decision-making are more likely to adapt and recover from stress and shocks (Vanclay, 2017). The literature has shown a lack of participation of local actors in dam development (Garcia et al., 2021; Mayer, Garcia, et al., 2022). However, local actor participation could help reduce the negative impacts on people's livelihoods (Castro-Diaz, Garcia, et al., 2022). Since there is a persistent lack of participation, researchers have already described participation issues in decision-making processes for the construction of Jirau and Santo Antonio (Cavalcanti et al., 2020; Novoa Garzon, 2008; Scabin et al., 2014). We use a proxy for participation (a low level of participation): attending a meeting before the dam's construction. We expect households participating in the meeting will have higher food and energy security. Only 30% of the respondents report having attended a meeting before the dams were built.

Control Variables

We also included household and individual information as control variables. In particular, we added whether households were resettled and the socio-demographic characteristics of the respondents. For resettlement, we asked: *Did you and your household move from one community to another community as a result of the dam construction?* This is relevant because resettlement processes are supposed to restore or improve the livelihoods of resettled communities, at least in the long run (Cernea, 1997, 2000). However, resettled communities face diverse constraints in the new settlement, such as loss of social capital (Mayer, Lopez, Leturcq, et al., 2022), food insecurity (Scudder & Gay, 2011), loss of fisheries access (Doria et al., 2018, 2021), and higher prices of electricity (Siciliano & Urban, 2017). We expect that resettled households will have lower levels of food security but higher levels of energy security. Twenty-two percent (22%) of the respondents were resettled.

We also included information related to the respondent. We had a binary variable for the sex of the respondent. Age is scored in years and whether the respondent was a fisher, farmer, or neither. We expect that fishers, farmers, and women respondents will report lower levels of food security.

Hypotheses

Above we reviewed the relevant literature on the impacts of dam development on communities living nearby the construction sites, adaptive capacity, food, and energy security. From this context, we test five groups of hypotheses that have been little explored in the literature on dam development (see Table 24). First, we expect that households' generic adaptive capacity will decrease due to the impacts on dam development (Hypothesis 1). We also expect that households that reported their generic adaptive capacities decreased to be more likely to report that food security decreased (Hypothesis 2). We also hypothesize that households with lower levels of specific adaptive capacity are more likely to report decreased food security (Hypothesis 3). We expect that households that reported their generic adaptive capacity decreased are more likely to report that energy security did not increase (Hypothesis 4). Lastly, we hypothesize that households with lower levels of specific adaptive capacity are more likely to report that energy security did not increase (Hypothesis 5). As presented in Table 24, a series of hypotheses emerged from each of the five principal hypotheses.

Table 24. Hypotheses

Hypotheses		
1. Generic adaptive capacity and dam development		Households' generic adaptive capacity will decrease due to the impacts on dam development
2. Households that reported their generic adaptive capacity decreased are more likely to report that food security decreased	Food Availability	Households that reported their financial status decreased are more likely to say that food availability decreased
		Households that lost access to the river will report that food availability decreased
		Households that reported a decrease in their health status would be more likely to report food availability decreased
		Households with higher education levels will be less likely to report their food availability decreased
	Food Prices	Households that reported their financial status decreased are more likely to report that food prices increased
		Households that lost access to the river will report that food prices increased
		Households that reported a decrease in their health status would be more likely to report food prices increased
		Households with higher education levels will be more likely to report food prices increased
3. Households that reported lower levels of specific adaptive capacity are more likely to report that food security decreased	Food Availability	Households that reported knowing either positive or negative aspects of dam development will be less likely to say that their food availability decreased
		Households that reported attending a meeting before the construction of the dams will be less likely to report food availability decreased
		Households that got compensation will be less likely to report their food availability decreased
	Food Prices	Households that reported knowing either positive or negative aspects of dam development will be more likely to report that food prices increased
		Households that reported attending a meeting before the construction of the dams will be more likely to report food prices increased
		Households that got compensation will be more likely to report food prices increased
4. Households that reported their generic adaptive capacity decreased are more likely to report that energy security did not increase	Electricity Source	Households that reported their financial status decreased will be more likely to report having diesel generators
		Households that lost access to the river will be less likely to report they have diesel generators
		Households that reported a decrease in their health status would be more likely to report having diesel generators
		Households with higher education levels will be less likely to report having diesel generators
	Electricity Access	Households that reported their financial status decreased will report a decrease in their electricity access
		Households that lost access to the river will report their electricity access increased
		Households that reported a decrease in their health status will not report changes in their electricity access
		Households with higher education levels will be more likely to report an increase in electricity access

Table 24 (cont'd)

	Electricity Price	Households that reported their financial status decreased will be more likely to report electricity prices increased
		Households that lost access to the river will report electricity prices increased
		Households that reported a decrease in their health status will not report changes in their electricity prices
		Households with higher education levels will be more likely to report an increase in the price of electricity
5. Households reported lower levels of specific adaptive capacity are more likely to report that energy security did not increase	Electricity Source	Households that reported knowing either positive or negative aspects about dam development will be less likely to report having diesel generators
		Households that reported attending a meeting before the construction of the dams will be less likely to report having diesel generators
		Households that got compensation will be less likely to report having diesel generators
	Electricity Access	Households that reported knowing either positive or negative aspects of dam development will be more likely to report electricity access increased
		Households that reported attending a meeting before the construction of the dams will be less likely to report electricity access decreased
		Households that got compensation will be more likely to report electricity access increased
	Electricity Price	Households that reported knowing either positive or negative aspects of dam development will be more likely to report electricity prices increased
		Households that reported attending a meeting before the construction of the dams will be more likely to report electricity prices increased
		Households that got compensation will be more likely to report electricity prices increased

Analytic strategy

To explore how the generic adaptive capacity of the eight communities surveyed in our study changed after the dam's construction, we present descriptive statistics of people reporting changes in their financial status, access to natural resources (river), health status, and education level. Then, we ran binary logistic regressions for the five dependent variables to assess how generic and specific capacity influences food and energy security changes among the surveyed households. Even if those variables were not binary to start with, we decided to run binary regressions since when running the ordinal regression models, the brant tests were violated with several independent variables. Table 25 presents the distribution of the recoded variables. To assess the change in food availability, we differentiate between those who reported food availability decreased and those who said it increased or stayed the same. For food prices, we compared those who reported food prices increased and those who reported these decreased or stayed the same. We differentiate between those who reported their electricity access decreased and those who said it increased or stayed the same. Likewise, we compared those who said electricity prices increased and those who reported it decreased or stayed the same.

Table 25. Descriptive statistics

Variable	Obs	Description	Mean	Std. Dev.	Min	Max
Outcome Variables						
Food Availability	652	1= Decreased; 0= Increased or Stayed the same	0.46	0.50	0	1
Food Price	652	1= Increased; 0= Decreased or Stayed the same;	0.80	0.40	0	1
Electricity Source	665	1= Diesel; 0= Transmission line	0.36	0.48	0	1
Electricity Access	653	1= Decreased; 0= Increased or Stayed the same	0.53	0.50	0	1
Electricity Price	615	1= Increased; 0= Decreased or Stayed the same	0.84	0.37	0	1
Generic Capacity						
Self-reported worse Finances	657	1=Yes; 0=No	0.42	0.49	0	1
Lost river access	535	1=Yes; 0=No	0.52	0.50	0	1
Household health worse	654	1=Yes; 0=No	0.41	0.49	0	1
Education of respondent	670	1=No formal education; 2=Primary; 3= Secondary; 4= Technical & University	2.31	0.78	1	4
Specific Capacity						
Got Compensation	665	1=Yes; 0=No	0.15	0.36	0	1
Prior knowledge	631	1=Yes; 0=No	0.54	0.50	0	1
Attended a meeting	644	1=Yes; 0=No	0.30	0.46	0	1
Control						
Resettled	661	1=Yes; 0=No	0.22	0.41	0	1
Respondent Female	669	1= Female; 0= not female	0.52	0.50	0	1
Age of respondent	667	Age in continuous years	48.09	15.19	18	87
Fisher or Farmer (respondent)	669	1= Fisher/Farmer; 0= Otherwise	0.20	0.40	0	1

Results

Description of changes in adaptive capacity

In this section, we present the descriptive statistics showing how the generic and specific adaptive capacities variables included in this analysis changed due to the construction of the Madeira hydroelectric complex.

Generic adaptive capacity

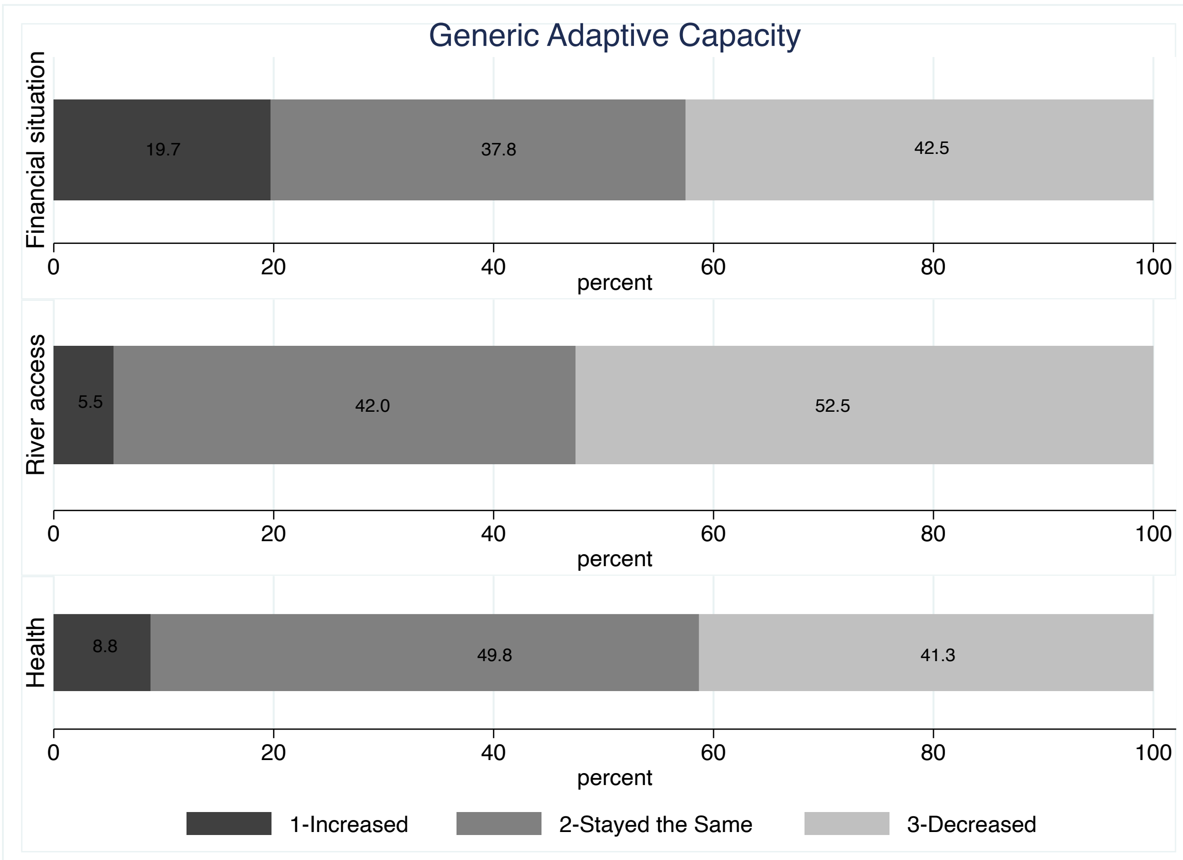


Figure 8. Changes in generic adaptive capacity after dam construction

Figure 8 shows the change in generic adaptive capacity after constructing the hydroelectric complex. Forty-two percent (42.5%) of the respondents stated that their financial situation decreased after the construction of the dams, while 37.8% said that their financial situation stayed the same, and 19.7% reported that their financial status increased

Half of the respondents (52.5 %) noted their access to the river decreased after the construction of the dams, 42% stated their access to the stayed the same, and 5.5% stated that their access to the river increased. Forty-one percent of the respondents (41.3%) said that their household's overall health decreased after the hydroelectric complex, 49.8% stated that their health stayed the same, and 8.8% reported that it increased.

As mentioned above, the fourth variable we included for generic adaptive capacity is education. Eleven percent (11.4%) of the respondents indicated they had no formal education. Fifty-three percent (53.4%) indicated they had primary education. Twenty-seven percent (27 %) had secondary education, and just eight percent (8%) had technical or university-level education.

The Amazon region has the highest proportion of multidimensional poor in Brazil (da Silva et al., 2017). By 2013 the incidence of deprivation of education was above 90%, and access to drinkable water and food was above 36% (da Silva et al., 2017). Our results show how the construction of dams is increasing the burden in communities that have already suffered from multidimensional poverty, reducing their adaptive capacity to mitigate and resist shocks.

Specific adaptive capacity

Figure 9 displays the three variables included for assessing specific adaptive capacity. Most respondents stated that they did not get compensation (85.1%). Almost half of the respondents (53.8%) noted that they had access to information before the construction of the dams about the positive or adverse effects. Lastly, 69.7% of the respondents stated they did not attend a meeting about the dam projects before the construction.

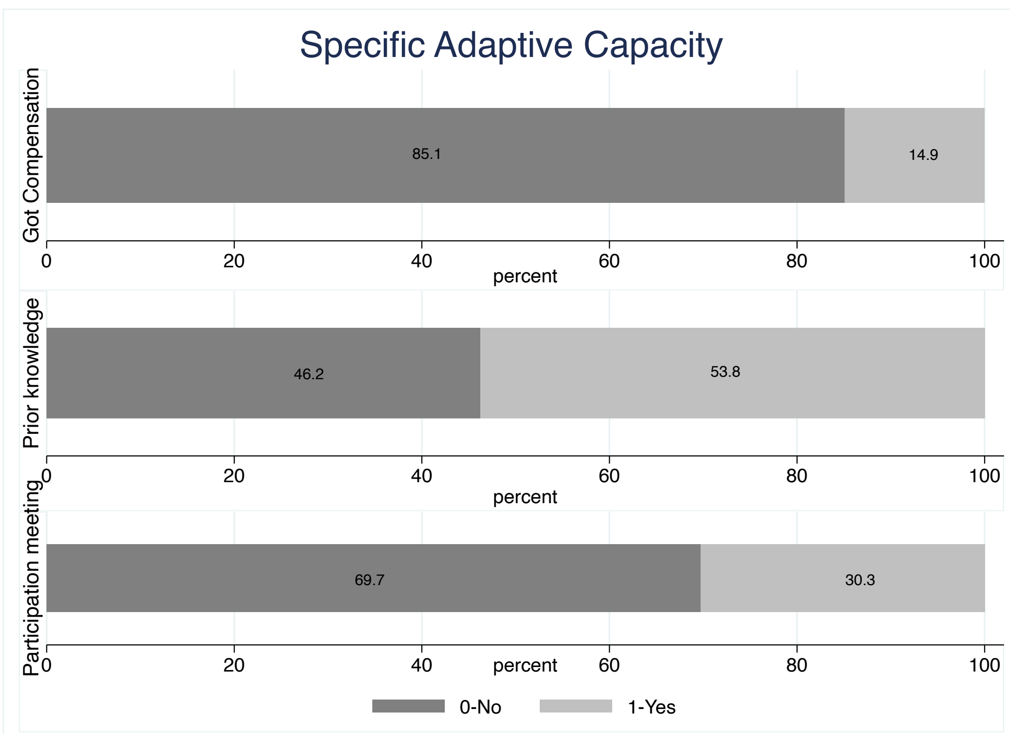


Figure 9. Distribution of specific adaptive capacity variables

Models explaining the association of generic and specific adaptive capacity with changes in food security after dam construction.

Table 26 displays the results of three binary logistic models explaining the variables associated with changes in food availability and food access (price) after dam construction. Model 1 includes the generic adaptive capacity variables. Model 2 assesses the specific adaptive capacity variables, while Model 3 integrates generic and specific adaptive capacity variables. All the models include the control variables. Table 26 reports the models' odds ratios and standard errors.

Food Availability

Almost half of the population living near the construction of the dam (46%) report that their food availability decreased after the construction of the dams (Figure 6). The models in Table 26 show that generic adaptive capacity variables are associated with food availability outcomes, including changes in household finances and decreased health. It shows that variables of specific adaptive capacity are not associated (at least significantly) with food availability. Control variables (resettlement, age, gender, and occupation) also explain food availability after the shock of dam construction.

Household finances and health are the generic adaptive capacity variables explaining food availability after dam construction. Models 1 and 3 report that decreased household finances is associated with lower food availability (OR=3.12; OR=3.13, $p < 0.001$). Likewise, those who reported a decrease in their health after dam construction were more likely to state that their availability to get food decreased. Models 1 and 3 show that decreased health is associated with lower food availability (OR=1.59; OR=1.54, $p<0.05$).

The models also show that control variables are significant explanatory variables for food availability. Those who were resettled were more likely to state that food availability decreased. Models 1 and 2 show that resettlement is associated with lower food availability (OR=1.87, $p<0.01$; OR=1.70, $p<0.05$). However, this was not true in Model 3. Women respondents were more likely to report that food availability decreased when adjusting for the effects of specific capacity variables; this can be seen in Model 2 displays (OR=1.48, $p<0.05$). However, that effect is not present in Model 3, when we have both adaptive capacities. Additionally, for every year increment in respondents' age, the likelihood of reporting food availability decreased is reduced in all models (OR=0.98; OR=0.99; OR=0.98, $p<0.05$).

As expected, our results show that households with decreased financial and health status are more likely to report food availability decreased. Nevertheless, none of the models show a significant relationship between losing access to the river and reporting a decreased food availability. We did not find a significant relationship between education level and food availability change. Likewise, none of the specific adaptive capacity variables significantly explain changes in food availability. Lastly, farmers and fisher respondents were more likely to report that food availability decreased when adjusting for the effects of specific adaptive capacity. Model 2 shows that farmers and fisher respondents reported lower food availability (OR=1.52, $p<0.05$). However, that effect is not present in Model 3, when we have both adaptive capacities.

Food Price (Access)

Most surveyed households (80%) reported that food prices increased after the dam construction (Figure 6). Table 26 presents the results of three binary logistic models aiming to explain the associates for changes in food prices. The models show that access to the river, a variable of generic adaptive capacity, is associated with how people perceive food prices change after dam construction. As for the case of food availability, none of the specific adaptive capacity variables are associated with the change in food prices. Age is also significant for explaining the perception of changes in food prices, whereas gender is only significant in Model 2.

One variable of generic adaptive capacity is significant for explaining the food price change. Models 1 and 3 show that households losing access to the river is associated with reporting increased food prices (OR=1.82; OR 1.95, $p<0.05$). This result supports our hypothesis. However, our results do not show a significant relationship between decreased financial and health status and increased food prices. Likewise, we did not find a significant relationship between the level of education and the change in food prices. None of the specific adaptive capacity variables, knowledge, participation, and compensation, significantly explain changes in food prices.

Women respondents were more likely to state that food prices increased when controlled by specific adaptive capacity. Model 2 presents that female respondents were associated with reporting increased food prices after dam construction (OR=1.56, $p<0.05$). However, that effect is not present in Model 3, when we have both adaptive capacities. Lastly, for every year increment in respondents' age, the less likely they report food prices increased in all models (OR=0.97; OR=0.98; OR=0.98, $p<0.01$).

Table 26. Binary logistic regressions for Food availability decreased & Food prices increased Food Insecurity

VARIABLES	Food Availability: decreased Model 1 OR(SE)	Model 2 OR(SE)	Model 3 OR(SE)	Food Prices: increased Model 1 OR(SE)	Model 2 OR(SE)	Model 3 OR(SE)
Generic Adaptive Capacity						
Finances decreased	3.12***		3.13***	1.27		1.25
	(0.64)		(0.67)	(0.32)		(0.34)
Lost river access	1.33		1.28	1.82*		1.95*
	(0.27)		(0.27)	(0.46)		(0.53)
Decreased health	1.59*		1.54*	1.40		1.44
	(0.32)		(0.32)	(0.35)		(0.38)
Education	1.03		1.01	0.89		0.85
	(0.15)		(0.15)	(0.15)		(0.15)
Specific Adaptive Capacity						
Received Compensation		0.93	1.27		0.80	0.86
		(0.27)	(0.42)		(0.29)	(0.36)
Prior knowledge = 1, 1-YES		1.13	1.15		1.28	1.55
		(0.21)	(0.25)		(0.30)	(0.43)
Participated in meeting		1.01	0.96		0.75	0.57
		(0.21)	(0.23)		(0.19)	(0.17)
Control						
Resettled	1.87**	1.70*	1.63	0.89	1.06	1.00
	(0.44)	(0.45)	(0.49)	(0.26)	(0.36)	(0.39)
Female = 1, 1-Female	1.24	1.48*	1.35	1.31	1.56*	1.50
	(0.25)	(0.26)	(0.28)	(0.32)	(0.35)	(0.39)
age of respondent	0.98*	0.99*	0.98*	0.97**	0.98**	0.98**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Fisher or Farmer = 1, Fisher or Farmer	1.37	1.52*	1.46	0.85	0.91	0.93
	(0.32)	(0.32)	(0.35)	(0.24)	(0.24)	(0.28)
Constant	0.61	1.00	0.57	11.02**	9.20***	10.76**
	(0.39)	(0.35)	(0.38)	(8.61)	(4.19)	(8.86)
Observations	508	596	482	509	596	483

seEform in parentheses; *** p<0.001, ** p<0.01, * p<0.05

Models explaining the association of generic and specific adaptive capacity with changes in energy security after dam construction.

Table 27 displays the results of three binary logistic models explaining the variables associated with changes in electricity source, access, and price after dam construction. Model 1 includes the generic adaptive capacity variables. Model 2 assesses the specific adaptive capacity variables, while Model 3 integrates generic and specific adaptive capacity variables. All the models include the control variables. Table 27 reports the models' odds ratios and standard errors.

Electricity Source

After dam construction, 36% of the respondents said they still rely on diesel generators as the primary source of electricity (Figure 7). Meanwhile, 64% said that they have access to the transmission line. Table 27 reports the results of three logistic regression models explaining the variables associated with people having diesel or transmission lines after the construction of dams. The models present that generic adaptive capacity, specific adaptive capacity, and control variables (resettlement, gender) are associated with energy sources.

Access to the river is associated with households' electricity source. Models 1 and 3 show that those who lost access to the river were less likely to state that their primary electricity source was diesel generators (OR=0.36; OR=0.43, $p<0.001$).

Compensation and participation are the specific adaptive capacity variables associated with reporting dependence on diesel generators as a primary electricity source. Models 2 and 3 show that those who received compensation were less likely to report their electricity source was a diesel generator (OR=0.05, $p<0.01$). Likewise, Models 2 and 3 report that those who stated they attended a meeting about the dams before the construction were less likely to report having diesel generators as their primary electricity source (OR=0.47; OR=0.46 $p<0.01$).

As expected, households that reported losing access to the river were less likely to say they had diesel generators. Our results do not support the expectation that those who reported a decreased financial or health status were likelier to report having diesel generators. There was not a significant relationship between the level of education and electricity source. The results support our hypotheses that households that got compensation or participated in a meeting were less likely to report having diesel generators. Contrary to our expectations, we did not find a significant relationship between having knowledge about dam construction and reporting a type of electricity source.

The control variables associated with having diesel generators as the primary electricity source is resettlement and gender. All models show that resettled respondents were less likely to report their electricity source was diesel generators (OR=0.08; OR=0.18; OR=0.18, $p<0.001$). Models 1 and 2 show that women respondents were less likely to report diesel generators as their primary source of electricity (OR=0.64, p<0.05; OR=0.55, p<0.01). However, the gender effect is not present in Model 3, when we have both adaptive capacities.

Electricity Access

Figure 7 shows that eighteen percent of the respondents (18%) reported decreased electricity access. Table 4 presents the results of the three binary logistic models explaining the variables associated with the changes in electricity access after dam construction. Generic adaptive capacity variables (financial and health status) are associated with reporting changes in access to electricity. None of the specific adaptive capacity or control variables were associated with reporting changes in access to electricity

Models 1 and 3 show that households that reported a decrease in finances (OR=1.94, p<0.05; OR=2.14, p<0.01) and health status (OR=1.96; OR=2.17, p<0.01) are likely to report their access to electricity decreased. Model 1 indicates that those who lost access to the river were likelier to say their electricity access decreased (OR=2.04, p<0.01).

Our results support our expectation that financial status has a significant relationship when explaining changes in electricity access. However, our results do not support the hypothesis that health status would not report a change in electricity access. Likewise, we did not find a significant relationship between education level and electricity access. Our results do not support our hypotheses that reflect a significant relationship between specific adaptive capacities and electricity access changes.

Electricity Price

Figure 7 shows that most of the respondents (83%) reported increased electricity costs. Table 27 displays the results of three binary logistic models explaining the variables associated with changes in electricity prices after dam construction. The models show that generic and specific adaptive capacity variables are associated with reporting changes in electricity prices.

Model 1 presents that those who reported losing access to the river were more likely to state the price of electricity increased (OR=1.78, p<0.05). Models 2 and 3 show that those with positive or negative prior knowledge about the construction of the dams were likelier to report that electricity prices increased (OR=2.33, p<0.01; OR=1.96, p<0.05). None of the control variables are associated with changes in electricity prices.

Contrary to our expectations, we did not find a relationship between the financial status of the household or education level with electricity prices. Our results support our hypothesis that health status would not have a significant relationship with electricity prices and that those that lost access to the river will be more likely to report electricity prices increased. As expected, those who said having prior knowledge about the dams were more likely to report an increase in electricity prices. Our results do not support the hypotheses that indicate a relationship between access to compensation or participation with electricity prices.

Table 27. Binary logistic regressions for electricity source, access, and price

Energy insecurity									
VARIABLES	Source Diesel Generators			Electricity access decreased			Electricity price increased		
	Model 1 OR(SE)	Model 2 OR(SE)	Model 3 OR(SE)	Model 1 OR(SE)	Model 2 OR(SE)	Model 3 OR(SE)	Model 1 OR(SE)	Model 2 OR(SE)	Model 3 OR(SE)
Generic Adaptive Capacity									
Finances decreased	1.07		1.03	1.94*		2.14**	1.17		1.04
	(0.24)		(0.24)	(0.51)		(0.60)	-0.32		-0.3
Lost river access	0.36***		0.43***	2.04**		1.74	1.78*		1.59
	(0.08)		(0.10)	(0.56)		(0.51)	-0.48		-0.47
Worse health	1.06		1.08	1.96**		2.17**	1.2		1.27
	(0.23)		(0.25)	(0.50)		(0.58)	-0.32		-0.36
Education	1.10		1.13	0.87		0.93	1.45		1.35
	(0.16)		(0.18)	(0.16)		(0.17)	-0.28		-0.28
Specific Adaptive Capacity									
Received Compensation		0.05**	0.05**		1.51	1.38		1.06	1.03
		(0.05)	(0.05)		(0.56)	(0.57)		-0.42	-0.43
Prior knowledge = 1, 1-YES		0.73	0.75		1.55	1.26		2.33**	1.96*
		(0.14)	(0.17)		(0.37)	(0.36)		-0.64	-0.6
Participated in meeting		0.47**	0.46**		0.79	0.76		1.04	1.04
		(0.12)	(0.13)		(0.21)	(0.23)		-0.32	-0.35
Control									
Resettled	0.08***	0.18***	0.18***	0.78	0.77	0.78	0.68	0.58	0.5
	(0.03)	(0.08)	(0.08)	(0.23)	(0.27)	(0.29)	-0.2	-0.21	-0.19
Female = 1, 1-Female	0.64*	0.55**	0.64	1.08	1.18	1.13	0.62	0.61	0.61
	(0.14)	(0.11)	(0.15)	(0.30)	(0.28)	(0.32)	-0.17	-0.16	-0.18
age of r	0.99	0.99	1.00	0.99	1.00	0.99	1.01	0.99	1
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	-0.01	-0.01	-0.01
Fisher or Farmer = 1, Fisher or Farmer	1.12	1.11	1.08	0.70	0.87	0.72	1.74	1.64	1.69
	(0.27)	(0.26)	(0.28)	(0.21)	(0.25)	(0.23)	-0.59	-0.56	-0.6
Constant	2.01	2.64*	2.24	0.19*	0.18***	0.10**	1.02	6.30***	1.4
	(1.35)	(1.03)	(1.59)	(0.14)	(0.08)	(0.08)	-0.81	-2.86	-1.16
Observations	511	607	485	493	582	468	472	548	448

seEform in parentheses; *** p<0.001, ** p<0.01, * p<0.05

Discussion

In this paper, we assess the adaptive capacities of local communities living nearby two large-scale hydroelectric dams in the Madeira Basin in the Brazilian Amazon a few years after the construction of the dams and how the adaptive capacities impact food and energy security. First, we will discuss our descriptive results about food and energy security with the literature on the social impacts of dams. Then we will discuss our results in the context of the hypotheses we stated above.

Food and energy security after dam development

Our study also presents dam construction's disruptive effects on household food security. Our findings show that more than 40% of the respondents reported a decrease in food availability and 80% in food access (price). The literature shows negative impacts on local's food security after dam construction (Cernea, 1997, 2000; Urban et al., 2015; Wiejaczka et al., 2018; Wilmsen et al., 2011; Yankson et al., 2018). Our results are aligned with the literature since food availability and access, the dimensions of food security assessed in our analysis, were negatively affected after the construction of the hydroelectric complex.

The results show that household energy security did not improve after constructing two large-scale dams in our study area. Here we describe how the four interconnected dimensions of energy security (availability, reliability, affordability, and sustainability) did not improve after the construction of the dams. First, almost a third of the respondents (35%) still rely on diesel generators for their energy supply, a source commonly used in off-grid communities in the Amazon. This is an unreliable, inefficient, and unsustainable electricity source (Brown et al., 2022). The use of diesel generators causes issues in terms of affordability, mainly due to the increase in the cost of fuel (Hidalgo-Leon et al., 2021; Sánchez et al., 2015), which is related to the low availability of electricity generated by diesel generators, households often use the generators only 4 hours per day. Using diesel generators is an unsustainable strategy; they generate greenhouse emissions and contaminate the area where they are located (Hidalgo-Leon et al., 2021). Half of the respondents noted that the availability of electricity decreased or stayed the same. And more than 80% of the respondents indicated electricity prices increased, showing that there were no fair and stable prices in the electricity service and that it was less affordable.

Effects of dam development on generic adaptive capacity

First, we expected that households' generic adaptive capacity would decrease due to the impacts on dam development. Our descriptive statistics are aligned with the literature, showing a decrease in the financial situation of communities nearby dams (Wilmsen et al., 2011). We showed that forty percent of the respondents reported a decrease in their financial situation, and only 29% stated their finances increased. These results portray negative impacts on the adaptive capacity of communities since there is an association between households with higher financial status and less severe adverse effects aftershocks (Lemos et al., 2016).

Also, more than half of the respondents described losing access to the river. Two aspects are important to highlight here. As reported in the literature, the construction of dams affects local communities access to natural resources (Siciliano & Urban, 2017). For instance, after resettlement, communities lose access to their natural resources since they are often relocated to urban areas far from the forests and rivers (Mayer et al., 2021). Also, dam construction blocks fish migration, which disrupts the fisheries in areas nearby the construction sites (Arantes et al., 2021; Castro-Diaz et al., 2018). For our case study, accessing the river is essential for rural communities since fishing is one of the most important livelihoods in the Amazon (Coomes et al., 2010; Doria & Lima, 2015; Isaac & Barthem, 1995; N. Smith, 1981). Losing access to the river, or natural capital, which is the basis of the livelihoods for local communities (Flora et al., 2015) affects actors' ability to respond to shocks. Chapters 3 and 4 of this dissertation show that their livelihoods are disrupted when local communities lose access to the river. For instance, losing fishing spots and fish species is related to food security issues and decreased fisheries yield.

Lastly, forty percent of the respondents noted their health status decreased. Scholars have described how dam construction affects local populations' health (Cernea, 1997, 2000). For instance, there is an increase in the transmission of sexual diseases (Grisotti, 2016), vector-borne diseases (Aeria, 2016), and mental health issues (Bui & Schreinemachers, 2011), among others. Households with good health are more able to react and respond to shocks.

Then, our findings support our first hypothesis; Figure 4 shows that the household's generic adaptive capacities were lower after the Jirau and Santo Antônio dam construction. In other words, the conditions that support people to respond to shocks, reduce adverse effects, recover and take advantage of new opportunities (Cinner et al., 2018) were affected and are lower now.

Specific adaptive capacities

In relation to specific adaptive capacity, our results highlight that households were not provided with the capacity to recover from the effects of dam construction. Our findings are aligned with the literature, showing issues in compensation strategies, starting with lack of compensation (Cernea, 2003; Mayer, Lopez, & Moran, 2022; Nakayama et al., 1999; Vanclay, 2017). Our findings show that 85% of the respondents did not get compensation, even though compensation is portrayed as a way provided by dam authorities and governments to adapt and recover from the adverse effects of dam construction (Cernea, 1997; Yu & Xu, 2016).

Likewise, as shown in Chapter 3, dam development lacks information transparency (Morvaridi, 2004; Mwangi, 2007; Okuku et al., 2016). Local actors have no access to information about the positive and negative effects that the construction of dams will bring to their lives and livelihoods. Our results show that 46% of the respondents did not have prior knowledge about dam development. Therefore, nearly half of the local actors did not have the opportunity to understand and make sense of the potential changes the dams would generate, which reflects a lack of adaptive capacity.

Communities living near the construction sites are not included in decision-making processes (Garcia et al., 2021; Mayer, Garcia, et al., 2022). Our results show that 70% of the respondents did not attend meetings before the dams were constructed. This highlights a lack of participation at even the lowest level of participation: attending a meeting. If people are invited to meetings, this is an opportunity for them to learn about the projects and could help them respond to the effects of dam development. Of course, if local actors are included in a participatory project that guarantees they can govern and make decisions over the projects (Arnstein, 1969), their adaptive capacity will increase.

Adaptive capacities and food security after dam construction

Our results show different associations between generic adaptive capacities and food security; we operationalized this relationship using a series of questions related to food security. We expected that households that reported lower generic adaptive capacities (financial status, access to natural resources, health status, and education level) were more likely to report that food availability decreased (See Table 24) . We observed that households that reported their finances decreased were more likely to state that food availability decreased, supporting our hypothesis. Likewise, the results support our hypothesis that households that reported their overall health status decreased were more likely to indicate decreased food availability. Contrary to our expectations, none of the models show a significant relationship between losing access to the river and reporting a decrease in food availability. This is unexpected since, as explained above, rural communities living nearby dam construction depend on natural resources for their livelihoods. This should be further explored since the literature has shown that communities affected by dams that lose access to natural resources, like rivers, reduce their protein intake. We did not find a significant relationship between education level and food availability change.

We expected households that reported lower specific adaptive capacities (knowledge, participation, compensation) were likelier to say that food availability decreased (See Table 24). Our results do not show any significant relation of specific adaptive capacities to explain changes in food availability since they are not statistically significant in any models. This could be related to the compensation programs' issues, the fact that not all affected communities had access to compensation, and the low level of participation promoted by dam developers.

We expected that households that reported lower generic adaptive capacities (financial status, access to natural resources, health status, and education level) were more likely to report that food prices increased (See Table 24). We observed that households that reported their access to the river decreased were more likely to state that food prices increased, supporting our hypothesis. However, our results do not show an association between the other three generic adaptive capacities and food prices, which does not support our hypotheses.

Contrary to our expectations, there were no significant relationships between specific adaptive capacities and changes in food prices. Our control variables have effects that are worth to be mentioned. The effect of being resettled was statistically significant in the models of food availability, indicating that those resettled were more likely to report a decrease in food availability. This result is aligned with the literature, showing that communities after resettlement suffer from food insecurity (Cernea, 1997). More should be explored about the effect of social characteristics, such as gender and age of the respondent, that were significant for reporting a decrease in food availability and an increase in food prices.

In brief, our results show that the adverse effects on generic adaptive capacity are associated with food insecurity—particularly the changes in finances, access to the river, and health. Those with lower generic adaptive capacity were more likely to report a decrease in food availability and an increase in food prices.

Adaptive capacities and energy security after dam construction

Our results show different associations between generic adaptive capacities and energy security; we operationalized this relationship using a series of questions related to energy security. We expected that households that reported lower generic adaptive capacities (household financial status, access to natural resources, health status, and education level) were more likely to report having diesel generators as their primary source of electricity (see Table 24).).

Our findings showed that those who reported losing access to the river were less likely to say that their primary source of electricity was diesel generators. However, our results do not show a significant relationship between the other dimensions of generic adaptive capacity and electricity source.

As expected, some specific adaptive capacities were associated with reporting a type of electricity source. Our findings support the hypotheses by showing that those who received compensation and participated in meetings before the construction of the dams were less likely to report that their primary source of electricity was diesel generators—an unreliable and unaffordable electricity source. However, we did not find a significant relationship between having prior knowledge about the dams and electricity sources.

As expected, those who reported a decrease in their finances were more likely to say their electricity access decreased. Contrary to our expectation, households that reported having lost access to the river were more likely to indicate their electricity access decreased. We also found a significant relationship between those who reported a decrease in their health status and a decrease in electricity access. We did not find any significant relationship between education level and electricity access. Contrary to our hypotheses, we did not find any significant relationship between specific adaptive capacities and electricity access.

Our results show a significant relationship between reporting losing access to the river and increasing electricity prices, supporting our hypothesis. As expected, we did not find any significant relationship between health status and the price of electricity. However, our results do not support the expectation that financial status and education level will be associated with reporting an increase in electricity prices.

We found that those who reported having positive or negative prior knowledge about the effects of dam construction were more likely to report high electricity prices, which supports our hypothesis. We did not find significant relationships between getting compensation or participating in a meeting and reporting changes in electricity prices.

Our control variables have effects worth mentioning. The impact of resettlement was statistically significant; those resettled were less likely to report having diesel generators as their primary electricity source. The effect of being female is significant; they were more likely to report their primary source of electricity was diesel generators.

Conclusions

In this study, we assessed generic and specific adaptive capacities and their effects on food and energy security. We found that the variables included in each adaptive capacity have different effects on food and energy security dimensions. Our results show that the household's financial status is significantly associated with food availability and electricity access. We found a significant relationship between access to the river, food price, electricity source, price, and access. There is a significant association between health status, food availability, and electricity access. None of our models showed a significant relationship between education level and any food or energy security dimension. This is worth to be discussed since the literature on adaptive capacity argues that the level of education influences the ability to respond to change (Lemos et al., 2016). However, given the context of the area of study, where traditional education levels are low, the effect of local ecological knowledge should be assessed in a future study. Local’s knowledge about their social-ecological context could also influence their ability to respond to shocks.

Our results align with the literature that argues that dam builders' efforts to respond to dams' impacts are ineffective (Bird & Wallace, 2001). We did not find any significant relationship between specific adaptive capacities and changes in food security. This could be related to four main aspects. First, the programs developed by dam authorities and governments to support the adaptation of local communities to the changes generated by the construction of dams are not holistic. They do not consider all aspects of locals' livelihoods. Second, locals are not compensated for the impacts generated by dams (Castro-Diaz et al., 2018; Mayer, Lopez, & Moran, 2022). If affected communities get compensation, it is not tailored to locals' needs and is insufficient (Cernea, 2008; Mayer, Lopez, & Moran, 2022). Third, dam authorities provide low opportunities for communities to participate in processes of decision-making (Garcia et al., 2021; Hay et al., 2019). Fourth, there is a lack of information about dam development, and the information available in the media portrays the dam authorities and government speech of economic progress, disregarding the negative effects of dams (Mourão et al., 2022).

There were few significant relationships between specific adaptive capacities and energy security. The effect of compensation and participation was only significant on the source of electricity. At the same time, the impact of prior knowledge was only significant on electricity prices. Our results did not show any significant relationship between specific adaptive capacities and access to electricity. These results show how the construction of dams is not improving the energy security of communities living nearby construction sites. If dams are generating electricity and disrupting the lives and livelihoods of those in the construction area, the least they could get is access to reliable, clean electricity; however, this was not the case for the eight communities included in our analysis.

The effect of resettling was statistically significant in the food availability and electricity source models. These results show the immense negative effects of resettlement on food security resettlement (Urban et al., 2015; Wiejaczka et al., 2018; Wilmsen et al., 2011; Yankson et al., 2018). and the few benefits that local communities get from dam development. Resettled households were more likely to be connected to the transmission line, but there was no significant relationship between resettlement and access to electricity.

Another control variable that had significant effects on the models of food and energy security was the gender of the respondent. The age of the respondent had a significant effect on all models for food security. These two results should be further explored since elders and women are often ignored in development, as shown in Chapter 3 and the literature (Downing & Garcia-Downing, 2009).

Given the reduction in generic adaptive capacities after the construction of the dams, our findings indicate that in the case of a new shock, households might not have the adaptive capacity to recover and address the associated effects. This is particularly significant for rural communities in the Amazon Basin, which need to build capacity to help anticipate and deal with not only the changes generated by the construction of dams but with climate change events that continue to escalate, such as El Niño (extreme droughts) and La Niña (severe floods) (Da Cunha Ávila et al., 2021). Anthropogenic activities like gold mining are increasing in the Amazon and are already affecting riverine communities' food security and health (Hallwass et al., 2020).

REFERENCES

Aeria, A. (2016). Economic development via dam building: The role of the state government in the sarawak corridor of renewable energy and the impact on environment and local communities. Southeast Asian Studies, 5(3), 373–412. https://doi.org/10.20495/seas.5.3_373

Agostinho, A. A., Pelicice, F. M., & Gomes, L. C. (2008). Dams and the fish fauna of the Neotropical region: impacts and management related to diversity and fisheries. Brazilian Journal of Biology, 68(4), 1119–1132. https://doi.org/10.1590/S1519-69842008000500019

Alho, C., Reis, R. E., & Aquino, P. P. U. (2015). Amazonian freshwater habitats experiencing environmental and socioeconomic threats affecting subsistence fisheries. Ambio, 412–425. https://doi.org/10.1007/s13280-014-0610-z

Allan Silva, R., Aldo Alves Pereira, J., Antônio Coimbra Borges, L., Arantes de Barros, D., & Carlos Costa Guimarães, J. (2013). Análise Do Processo De Licenciamento Ambiental Do Complexo Hidrelétrico Do Rio Madeira. Revista Científica ANAP Brasil, 6(8), 12–28. https://doi.org/10.17271/19843240682013703

Almeida, R. M., Hamilton, S. K., Rosi, E. J., Barros, N., Doria, C. R. C., Flecker, A. S., Fleischmann, A. S., Reisinger, A. J., & Roland, F. (2020). Hydropeaking operations of two run-of-river mega-dams alter downstream hydrology of the largest Amazon tributary. Frontiers in Environmental Science, 8, 120.

Amazon Dams Network. (2022). Amazon Dams Network. 2022. https://amazondamsnetwork.org/

Anderies, J. M. (2014). Embedding built environments in social-ecological systems: Resilience-based design principles. Building Research and Information, 42(2), 130–142. https://doi.org/10.1080/09613218.2013.857455

Arantes, C. C., Laufer, J., Pinto, M. D. da S., Moran, E. F., Lopez, M. C., Dutka-Gianelli, J., Pinto, D. M., Chaudhari, S., Pokhrel, Y., & Doria, C. R. C. (2021). Functional responses of fisheries to hydropower dams in the Amazonian Floodplain of the Madeira River. Journal of Applied Ecology, October, 1–13. https://doi.org/10.1111/1365-2664.14082

Araujo, N. C. de, & Moret, A. D. S. (2016). Direitos Humanos e HIdrelétricas: uma análise dos impactos socioambientais e econômicos gerados em Rondônia. Veredas Do Direito: Direito Ambiental e Desenvolvimento Sustentável, 13(26), 167. https://doi.org/10.18623/rvd.v13i26.622

Arnstein, S. R. (1969). A Ladder Of Citizen Participation. Journal of the American Planning Association, 35(4), 216–224. https://doi.org/10.1080/01944366908977225

Bacon, C. M., Sundstrom, W. A., Stewart, I. T., & Beezer, D. (2017). Vulnerability to Cumulative Hazards: Coping with the Coffee Leaf Rust Outbreak, Drought, and Food Insecurity in Nicaragua. World Development, 93, 136–152. https://doi.org/10.1016/j.worlddev.2016.12.025

Baran, E., & Myschowoda, C. (2009). Dams and fisheries in the Mekong Basin. Aquatic Ecosystem Health & Management, 12(3), 227–234. https://doi.org/10.1080/14634980903149902

Bebbington, A. (1999). Capitals and Capabilities, A Framework for Analyzing and rural livelihoods. World Development, 27(12), 2021–2044. https://doi.org/10.1016/S0305-750X(99)00104-7

Béné, C., Wood, R. G., Newsham, A., & Davies, M. (2012). Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes. In IDS Working Papers (Vol. 2012, Issue 405). https://doi.org/10.1111/j.2040-0209.2012.00405.x

Berkes, F., Colding, J., & Folke, C. (2008). Introduction. In F. Berkes, J. Colding, & C. Folke (Eds.), Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press.

Bird, J., & Wallace, P. (2001). Dams and development - An insight to the report of the world commission on Dams. Irrigation and Drainage, 50(1), 53–64. https://doi.org/10.1002/ird.11

Boanada Fuchs, V. (2015). Breaking the walls down: the practice of prior, free, and informed consultation between colonial designs and a new environmental governance framework (The Belo Monte case). Geneva (CH).

Brown, E., Johansen, I. C., Bortoleto, A. P., Pokhrel, Y., Chaudhari, S., Cak, A., Sulaeman, S., Castro-Diaz, L., Lopez, M. C., Mayer, A., Walgren, J., Müller, N., & Moran, E. (2022). Feasibility of hybrid in-stream generator-photovoltaic systems for Amazonian off-grid communities. PNAS Nexus, June, 1–9. https://doi.org/10.1093/pnasnexus/pgac077

Bruckner, T., Bashmakov, I. A., Mulugetta, Y., Chum, H., Navarro, A. de la V., Edmonds, J., Faaij, A., Fungtammasan, B., Garg, A., Hertwich, E., Honnery, D., Infield, D., Kainuma, M., Khennas, S., Kim, S., Nimir, H. B., Riahi, K., Strachan, N., Wiser, R., & Zhang, X. (2014). Energy Systems. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Bui, T. M. H., & Schreinemachers, P. (2011). Resettling Farm Households in Northwestern Vietnam: Livelihood Change and Adaptation. International Journal of Water Resources Development, 27(4), 769–785. https://doi.org/10.1080/07900627.2011.593116

Calvi, M. F., Moran, E. F., Silva, R. F. B. da, & Batistella, M. (2019). The construction of the Belo Monte dam in the Brazilian Amazon and its consequences on regional rural labor. Land Use Policy, 90(October 2019), 104327. https://doi.org/10.1016/J.LANDUSEPOL.2019.104327

Castro-Diaz, L., Garcia, M. A., Villamayor-Tomas, S., & Lopez, M. C. (2022). Impacts on locals' livelihoods of hydropower development in the Global South. Manuscript Submitted for Publication.

Castro-Diaz, L., Lopez, M. C., Moore, S., Radonic, L., & Hodbod, J. (2022). Multidimensional energy injustices and dams: The case of a fishers' community.

Castro-Diaz, L., Lopez, M. C., & Moran, E. (2018). Gender-Differentiated Impacts of the Belo Monte Hydroelectric Dam on Downstream Fishers in the Brazilian Amazon. Human Ecology, 46(3), 411–422. https://doi.org/10.1007/s10745-018-9992-z

Cavalcanti, E., Torquato, C. C., & Dias, K. (2020). As hidrelétricas de Santo Antonio e Jirau: Dano socioambiental e seus reflexos sobre o reassentamento Nova Mutum Paraná. REJUR-Revista Jurídica UFERSA, 4(7), 173–192.

Cella-Ribeiro, A., da Costa Doria, C. R., Dutka-Gianelli, J., Alves, H., & Torrente-Vilara, G. (2017). Temporal fish community responses to two cascade run-of-river dams in the Madeira River, Amazon basin. Ecohydrology, 10(8), 1–11. https://doi.org/10.1002/eco.1889

Cernea, M. (1997). The Risk and Reconstruction Model for Resettling displaced populations. World Development, 25(10), 1569–1587.

Cernea, M. (2000). Risks, Safeguards and Reconstruction: A model for population displacement and resettlement. Economic And Political Weekly, 35(41), 3659–3678. https://doi.org/10.2307/4409836

Cernea, M. (2003). For a new economics of resettlement: a sociological critique of the compensation principle. International Social Science Journal, 55(175), 1–2. https://doi.org/10.1111/1468-2451.5501019_3

Cernea, M. (2008). Compensation and benefit sharing: Why resettlement policies and practices must be reformed. Water Science and Engineering, 1(1), 89–120. https://doi.org/10.1016/S1674-2370(15)30021-1

Cernea, M., & Maldonado, J. (2018). Challenging the prevailing paradigm of displacement and resettlement. ts evolution, and constructive ways of improving it. In M. M. Cernea & J. K. Maldonado (Eds.), Challenging the Prevailing Paradigm of Displacement and Resettlement. I (pp. 1–42). Routledge.

Chester, L. (2010). Conceptualising energy security and making explicit its polysemic nature. Energy Policy, 38(2), 887–895. https://doi.org/10.1016/j.enpol.2009.10.039

Cinner, J. E., Adger, W. N., Allison, E. H., Barnes, M. L., Brown, K., Cohen, P. J., Gelcich, S., Hicks, C. C., Hughes, T. P., Lau, J., Marshall, N. A., & Morrison, T. H. (2018). Building adaptive capacity to climate change in tropical coastal communities. Nature Climate Change, 8(2), 117–123. https://doi.org/10.1038/s41558-017-0065-x

Coomes, O., Takasaky, Y., Abizaid, C., & Barham, B. L. (2010). Floodplain fisheries as natural insurance for the rural poor in tropical forest environments : evidence from Amazonia. Fisheries Management and Ecology, 6, 1–9.

Cornwall, A. (2008). Unpacking “Participation” Models, meanings and practices. Community Development Journal, 43(3), 269–283. https://doi.org/10.1093/cdj/bsn010

Da Cunha Ávila, J. V., Clement, C. R., Junqueira, A. B., Ticktin, T., & Steward, A. M. (2021). Adaptive Management Strategies of Local Communities in Two Amazonian Floodplain Ecosystems in the Face of Extreme Climate Events. Journal of Ethnobiology, 41(3), 409–426. https://doi.org/10.2993/0278-0771-41.3.409

da Silva, A. F., de Sousa, J. S., & Araujo, J. A. (2017). Evidences on multidimensional poverty in the Northern Region of Brazil | Evidências sobre a pobreza multidimensional na região Norte do Brasil | Pruebas en pobreza multidimensional del norte de Brasil. Revista de Administracao Publica, 51(2), 219–239.

Doria, C., Dutka-Gianelli, J., Athayde, S., Luiz, A. M. M. T., Brasil, W., Estupiñán, G. M. B., Hauser, M., Damme, P. A. Van, & Torrente-Vilara, G. (2018). Grandes hidrelétricas na Amazônia: impactos no recurso pesqueiro e na pesca artesanal, desafios e lições aprendidas na bacia do Rio Madeira. Revista Ciências Da Sociedade, 2(4), 79–106. https://doi.org/10.30810/rcs.v2i4.904

Doria, C., Dutka-Gianelli, J., Brasil de Sousa, S. T., Chu, J., & Garlock, T. M. (2021). Understanding impacts of dams on the small-scale fisheries of the Madeira River through the lens of the Fisheries Performance Indicators. Marine Policy, 125(May 2020), 104261. https://doi.org/10.1016/j.marpol.2020.104261

Doria, C., & Lima, M. A. L. (2015). Rio Madeira, Seus peixes e sua pesca. RiMa Editora.

Downing, T., & Garcia-Downing, C. (2009). Routine and Dissonant Culture: A theory about the psycho-socio-cultural disruptions of involuntary displacement and ways to mitigate them without inflicting even more damage. In Development and Dispossession: The Anthropology of Displacement and Resettlement (Issue June, pp. 225–253). https://doi.org/10.13140/RG.2.1.1121.7528

Eakin, H. C., Lemos, M. C., & Nelson, D. R. (2014). Differentiating capacities as a means to sustainable climate change adaptation. Global Environmental Change, 27(1), 1–8. https://doi.org/10.1016/j.gloenvcha.2014.04.013

EJAtlas. (2022). Global Atlas of Environmental Justice. Environmental Justice Atlas. https://ejatlas.org/

FAO, IDAD, UNICEF, WFP, & WHO. (2022). The State of Food security and nutrition in the world 2022. In Repurposing food and agricultural policies to make healthy diets more affordable. FAO. https://doi.org/10.1016/S2213-8587(22)00220-0

Fearnside, P. M. (1999). Social impacts of Brazil's Tucurui Dam. Environmental Management, 24(4), 483–495. https://doi.org/10.1007/s002679900248

Fearnside, P. M. (2014). Impacts of Brazil's Madeira River Dams: Unlearned lessons for hydroelectric development in Amazonia. Environmental Science and Policy, 38, 164–172. https://doi.org/10.1016/j.envsci.2013.11.004

Flecker, A. S., Shi, Q., Almeida, R. M., Angarita, H., Gomes-Selman, J. M., García-Villacorta, R., Sethi, S. A., Thomas, S. A., LeRoy Poff, N., Forsberg, B. R., Heilpern, S. A., Hamilton, S. K., Abad, J. D., Anderson, E. P., Barros, N., Bernal, I. C., Bernstein, R., Cañas, C. M., Dangles, O., … Gomes, C. P. (2022). Reducing adverse impacts of Amazon hydropower expansion. Science, 375(6582), 753–760. https://doi.org/10.1126/science.abj4017

Flora, C., Flora, J., & Gasteyer, S. (2015). Community Capitals and the Rural Landscape. In Rural Communities: Legacy + Change (pp. 5–32). https://doi.org/10.4324/9780429494697-2

Folke, C. (2016). Resilience (Republished). Ecology and Society. https://doi.org/10.5751/ES-09088-210444

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chappin, T., & Rockstrom, J. (2010). Resilience thinking: Integrating resiliencem adaptability and transformability. Ecology and Society, 15(4), 20–28. https://doi.org/10.5751/ES-03610-150420

Fonseca, I., Rezende, R., Oliveira, M., & Pereira, A. (2013). Audiências Públicas do Poder Executivo Federal: Fatores de Efetividade.

Fundo Brasil. (2022). Conselho Ribeirinho-Pará. Projetos. https://www.fundobrasil.org.br/projeto/conselho-ribeirinho/

Garcia, M. A., Castro-Díaz, L., Villamayor-tomas, S., & Lopez, C. (2021). Are large-scale hydroelectric dams inherently undemocratic ? Global Environmental Change, 71, 1–11. https://doi.org/10.1016/j.gloenvcha.2021.102395

Gerlak, A. K., Saguier, M., Mills-Novoa, M., Fearnside, P. M., & Albrecht, T. R. (2019). Dams, Chinese investments, and EIAs: A race to the bottom in South America? Ambio, February. https://doi.org/10.1007/s13280-018-01145-y

Goldthau, A., & Sovacool, B. (2012). The uniqueness of the energy security, justice, and governance problem. Energy Policy, 41, 232–240. https://doi.org/10.1016/j.enpol.2011.10.042

Goulding, M., Barthem, R., & Ferreira, E. (2003). The Smithsonian atlas of the Amazon.

Goulet, D. (2005). Global Governance, Dam Conflicts, and Participation. Human Rights Quarterly, 27(3), 881–907. https://doi.org/10.1353/hrq.2005.0036

Green, N., & Baird, I. G. (2016). Capitalizing on compensation: Hydropower resettlement and the commodification and decommodification of nature-society relations in Southern Laos. Annals of the American Association of Geographers, 106(4), 853–873.

https://doi.org/10.1080/24694452.2016.1146570

Grisotti, M. (2016). The Construction of Health Causal Relations in the Belo Monte Dam Context. Ambiente & Sociedade, 19(2), 287–304. https://doi.org/10.1590/1809-4422ASOC0252V1922016

Gugliano, A. A., & Luiz, A. M. M. T. (2019). Reducing public participation in a formal procedure: Limits of public meetings concerning the installation of the dams of the Madeira River (Brazilian Amazon). Environmental Quality Management, November 2006, 21–26. https://doi.org/10.1002/tqem.21631

Hallwass, G., da Silva, L., Nagl, P., Clauzet, M., & Begossi, A. (2020). Small-scale Fisheries, Livelihoods, and Food Security of Riverine People. In R. Silvano (Ed.), Fish and Fisheries in the Brazilian Amazon (pp. 23–39). https://doi.org/https://doi.org/10.1007/978-3-030-49146-8_3

Hay, M., Skinner, J., & Norton, A. (2019). Dam-Induced Displacement and Resettlement : A Literature Review FutureDAMS (Issue September).

Hess, C. E. E., Costa Ribeiro, W., & Wieprecht, S. (2016). Assessing Environmental Justice in Large Hydropower Projects: The Case of São Luiz do Tapajós in Brazil. Desenvolvimento e Meio Ambiente, 37, 91–109. https://doi.org/10.5380/dma.v37i0.45273

Hidalgo-Leon, R., Amoroso, F., Litardo, J., Urquizo, J., Torres, M., Singh, P., & Soriano, G. (2021). Impact of the reduction of diesel fuel subsidy in the design of an off-grid hybrid power system: A case study of the bellavista community in ecuador. Energies, 14(6). https://doi.org/10.3390/en14061730

IEA. (2021). Hydropower Special Market Report - Analysis and forecast to 2030. 126. https://iea.blob.core.windows.net/assets/4d2d4365-08c6-4171-9ea2-8549fabd1c8d/HydropowerSpecialMarketReport_corr.pdf.

Infoamazonia. (2022). Improving the position of hydroelectric plants would reduce impacts on the Pan-Amazon. https://infoamazonia.org/en/2022/02/25/improving-the-position-of-hydroelectric-plants-would-reduce-impacts-on-the-pan-amazon/

International Rivers. (2022). International Rivers. https://www.internationalrivers.org/

Isaac, V. J., & Barthem, R. (1995). Os Recursos Pesqueiros da amâzonia brasileira. Boletim Do Museu Paraense Emílio Goeldi. Série Antropologia, 11(2), 295–339.

Jakstas, T. (2020). What does energy security mean? In Energy Transformation Towards Sustainability (pp. 99–112). Elsevier Inc. https://doi.org/10.1016/B978-0-12-817688-7.00005-7

Kanbur, R. (2003). Development economics and the compensation principle. International Social Science Journal, 55(175), 27–35. https://doi.org/10.1111/1468-2451.5501003

Kedia, S. (2004). Changing food production strategies among Garhwali resettlers in the Himalayas. Ecology of Food and Nutrition, 43(6), 421–442. https://doi.org/10.1080/03670240490500271

Legese, G., Van Assche, K., Stelmacher, T., Tekleworld, H., & Kelboro, G. (2018). Land for food or power? Risk governance of dams and family farms in Southwest Ethiopia. Land Use Policy, 75, 50–59.

Lemos, M. C., Agrawal, A., Eakin, H., Nelson, D. R., Engle, N. L., & Johns, O. (2013). Building Adaptive Capacity to Climate CHange in Less Developed Countries. In Climate Science for Serving Society (pp. 437–457). https://doi.org/10.1007/978-94-007-6692-1

Lemos, M. C., Lo, Y. J., Nelson, D. R., Eakin, H., & Bedran-Martins, A. M. (2016). Linking development to climate adaptation: Leveraging generic and specific capacities to reduce vulnerability to drought in NE Brazil. Global Environmental Change, 39, 170–179. https://doi.org/10.1016/j.gloenvcha.2016.05.001

Li, D., Lu, D., Moran, E., & Bicudo da Silva, R. F. (2020). Examining Water Area Changes Accompanying Dam Construction in the Madeira River in the Brazilian Amazon. Water, 12(1921).

Martínez, V., & Castillo, O. L. (2016). The political ecology of hydropower: Social justice and conflict in Colombian hydroelectricity development. Energy Research and Social Science, 22, 69–78. https://doi.org/10.1016/j.erss.2016.08.023

Mathur, H. M. (2011). A historic Landmark in Development: Reflcting on the First Resettlement Policy, An interview with Professor Michael M.Cernea. In Resettlement News. https://www.brookings.edu/wp-content/uploads/2016/06/Resettlement-News_2011_MCernea.pdf

Mayer, A., Castro-Diaz, L., Lopez, M. C., Leturcq, G., & Moran, E. F. (2021). Is hydropower worth it? Exploring amazonian resettlement, human development and environmental costs with the Belo Monte project in Brazil. Energy Research and Social Science, 78(January), 102129. https://doi.org/10.1016/j.erss.2021.102129

Mayer, A., Garcia, M. A., Castro-Diaz, L., Lopez, M. C., & Moran, E. F. (2022). Pretend participation: Procedural injustices in the Madeira hydroelectric complex. Global and Environmental Change, 75, 102524. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2022.102524

Mayer, A., Lopez, M. C., Cavallini Johansen, I., & Moran, E. (2022). Hydropower, Social Capital, Community Impacts, and Self-Rated Health in the Amazon. Rural Sociology, 87(2), 393–426. https://doi.org/10.1111/ruso.12419

Mayer, A., Lopez, M. C., Leturcq, G., & Moran, E. (2022). Changes in Social Capital Associated with the Construction of the Belo Monte Dam: Comparing a Resettled and a Host Community. Human Organization, 81(1), 22–34. https://doi.org/10.17730/1938-3525-81.1.22

Mayer, A., Lopez, M. C., & Moran, E. F. (2022). Uncompensated losses and damaged livelihoods: Restorative and distributional injustices in Brazilian hydropower. Energy Policy, 167(September 2021), 113048. https://doi.org/10.1016/j.enpol.2022.113048

Moraes Ribeiro, A. (2013). Os Atingidos Pela UHE Santo Antonio Em Porto Velho, RO: Analise da comunidade Sao Domingos. Fundacao Universidade federal de Rondonia.

Moran, E. F. (2016). Roads and Dams: Infrastructure-Driven Transformations in the Brazilian Amazon. Ambiente & Sociedade 2016, XIX, 207–220. https://doi.org/10.1590/1809-4422ASOC256V1922016

Mortreux, C., & Barnett, J. (2017). Reflections on climate change communication research and practice in the second decade of the 21st century: What more is there to say? Wiley Interdisciplinary Reviews: Climate Change, 8, 1–12. https://doi.org/10.1002/wcc.467

Morvaridi, B. (2004). Resettlement, rights to development and the Ilisu dam, Turkey. Development and Change, 35(4), 719–741. http://ezproxy.msu.edu/login?url=https://search.proquest.com/docview/37977141?accountid=12598

Mourão, R. R., Neuls, G. S., & Ninni, K. (2022). Hydropower in the News : how Journalists do (not

) Cover the Environmental and Socioeconomic Costs of Dams in Brazil. Environmental Communication, 0(0), 1–14. https://doi.org/10.1080/17524032.2022.2115095

Mwangi, O. (2007). Hydropolitics, ecocide and human security in Lesotho: A case study of the Lesotho Highlands Water Project. Journal of Southern African Studies, 33(1), 3–17. https://doi.org/10.1080/03057070601136509

Nakayama, M., Yoshida, T., & Gunawan, B. (1999). Compensation Schemes for Resettlers in Indonesian Dam Construction Projects. Water International, 24(4), 348–355. https://doi.org/10.1080/02508069908692187

Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to Environmental Change: Contributions of a Resilience Framework. Annual Review of Environment and Resources, 32(1), 395–419. https://doi.org/10.1146/annurev.energy.32.051807.090348

Novoa Garzon, L. F. (2008). O Licenciamento Automático Dos Grandes Projeto De Infra Estrutura No Brasil O Caso Das Usinas No Rio Madeira. Universidade e Sociedade, 42(June), 37–57.

Obour, P. B., Owusu, K., Agyeman, E. A., Ahenkan, A., & Madrid, À. N. (2016). The impacts of dams on local livelihoods: a study of the Bui Hydroelectric Project in Ghana. International Journal of Water Resources Development, 32(2), 286–300. https://doi.org/10.1080/07900627.2015.1022892

Okuku, E. O., Bouillon, S., Ochiewo, J. O., Munyi, F., Kiteresi, L. I., & Tole, M. (2016). The impacts of hydropower development on rural livelihood sustenance. International Journal of Water Resources Development, 32(2), 267–285. https://doi.org/10.1080/07900627.2015.1056297

Orr, S., Pittock, J., Chapagain, A., & Dumaresq, D. (2012). Dams on the Mekong River : Lost fish protein and the implications for land and water resources. Global Environmental Change, 22(4), 925–932. https://doi.org/10.1016/j.gloenvcha.2012.06.002

Passos, R. M., & Praxedes, N. S. L. F. M. B. (2013). Reinserção em Nova Mutum Paraná e Condições de Vida dos Atingidos pela Construção da Hidrelétrica de Jirau em Rondônia . Revista de Administração e Negócios Da Amazônia, 5(1), 20–31.

Pretty, J. N. (1995). Participatory learning for sustainable agriculture. World Development, 23(8), 1247–1263. https://doi.org/10.1016/0305-750X(95)00046-F

Sánchez, A. S., Torres, E. A., & Kalid, R. A. (2015). Renewable energy generation for the rural electrification of isolated communities in the Amazon Region. Renewable and Sustainable Energy Reviews, 49, 278–290. https://doi.org/10.1016/j.rser.2015.04.075

Scabin, F. S., Junior, N. N. P., & Cruz, J. C. da C. (2014). Judicialização de grandes empreendimentos no Brasil: uma visão sobre os impactos da instalação de usinas hidrelétricas em populações locais na Amazônia. Revista Pós Ciências Sociais, 11(22), 130–150. http://www.periodicoseletronicos.ufma.br/index.php/rpcsoc/article/view/3418

Schlosberg, D. (2007). Distribution and Beyond: Conceptions of Justice in Contemporary Theory and Practice. In Defining Environmental Justice. Theories, Movements, and Nature (pp. 3–45). Oxford University Press.

Scudder, T., & Gay, J. (2011). A Comparative Survey of Dam-induced Resettlement in 50 Cases With the Statistical Assistance of John Gay. In The Future of Large Dams: Dealing with Social, Environmental. Institutional and Political Costs (pp. 56–86).

SEforALL. (2021). SEforALL Analysis of SDG7 Progress. In Sustainable Energy For All. https://www.seforall.org/data-stories/seforall-analysis-of-sdg7-progress-2021

Siciliano, G., & Urban, F. (2017). Equity-based Natural Resource Allocation for Infrastructure Development: Evidence From Large Hydropower Dams in Africa and Asia. Ecological Economics, 134, 130–139. https://doi.org/10.1016/j.ecolecon.2016.12.034

Siciliano, G., Urban, F., Tan-Mullins, M., Pichdara, L., & Kim, S. (2016). The political ecology of Chinese large dams in Cambodia: Implications, challenges and lessons learnt from the Kamchay Dam. Water (Switzerland), 8(9), 1–18. https://doi.org/10.3390/w8090405

Smith, L., & Frankenberger, T. (2018). Does Resilience Capacity Reduce the Negative Impact of Shocks on Household Food Security? Evidence from the 2014 Floods in Northern Bangladesh. World Development, 102, 358–376. https://doi.org/10.1016/j.worlddev.2017.07.003

Smith, N. (1981). Man, Fishes, and the Amazon. Columbia University Press.

Sovacool, B. (2011). Introduction. Defining, measuring, and exploring energy security. In The Routledge Handbook of Energy Security. https://doi.org/10.1080/10632921.2021.1894285

Sovacool, B., & Brown, M. A. (2010). Competing dimensions of energy security: An international perspective. In Annual Review of Environment and Resources (Vol. 35). https://doi.org/10.1146/annurev-environ-042509-143035

Sovacool, B., Burke, M., Baker, L., Kotikalapudi, C. K., & Wlokas, H. (2017). New frontiers and conceptual frameworks for energy justice. Energy Policy, 105, 677–691. https://doi.org/10.1016/j.enpol.2017.03.005

Stenberg, R. (2006). Damming the river: a changing perspective on altering nature. Renewable and Sustainable Energy Reviews, 10(3), 165–197. https://doi.org/10.1016/j.rser.2004.07.004

Thapa, B., Scott, C., Wester, P., & Varady, R. (2016). Towards characterizing the adaptive capacity of farmer-managed irrigation systems: learnings from Nepal. Current Opinion in Environmental Sustainability, 21, 37–44. https://doi.org/10.1016/j.cosust.2016.10.005

Trussart, S., Messier, D., Roquet, V., & Aki, S. (2002). Hydropower projects: A review of most effective mitigation measures. Energy Policy, 30(14), 1251–1259. https://doi.org/10.1016/S0301-4215(02)00087-3

United Nations. (2015). Transforming our world: the 2030 Agenda for Sustainable Development. https://www.unep.org/resources/report/transforming-our-world-2030-agenda-sustainable-development

Urban, F., Nordensvard, J., Siciliano, G., & Li, B. (2015). Chinese Overseas Hydropower Dams and Social Sustainability: The Bui Dam in Ghana and the Kamchay Dam in Cambodia. Asia and the Pacific Policy Studies, 2(3), 573–589. https://doi.org/10.1002/app5.103

Vanclay, F. (2017). Project-induced displacement and resettlement: from impoverishment risks to an opportunity for development? Impact Assessment and Project Appraisal, 35(1), 3–21. https://doi.org/10.1080/14615517.2017.1278671

von Sperling, E. (2012). Hydropower in Brazil: Overview of positive and negative environmental aspects. Energy Procedia, 18, 110–118. https://doi.org/10.1016/j.egypro.2012.05.023

Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G. D., & Pritchard, R. (2002). Resilience management in social-ecological systems: A working hypothesis for a participatory approach. Ecology and Society, 6(1). https://doi.org/10.5751/es-00356-060114

WCD. (2000). Dams and development: a New Framework for Decision-Making. In The report of the World Comission on Dams (Vol. 23, Issue November).

https://doi.org/10.1097/GCO.0b013e3283432017

White, S. (2011). Depoliticizing development: the uses and abuses of participation. 142–155. https://doi.org/10.1080/0961452961000157564

Wiejaczka, Ł., Piróg, D., Tamang, L., & Prokop, P. (2018). Local Residents' Perceptions of a Dam and Reservoir Project in the Teesta Basin, Darjeeling Himalayas, India. Mountain Research and Development, 38(3), 203. https://doi.org/10.1659/mrd-journal-d-16-00124.1

Williams, C., Fenton, A., & Huq, S. (2015). Knowledge and adaptive capacity. Nature Climate Change, 5(2), 82–83. https://doi.org/10.1038/nclimate2476

Wilmsen, B., Webber, M., & Yuefang, D. (2011). Development for whom? rural to Urban resettlement at the three Gorges Dam, China. Asian Studies Review, 35(1), 21–42. https://doi.org/10.1080/10357823.2011.552707

Winemiller, K. O., McIntyre, P. B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., Baird, I. G., Darwall, W., Lujan, N. K., Harrison, I., Stiassny, M. L. J., Silvano, R. A. M., Fitzgerald, D. B., Pelicice, F. M., Agostinho, A. A., Gomes, L. C., Albert, J. S., Baran, E., Petrere, M., … Saenz, L. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. Science, 351(6269), 128–129. https://doi.org/10.1126/science.aac7082

Yankson, P., Asiedu, A. B., Owusu, K., Urban, F., & Siciliano, G. (2018). The livelihood challenges of resettled communities of the Bui dam project in Ghana and the role of Chinese dam-builders. Development Policy Review, 36(October 2016), O476–O494. https://doi.org/10.1111/dpr.12259

Yu, B., & Xu, L. (2016). Review of ecological compensation in hydropower development. Renewable and Sustainable Energy Reviews, 55, 729–738. https://doi.org/10.1016/j.rser.2015.10.038

Chapter 3: Multidimensional and multitemporal energy injustices near hydropower dams

"To have justice, it becomes imperative first to identify injustices that exist and then address underlying causes." (Sultana, 2022, p. 119).

Introduction

The most recent Intergovernmental Panel on Climate Change report (IPCC, 2022) emphasizes the urgency of a swift energy transition from fossil fuels to cleaner, low-carbon energy sources. Countries in the Global South favor hydropower under the premise that it is a low-carbon and sustainable energy source that will satisfy their energy needs and will allow them to meet the anticipated increase in global energy demand of 50% by 2050 while facilitating the energy transition (Gutierrez et al., 2019; Kelly-Richards et al., 2017; Raimi et al., 2022). However, it is well documented that the construction of hydroelectric dams increases social and environmental inequities across multiple scales with the blunt of negative externalities born by nearby communities through loss of livelihoods and an increased in resource insecurity (Duarte et al., 2015; Hess et al., 2016; Hodbod et al., 2019; Nguyen et al., 2017). These effects include the displacement and resettlement of human populations with little or no prior consultation (Boanada Fuchs, 2016; Mayer, Lopez, & Moran, 2022; Trussart et al., 2002; von Sperling, 2012); increase in deforestation (Alho et al., 2015; Winemiller et al., 2016); reduced access to common-pool resources such as fisheries and forests (Arantes et al., 2021; Sayatham & Suhardiman, 2015), increased food insecurity (Begossi et al., 2018; Castro-Diaz et al., 2018), reduced social capital (Mayer, Lopez, Leturcq, et al., 2022; Tilt & Gerkey, 2016), among others. Collectively, the scholarships shows that the construction of dams deepened poverty and hunger near the construction areas (Goodland, 2010; Manorom et al., 2017; Richter et al., 2010; Yankson et al., 2018) and also negatively impacted the livelihoods of people in nearby communities (Arantes et al., 2021; Baird et al., 2021; Bro et al., 2018; Calvi et al., 2019; Cernea, 1997; Mayer et al., 2021; Pinto et al., 2022; Scudder, 2005). Some regions within the Global South that have seen an expansion in the construction of hydroelectric dams correspond to rich cultural and biological river basins, such as the Amazon and the Mekong (Moran et al., 2018; Winemiller et al., 2016; Zarfl et al., 2015). To illustrate, Brazil has the largest hydropower capacity in the world, after China (IEA, 2021), and in particular, the Amazon region has the greatest hydropower potential within the country, with 221 hydropower dams already operating and more than 200 dams planned (Flecker et al., 2022; Infoamazonia, 2022). It is noteworthy that while the energy from these hydroelectric facilities is generated in the Amazon, the main consumption centers are in the southern and coastal areas of the country, where larger cities and industries are concentrated (Hess et al. 2016). Belo Monte, the fourth largest dam in the world, is in the Amazon region. The government and the construction consortium promoted it as a project of national interest, disregarding local social-ecological impacts and opposition from civil society (Atkins, 2019b; Garcia et al., 2021). Belo Monte has been the focus of worldwide attention for over thirty years since social movements stopped its construction because of its potential environmental and social impacts. However, before the completion of the Environmental Impact Assessment (EIA) and against the recommendations of the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), President D. Rouseff gave her approval for the construction in 2011 (Fainguelernt, 2016; Mayer, Lopez, Leturcq, et al., 2022).

In this study, we use the tenets approach of energy justice to explore, from a multidimensional and multitemporal perspective, the injustices faced by the inhabitants of a community located downstream from the Belo Monte hydroelectric dam. We conduct a qualitative longitudinal analysis, which adds to the literature on dam development given that most studies around dams are done in one period of time (Braun, 2005) overlooking the temporal dynamics of the effects generated by dams (Kirchherr & Charles, 2016; Scudder, 2005). Energy justice provides a way to understand and assess energy dilemmas since it allows researchers to explore the uneven distribution of harms and benefits (distributional justice), wherein historically disadvantaged stakeholders are involved, misrecognized or ignored (recognition justice) and whether stakeholders were included in the processes of decision-making (procedural justice), and how to redress historic and longstanding injustices (restorative justice). More recently, energy justice scholars have started to include capabilities justice in the framework, since it complements the tenets by focusing on aspects of social, political, cultural, and economic well-being (Nussbaum, 2003, 2007; Robeyns, 2009; Sen, 2009). For example, in terms of energy access, it focuses on what people want to achieve with electricity access rather than the electricity itself (Day et al., 2016). But above all, capabilities justice acknowledges differential needs (Schlosberg, 2007).

In the Global South, most of the literature on energy justice focuses on integrating distributional and procedural justice (Lacey-Barnacle et al., 2020), downplaying the full multidimensionality of energy (in)justices. Likewise, the hydropower literature mainly focuses on distributional and procedural injustices faced by communities affected by the construction of dams (Mayer et al., 2021; Mayer, Garcia, et al., 2022; Siciliano & Urban, 2017). As such, some energy justice issues have been identified, such as the negative impacts of hydroelectric dams on communities living near the construction sites and their lack of participation in meaningful decision-making processes. But only focusing on two tenets misses a deeper understanding of how local actors experience the full range of energy justice issues (distributional, procedural, recognition, restorative, and capabilities justice) and how these interact to further the injustices. By understanding these issues altogether, we present a systematic overview of the energy injustices experienced by local actors in a community located downstream of the Belo Monte dam.

Given that temporality is another under-studied dimension, this paper will also demonstrate the value of understanding the time-dependent change processes and energy justice tenets in an area near a hydropower dam. In particular, we studied the energy injustices perceived by individuals living in a community downstream from the Belo Monte dam in three different periods: during the late stages of construction (2016) and the early period of operation (2017, 2019). Our approach highlights how energy injustices manifest themselves over time and how it may be possible to address them in the future.

We also contribute geographic insights, as this study expands the understanding of the justice implications of hydropower development in the Brazilian Amazon, a timely issue and a research gap in the literature (Athayde et al., 2019). Finally, this research is focused on a community downstream from the dam, who are under-represented in the literature. Communities living downstream from dams are not recognized as impacted in Environmental Impact Assessments (EIAs); therefore, dam developers do not involve them in decision-making (Castro-Diaz et al., 2018). Consequently, these communities are not compensated for the impacts they inevitably suffer. Dam developers and researchers have systematically ignored the effects on downstream communities in the Amazon Region and worldwide (Baird et al., 2021; Richter et al., 2010; Scudder, 2005). Thus, this paper illustrates how downstream communities face multidimensional and multitemporal energy injustices.

Theoretical Background

Energy Justice

This section reviews the literature on energy justice in the context of hydroelectric dams in the Global South. At its core, energy justice directs attention to how social effects related to energy are distributed across space and time to human populations (Sovacool & Dworkin, 2014). There are two main theoretical frameworks to explore energy justice. One focuses on a set of principles for providing tools for energy decisions. It considers availability, affordability, due process, transparency and accountability, sustainability, intragenerational equity, intergenerational equity, responsibility, resistance, and intersectionality (Sovacool et al., 2017; Sovacool & Dworkin, 2014, 2015). The second framework is motivated by the theories of justice, which initially considered three central tenets of justice: distribution, recognition, and procedural (Jenkins et al., 2016; McCauley et al., 2013). Then, Heffron and McCauley (2017) included restorative justice as a new tenet. In this study, we use the latter framework because it provides a multidimensional and systemic perspective of energy (in)justices and allows the inclusion of other justice theories, such as capabilities, that are meaningful to comprehend this case study. The principles framework assumes a universalism that risks being hegemonic. This is particularly salient for this study since the researchers are determining how to categorize issues of justice implicitly addressed by research participants.

Distributional justice refers to the uneven allocation of outcomes generated by an energy facility, such as electric infrastructure and long-term employment (Sovacool & Dworkin, 2014). It also recognizes the unequal distribution of environmental ills, such as water and air pollution (Jenkins et al., 2016; Munro et al., 2017). Distributional injustices can occur in energy consumption and production, and at different geographical scales. Regarding energy consumption, distributional justice is more clearly observed in disparities in energy poverty. Worldwide, over 759 million people have no reliable, safe, and efficient electricity access (SEforALL, 2021). In terms of hydropower development, communities living nearby the energy infrastructure face most of its damaging social and ecological impacts without necessarily benefiting from increased energy security, while farther away communities receive the benefits without experiencing the ills (Hess et al., 2016; Richter et al., 2010).

Procedural justice refers to the fairness of institutional decision-making processes (Schlosberg, 2007). It focuses on how decisions are made, who participates and the level of participation of each actor by looking, for example, at transparency and accessibility to participation and information (Jenkins et al., 2016; Lukasiewicz & Baldwin, 2017; McCauley et al., 2013; Sovacool & Dworkin, 2014). In the context of energy, it includes access to free prior informed consent, and fair representation in decision-making, among other (Sovacool & Dworkin, 2015). Research has shown that in the context of large-scale hydroelectric dams, there is a persistent lack of participation of local communities regardless of the state’s political regime (Garcia et al., 2021; Mayer, Garcia, et al., 2022).

Social and institutional structures are the basis for patterns of distribution and participation (Young, 1990). *Recognition justice* calls attention to local histories of oppression and exclusion; therefore, understanding how individuals and communities are recognized is inseparable from distributional and procedural justice (Fraser, 2000). Fraser (1996) explores injustices that are rooted in social patterns of representation and which include the following: cultural domination, subjection to patterns of interpretation associated with another culture hostile to one’s own; nonrecognition, being invisible; and disrespected, being routinely abused (Fraser, 1996). In theory, energy projects should acknowledge all those affected by energy injustices; however, there are often issues of misrecognition or complete lack of recognition that lead to the production and perpetuation of energy injustices. In the context of dam development, many of the communities around dams do not have political and economic clout; therefore, they have not been a priority of governments for consultation processes. As Randell and Klein (2021) argue, they are, in fact, invisible unless someone wants to extract their resources.

Restorative justice aims to repair the harm done to society or the environment, including those caused by energy projects. Restorative justice focuses on the victims; this tenet seeks recognition, reparation of their harm, and restoration of their dignity (Uprimny & Saffon, 2005). It aims to repair the damage concretely and symbolically; it requires "those who have been harmed to provide an opportunity to define their needs, rather than having others or a system define needs for them" (Zehr, 2015, p. 19). Heffron and McCauley (2017) state that including this justice tenet will open the possibility for decision-makers to consider the whole energy system (from project planning to operation), its issues, injustices, and means of rectification. It can help point where prevention strategies and restorations are needed along the way (Hazrati & Heffron, 2021; Heffron & McCauley, 2017). Thus, restorative justice could be implemented before an injustice occurs (to prevent it) and after an injustice has taken place (to restore it) (Hazrati & Heffron, 2021).

If an injustice occurs, restorative justice can be used to bring the voice of those impacted, which can lead to remediation of the harm and seeking compensation (Hazrati & Heffron, 2021). Scholars have recognized the mechanisms that could help prevent and mitigate potential injustices, such as EIAs and SIAs (Hazrati & Heffron, 2021; Siciliano et al., 2018). Unfortunately, as mentioned before, in the case of Belo Monte, the decision to build the dam was made before IBAMA approved the assessments. This, unfortunately, was not an exception in Brazil, as it has occurred for other important dams such as Jirau and Santo Antonio (Fearnside, 2020). As Moran et al. (2018) note, it is often the case that the EIAs and SIAs are done by the same firm in charge of the dam construction, putting in question the validity of the results. In addition, some have pointed to other significant problems, such as the lack of consistent rules for compensating populations for the impacts generated (World Bank, 2008).

Capabilities justice is based on the work of Amartya Sen (2009) and Martha Nussbaum (2003, 2007). The capabilities approach broadens the idea of justice by considering how the distribution of in(justices) affects people's well-being (Schlosberg, 2007) or their freedom to do things they value and the ability to achieve valuable functionings (Sen, 2009). Sen (2009) noted that there are two main reasons why freedom is valuable in this approach. First, it gives more opportunities to pursue objectives as it increases a person's ability to decide how they would like to live. Second, freedom has importance in the process of choice since it matters whether individuals are being forced into something because of others' imposed actions— in other words, freedom of choice matters for achieving justice (Sen, 2009). For instance, someone who decides to move from their house has more freedom than someone obliged to leave their home and be resettled. Nussbaum (2003, 2007) added a list of capabilities that are central requirements for a life with dignity - these capabilities are supposed to be a minimum account of social justice to secure human rights: *life*; *body health*; *bodily integrity*; *senses, imagination, and thought*; *emotions*; *practical reason*; *affiliation*; *other species*; *play;* and *control over one's environment* (Nussbaum, 2003, 2007). Capabilities justice calls to look beyond the resource to what people could do or become because of this resource. In this approach, energy systems should aim not only to provide energy but also to expand the capabilities of individuals, households, and communities to achieve more of their goals and reach their human potential.

Energy projects could impede or enhance people's capabilities (Moore, 2019). For instance, the lack of access to energy could limit an individual or a community's capability to live (by increased premature death). Also, constructing a hydroelectric dam could limit human capabilities for communities at the construction site or downstream, such as good health, shelter, and nourishment. In the case of dam projects, researchers have not simultaneously applied all the theories of justice described above. However, some scholars have studied the distribution of costs and benefits (Hay et al., 2019). For instance, Hess et al., (2016) showed that dams have poor performance in distributional justice because local communities suffer the negative impacts (burdens) but use very little of the electricity (benefits). Siciliano et al., (2019) explored Chinese investment in Global-South dam development. The authors reported procedural injustices in the form of poor participation of affected communities and distributional injustices due to irregular compensation. Mayer et al., (2021) found procedural injustices in the form of a lack of participation of local communities in the process of resettlement and compensation for the Belo Monte hydroelectric dam. Garcia et al. (2021) showed through a qualitative meta-analysis of 23 dams built between the 1950s and 2010s in the Global South that dams are undemocratic because the populations living nearby do not get to participate in the decisions, hence lacking procedural justice. Mayer et al. (2022) described that in the Madeira hydroelectric complex, composed of Santo Antônio and Jirau dams in Brazil, locals had faced procedural injustices such as limited access to information about the projects, and the participation process was not transparent.

The Belo Monte Hydroelectric Complex

Belo Monte is located in the Amazon region's Xingu River (Hess et al., 2016). The complex has two dams, *Pimental* and *Belo Monte.* The former supplies water to an artificial channel that powers the turbines at the central power station: *Belo Monte* (See Figure 10). The project is located near the municipalities of Vitória do Xingu and Altamira. The larger resettlement impact occurred in

Altamira, where over 20,000 people were resettled from low-lying areas and islands that would be flooded by the dams (Randell, 2016). Both sites suffered a demographic boom. Altamira's population increased from 85,000 in 2010 to approximately 150,000 in 2014 (Moran, 2016). After construction, the population settled back to about 100,000 with the departure of the construction personnel and the service sector (IBGE, 2021). During the construction boom period, wages doubled for the area, followed by a significant drop in employment in the late stages of construction in 2015 (Calvi et al., 2019).

In Altamira, the dam consortium constructed urban settlements for most of the resettlers (Atkins, 2019a; Mayer et al., 2021). However, scholars have noted that many resettlers were neither consulted nor had the opportunity to discuss and negotiate resettlement and compensation options (Boanada Fuchs, 2016; Mayer et al., 2021). In 2015, amid the construction, people in Altamira supported the construction of Belo Monte; they saw it as essential for Brazil and its economic development, but it was not generating any benefit to them locally (Mayer et al., 2021). In addition, early in the resettlement process, resettlers perceived a decline in their structural social capital as they were isolated and did not have schools, churches, or accessible transportation to Altamira upon arrival in the new settlements (Mayer, Lopez, Leturcq, et al., 2022). Even six years later (i.e., 2022), one of the authors of this paper observed on a visit to the area that public transportation to town was still limited to carry out necessary shopping and banking activities. The public school had only opened recently, six years after the people had been resettled.

This area provides the opportunity to study the multidimensional energy injustices faced by the inhabitants of a community located downstream from a hydroelectric dam.

Methods

Data collection

We collected data in Vila Nova, a community downstream from the Belo Monte hydroelectric dam, located in the Senador José Porfirio municipality in the State of Pará. We visited Vila Nova in the summers of 2016, during the late stages of construction, and in 2017 and 2019 , during the early operation of the dam project. We used in-depth semi-structured interviews and direct observation. We selected Vila Nova because of its location downstream from the dam, which meant that they were not considered as affected or a part of the EIA or SIA, and because its dwellers, riverine people or *Ribeirinhos,* depend primarily on fisheries in the river for their livelihoods (Berno de Almeida & Acevedo Marin, 2014). Riverine people are of diverse origins and ethnicities (Boanada Fuchs, 2015).

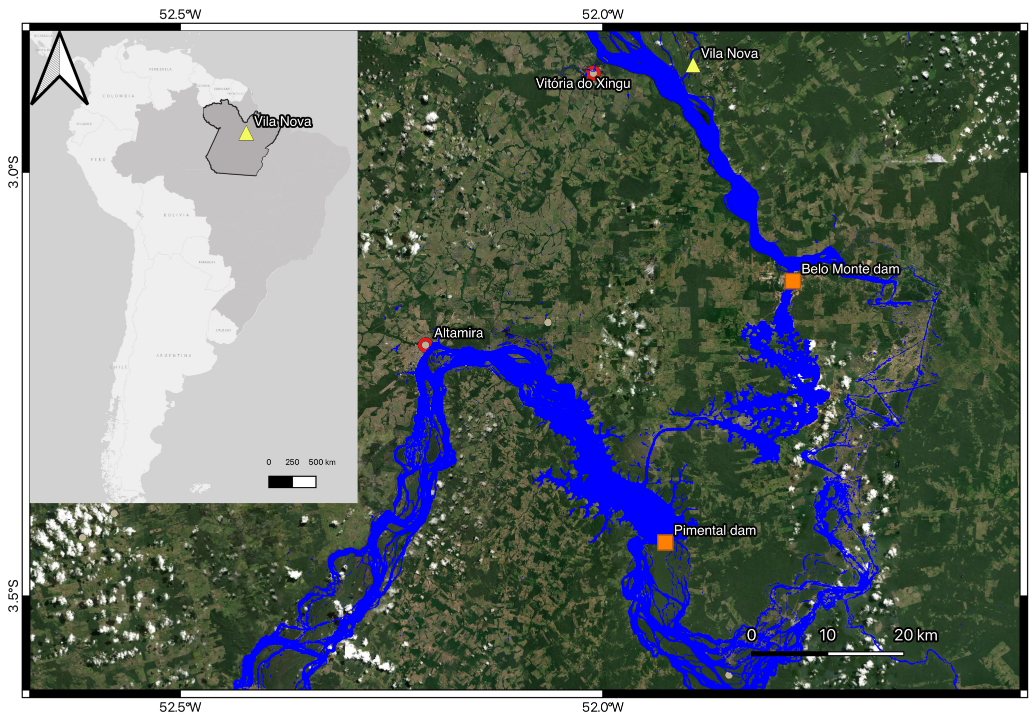


Figure 10. Area of study

The first visit to Vila Nova was in 2016 when the Belo Monte dam was still under construction, and the reservoir down from the Pimental dam had just been filled. At that time, the first author started observing people's everyday life and having informal conversations with locals, which allowed her to gain insights into the community dynamics and their perceptions of Belo Monte. She also identified the different activities men and women did to support their livelihoods and how these had begun to change because of the dam's construction. The second visit was in 2017 during the early operation of the Belo Monte dam—- still, only five of the eighteen turbines were under operation. The second visit aimed to follow up on the changes Belo Monte generated in the lives of Vila Nova inhabitants and the community. Finally, the third visit was in 2019, when Belo Monte already had 13 turbines in operation. During this visit, the first author collected data on the impacts of the dam on local actors' lives and livelihoods and how they were coping and adapting.

During the three years, we collected information through in-depth interviews to get detailed and comparable data over time (Hesse-Biber et al., 2006). We conducted in-depth interviews with women and men of different ages living in the community. This type of interview lets the interviewer guide the conversation with a semi-structured protocol and facilitates interviewees to bring up topics and issues of interest (Hesse-Biber et al., 2006). We designed the interview guide for 2016 to explore the community's context, their relationship with the dam, and how their lives and livelihoods were affected by the dam's construction. The interview guides for the following years were adapted to consider the information collected in the previous year related to the energy injustices perceived by local actors. We recorded the interviews with the interviewees' consent, and research assistants transcribed them verbatim. Through our visits, we conducted 70 interviews with the inhabitants of Vila Nova, including 22 women and 17 men. We interviewed 8 individuals at all three years of data collection, 13 on two occasions, and 20 only in one year. All interviews were conducted in Portuguese by the first author. Table 28 summarizes the number of participants per year of data collection. In 2017, we interviewed a group of fishers composed of 1 woman and two men; this is counted as one interview.

Table 28. Interview sample size

Participants	2016	2017	2019
Women	14	9	15
Men	14	8	11
Total	28	17	26

To better understand the context, we also conducted eight interviews with members of diverse organizations in the region. In 2016, we interviewed a member of the regional office of IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources), a representative from the Fishers Association, and a member of MAB (Movement of those Affected by Dams). In 2016 and 2019, we interviewed two members of LEME Engenharia, Tractebel (Energy, infrastructure, and engineering), a company that oversaw a project that monitors the fishing activity in the region financed by the dam consortium Norte Energia. In 2019, we also interviewed three members of the health center in Vila Nova.

Data analysis

After each fieldwork stage, the first author reviewed all the transcripts and compiled all information with field notes. For data analysis, we followed Miles, Huberman & Saldaña's (2014) system, which means we created a codebook based on deductive codes from the energy justice literature. The code book includes all tenets of energy justice described before as parent codes (Appendix 6). We used NVivo 12 for the coding process. To understand the issues of energy justice experienced by local actors, we coded all data for 2016, followed by data for 2017, and lastly, data collected in 2019. We extracted excerpts for each code, then summarized those in memos and compared them across data collection points.

Results

In this section, we present the energy justice issues experienced by the inhabitants of Vila Nova. First, we present a brief overview of the frequency of references that the researchers categorized as related to each tenet of justice (Figure 11). Then, we will provide a qualitative overview of each tenet followed by the in(justices) experienced by the inhabitants of Vila Nova. This case shows that, over the years, local actors have voiced issues of distributional justice more frequently, followed by capabilities, procedural, restorative, and recognition justice. This is not to say that distributional justice is more important than the others, but just that in the interviews, it came up more often. The analysis also suggests that other injustices came to the fore, gaining importance over time.

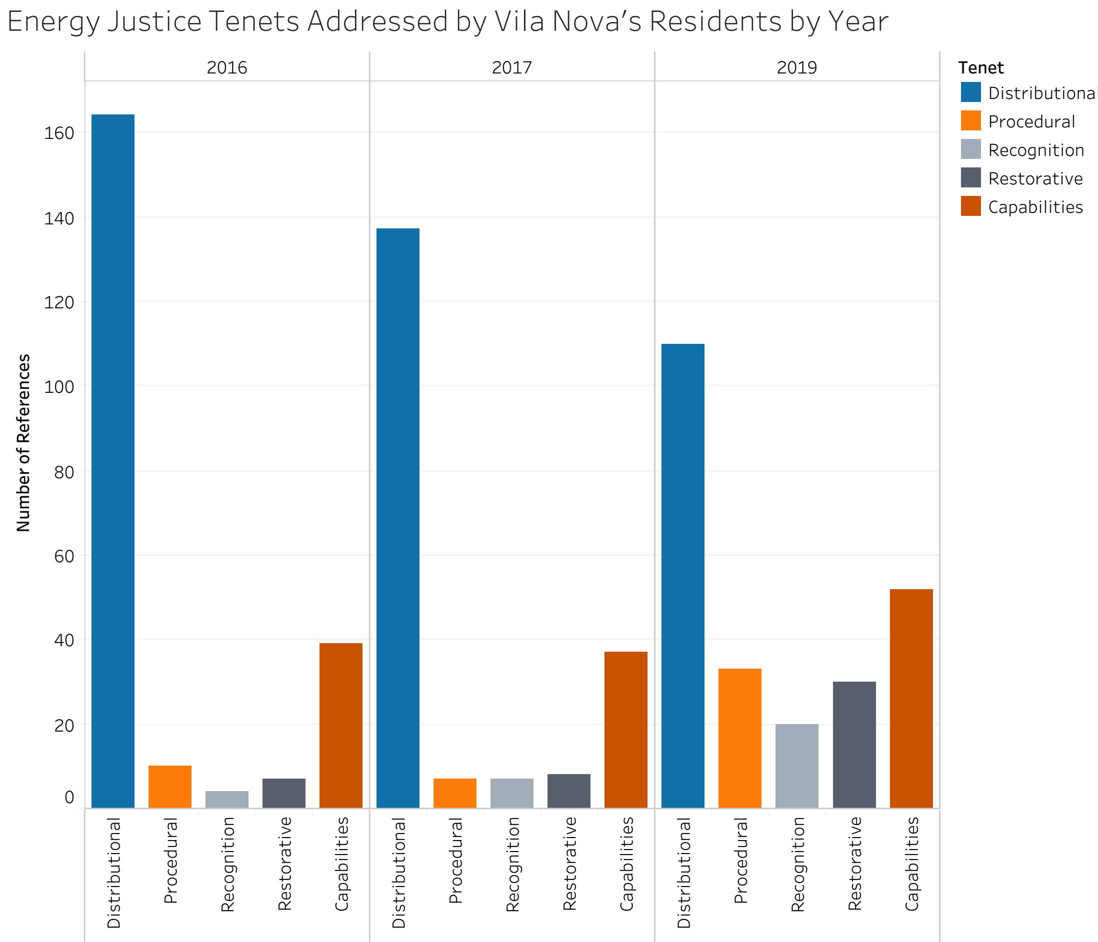


Figure 11. References to energy (in)justices over time

Distributional justice issues

Vila Nova's inhabitants experienced an unequal distribution of the benefits and negative impacts of the construction of Belo Monte. Data revealed social-ecological, economic, and energy access issues.

Social-ecological issues generated by the dam

Most of the references about distributional justice are focused on the negative impacts that interviewees faced because of the dam's effects on their social-ecological system and fishing livelihoods. As reported in the literature (Arantes et al., 2019, 2021; Castro-Diaz et al., 2018; Pinto et al., 2022) and articulated by the interviewees, dams generate immense impacts on fisheries by blocking fish migration. In Vila Nova, this led to the loss of the top predator fish species, which are economically very important because they are much larger and highly valued in the market. In 2016, locals reported high fish mortality as the floodgates from the dam closed, which immediately affected their livelihoods. The persistent blockage of the river to migrating species maintained this impact thereafter. While both men and women are active fishers in Vila Nova, their fishing practices differ due to patterns of mobility, fishing gear used, and household responsibilities. Men's perceptions of the effects of Belo Monte are related to the loss of fish, whereas women are concerned about their families' food security and the turbidity of the water. The decline in river water quality had an immediate social-ecological impact on women who washed their clothes in the water near the community and drew water from it to drink. Whereas the Xingu was a famously crystalline river, it has never returned to this clarity, even six years after the dam's completion. Thus, they highlight different but interconnected impacts.

The adverse effects on fisheries have been constant over the years of our study. From the first year of data collection, interviewees noted that Belo Monte changed the river's flow. Additionally, interviewees indicated that because of this change, specifically during the rainy season, fish could not travel upstream to spawn or eat the fruits and seeds from the flooded forest. Women also reported that they found dried eggs inside the fish when cleaning it for cooking. Fishers remarked on the loss of preferred fish species such as Filhote (*Brachyplatystoma filamentosum*) and Barba-Chata (*Pinirampus pirinampu*) and a decrease in the abundance of fish. A participant explained:

> We fish in the rainy season. The thing [the dam] diminished the number of fish. We used to catch many fish, but now in this season, there are few, very few fish. The water didn't rise anymore. If it had risen, I think the fish would have come here. But it did not. —Man, 2016.

In 2017, when the dam was starting its operation, interviewees continued describing the change in the river's flow, claiming that during the rainy season, the water level was lower than before the dam's construction, and fish abundance decreased. As they had done in the previous year, they described how the dam had affected fish migration and noticed more substantial periods of drought during the summer (June to November), limiting their transportation and affecting their fisheries.

> The fish disappeared, it's disappearing, and the water also dried up. It didn't rise the way it used to because when it was wintertime, from December on, this igapó [flooded forest] was filled up with water, and the fish used to eat there. Now it doesn't fill up with water like it used to. No! For example, here, on this island [pointing at a fishing spot], everything used to flood, it used to flood, half of the island used to flood, we used to go inside the bush and the forest. This one was only water. We used to catch a lot of *Pacu and Piau*, and now it doesn't fill up the way it used to; some parts stay dry, and water doesn't come in anymore. —Man 2017.

Three years after the dam's impoundment, in 2019 fishers described how fishing with their traditional fishing gear (e.g., hooks and lines) was getting more challenging because that gear was used to catch one fish at a time. According to the interviewees, catching one fish at a time required patience, but they used to catch enough for household consumption and sale. After Belo Monte, they could not catch enough fish for subsistence by using their traditional gear. In the last year of data collection, fishers continued catching fewer and smaller fish.

As the river flow during the rainy season was lower than before the dam's construction, interviewees described a dichotomy related to its impact on their lives. On the one hand, they said they enjoy the dam's flood control because the community was not getting flooded every rainy season as it used to. On the other hand, they are bearing negative impacts on their fisheries, such as a reduction in fish abundance, size, and diversity and adverse effects on water quality. An interviewee summarized this complexity: "*So, because for us here it is not so bad because we don't have to wade in the water, but it is bad for fishing because when the water does not rise, there are not many fish.*" —Woman, 2019.

Economic issues

The dam affected Vila Nova's inhabitants economically through loss of income and increased expenditures. During the first year of data collection, participants were concerned about the increase in the price of goods. The construction of dams aims to boost the economy in the regions where these are built. However, particularly in nearby Belo Monte, communities face steep inflation early in construction (Calvi et al., 2019). For the interviewees, the dam brought hunger to the community because goods such as beans and *farinha* (cassava flour), the basis of Brazilian meals, were becoming very expensive and harder to source. As illustrated by a participant,

> There are times when the money we have is not enough to buy gasoline, even gasoline has gone up a lot, and here it costs R$5. 1 Kg of farinha costs R$6. We get

R$3 for a kg of fish, then a kg of fish is not enough to buy a kg of Farinha.

—Woman, 2016.

In 2017, the distributional issues highlighted by interviewees mainly focused on the loss of fish of high economic importance. Still, they continued to notice the high prices of goods which put at risk their food security and their ability to pay for gas to go out fishing to gain the income they needed to buy these now expensive items. In addition, interviewees started to observe that inhabitants of other communities were receiving compensation for the negative impacts of the dam, but they were not. They even described how relatives and acquaintances got compensation because they had a house in areas the dam consortium considered impacted.

> My brother was compensated because he lived in a little house in Altamira, a risky area, so he ended up being compensated. He lived here in our community too, and after the dam, he was compensated. He left, bought a house, and went to town [Altamira] to take his kids to study. —Woman, 2017.

In 2019, interviewees described that some inhabitants living in the cities of Altamira and Vitória do Xingu (Figure 10) had received compensation (at the community and household level) from the dam's construction. In the case of Vitória do Xingu, the closest urban center to Vila Nova, participants noted that Norte Energia, the dam construction company, had built and paved roads, medical posts, schools, and offices for the fisheries association. They also knew that some people received other types of compensation, such as houses, due to resettlement from areas where the project would have flooded. As the harmful effects of the dam on the fisheries became a chronic problem to the household economy, the lack of financial compensation became a salient issue and a perceived example of energy injustice.

> I think that Vitória do Xingu benefited the most. Vitória, Altamira, and Belo Monte, these cities, received many benefits from the dam. In Vitória, now, you can walk around. Before the dam, it was a crappy town with an old street, all ugly, aging, and messed up. Today you can walk around Vitória, all those streets have sidewalks, and everything is paved. It seems that they are reforming the asphalt on the roads. Vitória looks very pretty. The money that came out for Vitória would have been enough to pave it all over, lay carpet, and tile the streets all over, and there was still much money left over. Right here, oh, there's nothing from the dam here. –Man, 2019.

Electricity access issues

Surprisingly, Vila Nova inhabitants do not get their electricity from Belo Monte. Locals relied on individual diesel generators, which worked 4 hours daily, usually between 6 pm and 10 pm. In the 2000s they got access to the Senador José Porfirio's grid and the Tucurui hydroelectric dam, 300 km from Vila Nova. Since then, they have had access to electricity 24 hours a day, but the service is unreliable due to grid instability. People in the Vila can spend between 2 and 5 days without access to the service, as described by one respondent:

> There are times when we go three days without power, there is no power, we keep calling and calling [the electricity provider], and the people don't come until one day they decide to show up and fix it. —Man, 2019.

The electricity generated by Belo Monte is connected to the national grid that provides the service to the south of the country (Becard & Macedo, 2014; Pedroso et al., 2018). Vila Nova's lack of reliable electricity leads to other challenges, such as limited access to drinking water, as the community needs electricity to pump water. Some households have water storage tanks that allow them to have drinkable water for several days without electricity.

In 2019, interviewees' references to the dam also began to express concerns about the high electricity prices in the community, which led some to stop paying for electricity and others to tap into their neighbors' meters illegally.

> And the energy bill is up from R$50.00 up to R$65.00. It has increased. It has increased because we used to pay 20, up to 20 and a bit we used to pay, at most 30! —Woman, 2019.

As described above, distributional justice refers to the uneven allocation of harms and benefits. Our data shows that Vila Nova dwellers did not access any benefit from the construction of the dam. For example, one of the positive aspects of dam development, often promoted by dam developers, is the increase in employment. But none of the interviewees benefited directly from jobs offered by dam authorities, at least they did not mentioned that during the interviews.

In sum, interviewees acknowledged how other communities in the region benefited from the construction in terms of infrastructure and compensation but they did not and they did not know why benefits were not distributed to them. The most common distributional injustices issues include decreased fisheries' access and increased goods' prices, including gasoline which is crucial for them to engage in fishing and access markets. In addition, they have unreliable and expensive energy that affects their water access. As presented in Figure 11, these references decreased over time because it was an overwhelming situation initially; most of the interviewees' livelihoods depended on the fisheries. However, towards the last data collection in 2019, Vila Nova dwellers started diversifying their livelihoods; for instance, some began to plant crops, and others worked on nearby farms. Over the years, distributional issues emerged in ninety-four percent of the interviews.

Procedural Justice issues

Respondents experienced two issues related to procedural justice. The first is their lack of participation in the decision-making processes, and the second is the insufficient access to information they received about the dam. Both are related to the perception of unfair decision-making and, consequently, the lack of trust in dam developers. This became more salient over time as they became more aware with how differently they were treated from other communities, which had been considered from the start as affected by the dam construction, whereas they were not.

Lack of participation in decision-making

As Vila Nova was not slated to be permanently flooded—arguably the most immediate and visible impact of dam construction—its inhabitants were not invited to be part of the decision-making processes regarding the dam's construction. They were not consulted before or during the construction of Belo Monte, which led them to argue that the dam was approved by others, particularly by the Brazilian president, but not by them. The lack of consultation is a clear example of a procedural injustice, as an interviewee stated:

> The president signed to have this dam because it would not have happened if it were up to us. We never signed any document to do this dam; everyone was right against it. It was only the president who signed, and that's why the dam was built. But before it was excellent, before this dam, it was very good. It was very nice for us to be here. —Woman, 2019

Dam developers held meetings before and during the construction of Belo Monte in the main urban centers: Altamira and Vitória do Xingu. However, these meetings had limited space and were primarily focused on discussing the technical aspects of the dam by the consortium engineering team (Fearnside, 2018). Those who attended the meetings were intimidated by the presence of the National Public Security Force (Força Nacional). When asked questions, while in the meetings, the representatives from the consortium, IBAMA, LEME, and the government, provided evasive answers (Barros & Ravena, 2011). Residents of Vila Nova were not invited because the community was not considered affected by the project. Still, locals belonging to a regional fisheries association highlighted that they had a representative in some of the meetings as the president of the fisheries' association was invited. This association represents fishers from different communities, including areas where invitations to meetings and compensation were given, such as Vitória do Xingu. Nevertheless, in 2019, interviewees noted that they did not participate in the decision-making process and that their voices were not heard.

> The president [from the fisheries association] used to come [to the community], and he said we would get compensations. By now, we should have been

> compensated. They said that people who were members of the fisheries' association would get something. But no one has come here, just the president, who held some meetings with the members. They said they would give some boats, motors, and many things. —Woman, 2019

In short, interviewees mentioned a lack of access to meaningful participation over the years of data collection.

Insufficient access to information

An issue that emerged in the first year and stood out throughout the years of fieldwork was a lack of transparency and limited access to information. Since 2012, Norte Energia, the dam developers, has been collecting data as part of the "Sustainable Fishing Incentive Project" in eight localities about regional fisheries, including Vila Nova. This includes data about fish landings, fishing partners, fishing gear, visited fishing spots, species caught and quantity, and expenses. The project aims to create a system for monitoring and fishing effort. However, from the perception of fishers, this data is used to keep a record for the fisher's association of who are active fishers – without the record, they argue they could lose their fishing permit. However, it is a one-way flow of information. While fishers in Vila Nova share data with Norte Energia (and, in fact, feel forced to do so), the aims, results, and analysis of the data collected for years have not been shared with Vila Nova's inhabitants.

> They [data collectors] fill a form and give a copy to us …I think an inspector from the Fisheries Association came to get some papers from her [data collector], the records with our information. We keep one, and she keeps the other to deliver it to the association; with these records, they know who fish and who doesn't. —Woman, 2016

Difficulties accessing information about the "Sustainable Fishing Incentive Project" demonstrates its lack of transparency. For instance, it requires an internet connection, which is unavailable in Vila Nova. But even with internet access, one needs to know where the report summary is located to find it.

Interviewees shared another issue of procedural justice in 2019; they said they learned from others in the region and local media about a crack in the dam infrastructure, which generated nervousness among the region's inhabitants. According to them, Norte Energia held an unannounced meeting in Vila Nova—which shows a deficiency in the process of information sharing—to deny the rumors, stating that the dam was in good condition. Despite the meeting, interviewees still did not trust the information provided by the dam developers. As one respondent noted, "*they* [Norte Energia] *say* *no. But it's true, and the guys went there to film [the crack]. It's true; it's not a lie, it's them* [Norte Energia] *lying to us*."—Woman, 2019.

The quotation above illustrates a damaged relationship between locals and dam developers. From the early stages of data collection, interviewees expressed lack of trust in dam developers that intensified over time. Procedural justice issues emerged in thirty percent of the interviews.

Recognition Justice Issues

Data collection revealed two aspects of misrecognition faced by Vila Nova inhabitants: nonrecognition and disrespect. As described above, they are *Ribeirinhos,* or riverine people, a diverse group from different ethnicities (Boanada Fuchs, 2015). Riverine people have historically been ignored in decision-making processes, and they rarely benefit from official programs and policies (Adams et al., 2006; Boanada Fuchs, 2015; Doria et al., 2017). Then, unfortunately, they were no included in the licensing process of the dam and weren't recognized as impacted by the construction of Belo Monte (ISA, 2015).

Nonrecognition

As Vila Nova is located downstream from the dam, Norte Energia considers it not directly affected by the construction of Belo Monte. Also, Vila Nova locals are riverine people, a historically marginalized group often ignored in decision-making processes (Doria et al., 2017). This context has resulted in different types of nonrecognition. Interviewees highlighted how the community's location and proximity to the dam had affected them in three main ways. Firstly, their narratives shared feelings of being ignored by the dam developers and the government. These were primarily based on the negative impacts generated by the construction of the dam on their lives (see distributional justice), how dam developers have overlooked them and excluded them from processes of participation, and have no shared information (see procedural justice).

Finally, Vila Nova inhabitants recognized the lack of compensation and mitigation as another aspect of nonrecognition. Participants questioned why other people in the area, like inhabitants of Altamira, were resettled and compensated while they were not, as described by the following quote:

> Here is a zone of risk; why they [Norte Energia] don't want to compensate us? They don't want to compensate us, so we will be able to leave the community. What do they see in Altamira? They resettled people from the risky areas, built houses for people, and resettled them to higher altitudes; why not us? We are human beings like them there, we need help, but no one wants to help us. Nobody, I have said that we are forgotten, only God for us! —Woman, 2019.

Disrespect

The second issue of misrecognition reflected in the data was disrespect. For instance, the state and the company did not see the Vila Nova dwellers as having the right to be informed and consulted before the dam's construction, and they did not participate in the decision-making process (See procedural justice), which the dwellers perceived as disrespect.

> They [Norte Energia] didn't come! They went to other places, but here we were abandoned. They did not come to talk. They said they wouldn't harm us here, but this area is where most harm has been done —Woman, 2016

Data revealed issues of disrespect before, during, and after the construction of the Belo Monte. In the last year of data collection, interviewees described how they felt mistreated and derided by the dam developers and the police when they attended protests against the construction of the dam. One woman said:

> There were even children there, pregnant women. I didn't think we would get out of there alive! Those police with those things [shields] in front of them to protect themselves, as if we were bandits. The president comes here and cries when he speaks. "Segundo" was injured, "Lorenzo" was injured…—Woman, 2019.

In sum, references to issues of recognition justice increased over the years of data collection (see Figure 11). Over the years of data collection, women made more references to nonrecognition issues than men. In the last year of data collection, men shared disrespect problems, mainly explaining how dam developers mistreated them, particularly when they participated in protests. Issues of recognition justice emerged in twenty percent of the interviews.

Restorative Justice Issues

Data revealed issues of restorative justice in the mechanisms of prevention and restoration. As mentioned, communities downstream from Belo Monte were not involved in the EIA. Therefore, there are no formal strategies for addressing and restoring the harms and injustices that Vila Nova locals experienced.

Since 2016, interviewees' references to restorative justice issues primarily describe how the dam negatively impacted their lives and livelihoods and how Norte Energia should compensate them. They argue that despite their closeness to the dam and the consequences experienced, Norte Energia has not provided any compensation (See distributional and recognition justice sections). This issue of lack of compensation and mitigation was predominant in the fieldwork.

Participants discussed how they deserve to be compensated to sustain their families in the aftermath of dam construction and its effects on their fisheries. They also have clear ideas of how they think their livelihoods and lives could be restored. We present here three examples of what they mentioned. First, locals discussed their interest in getting some support for creating economic projects in the community, as described by a participant.

> They [Norte Energia] should create an alternative to compensate the fishermen's economy. For example, they can do projects for planting crops and raising pigs, poultry, or fish, like aquaculture. Any project that could stimulate fishermen's economy. —Man, 2016

Participants also revealed their interest in getting not only monetary compensation for the livelihoods lost but also supplies for their fishing activity under the new circumstances,

> Because of the change in the water, fishermen's activity is more complicated... People who are members of the fisheries association should get boats, motors, other things…maybe a salary, R$2,000 or R$3,000 a month, for each fisherman, but nothing has come. —Woman, 2019

The third form that locals described as a way to remediate the harms that the dam had generated in their livelihoods is an opportunity to migrate to other places, as portrayed by the following quote,

> They [Norte Energia] should give each family at least something to get out of here [Vila Nova]. We should get compensated; we are many fishers and not asking too much. If they compensate me, I will be the first to leave. I don't even know, if they gave me the chance to go away with my family, it would be too good! I just want to get out of here and find a place where I can get a job to support my children and my grandchildren —Woman, 2019

During the last data collection year, participants pointed out that they were still waiting for compensation. However, they were not hopeful about getting anything because, at the time, dam developers took no responsibility for the impacts generated by the dam in Vila Nova and neither provided any support nor helped to restore people's livelihoods. As described by the following quote: "Because for us here, the dam has done nothing for us. Nothing, nothing, nothing, there is nothing done by the dam here" —Man, 2019.

In sum, the themes of restorative injustices were constant over time. Local's references to lack of restoration strategies, especially compensation, increased over time. Restorative issues emerged in twenty-eight percent of the interviews.

Capabilities Justice Issues

Data from interviews and observations revealed how the dam's construction impacted individuals' well-being.

Bodily health

Interviews revealed that locals in Vila Nova lack opportunities to be healthy and well-nourished. The dam directly affected the conditions for this capability. Women referred to issues such as lack of drinkable water and struggled to find the means to buy sufficient food for their households and their children. Children were reported to have limited access to food, eat less protein and consume more processed foods than before the dam construction. In particular, women argue that limited access to fish was impacting their household food security and, therefore, the well-being of their children. Since 2016, interviewers acknowledged that the dam had brought hunger, as described by a participant,

> After that dam, that dam ended with us here in Vila Nova, right? It ended with us. It's over! Because families are going hungry, hungry! Do you know what hunger is? They [fishers] go out in the morning and try to catch the fish to sell, to buy rice, Farinha, coffee, and sugar. If they don't fish, how can they live? Sometimes you can't even catch one fish to cook for your kids. – Woman, 2016.

Lack of bodily health will affect other human capabilities, such as access to a good education and the ability to imagine, putting the focus of individuals' lives just on surviving.

Emotional well-being

Locals shared the challenges that dam construction has generated in their lives and livelihoods over the years of data collection. Women and men shared their emotions and attachment to their livelihoods. Men described some impacts on their well-being, such as feeling that they could not provide for their families as they used to do before the dam's construction. They used to be proud of their activity as fishermen, but not anymore.

> So today, it's tough for you to get food for your family. Fishing is no longer enough to survive. I mean that it has changed a lot. And so, in general, fishing has changed. It has changed a lot. Today it is more difficult for fishermen to sustain their families on fish. –Man, 2016.

That feeling of being unable to provide for their families is related to a sense of hopelessness toward the future. Elderly males stated that fishing is the only activity they can do to survive. They argue that they are not in conditions like younger males to learn other skills or to migrate looking for other job opportunities. In contrast, younger fishers are changing how they fish to support their families, such as using fishing gear with smaller mesh sizes, even though they know these will negatively impact the ecosystem.

> Now, we are going in the easiest direction because it is difficult to catch with hooks or hand nets. Now we are going to use the fishing nets more often, that's why, as I just

> told you, in a couple of years, this other year, things are going to get even worse because the water is going to dry out, the fish that stay here in the river, in the river! They won't die this year, but the fish left in the breeding lake will die. The water will decrease, and if it dries up, they will all die. Then the sentence is that the fish will be reduced even more. —Man, 2016.

The possible crack of the dam generated concerns in the population, particularly women, who were living in fear. They believe they are at risk due to the dam. In 2016, they were primarily afraid that dam developers would open the floodgates during the rainy season and the community would be underwater. They highlighted that they live downstream from the dam, so they will be affected.

> Ah, we have been worried here for a while, all worried, all afraid, because people say that it was cracked, when the rain was pouring down, it was breaking, and everyone was desperate, worried, a guy filmed it and posted it on the Internet, understand! And we had a hard time here with fear. And there is nowhere to run, no! If God forbid it blows up, it will be like those [dams that have collapsed in other regions], which are killing many people; there's nowhere for us to run. Where will we run? If they [Norte Energia] have to warn us, they say that they're going to put sirens, they came here and said that they're going to put sirens, but until the siren goes off, we're already dead. –Woman, 2019.

In brief, men's references to emotional well-being were mainly focused on their livelihoods and challenges in providing for their families. On the other hand, women's references were about their experiences of living in a risky area.

Control over one's environment & capability to resist

As described in the procedural and recognition justice sections, the inhabitants of Vila Nova could not participate in the decision-making process over a project that affected their lives and livelihoods, reflecting a lack of control over their environment. But they shared that they participated in protests against the dam in the last years of data collection. These events were emotional and sensitive for some of the respondents. Additionally, the response of the police was aggressive, and two of the male interviewees were injured by rubber bullets. Despite locals' participation in protests, it was not effective. They were neither considered as affected by the dam's construction nor received compensation. They did not have the capabilities and power to change the decision of the government and the company.

Additionally, Vila Nova dwellers did not have the support from an organization to represent them that would exhibit a greater capability to resist successfully. They were not even included in the creation of the Conselho Ribeirinho (Riverine Council), in 2016 whose aim is to ensure access to justice and reparation for displaced riverine families (Fundo Brasil, 2022).

In summary, the references to issues of capabilities justice increased over the years of data collection. Women noted a lack of opportunities to be healthy and well-nourished. Fishers, both men and women, described how the dam affected their emotional well-being. Men focused on livelihoods, and women about living in fear. Lastly, locals participated in protests against the project. However, it was not effective. Capabilities issues emerged in sixty percent of the interviews.

Discussion and conclusions

This paper presents a systematic overview of the energy injustices experienced in the last stages of construction and early operation by a community located downstream from the Belo Monte dam. We used the distributional, procedural, recognition, restorative, and capabilities energy justice tenets to understand how local actors experience different energy justice issues over time and how these interact to further the injustices.

Our results show how the multidimensional and multitemporal perspectives are intertwined. As described, the nonrecognition of Vila Nova inhabitants (that has occurred in all stages of the dam construction) has enhanced other types of injustices. To illustrate, our results portrayed a reinforcing feedback loop between a lack of recognition and procedural injustices. As Schlosberg (2007, p. 26) describes, "If you are not recognized, you do not participate; if you do not participate, you are not recognized." We explained how dam developers did not recognize Vila Nova as impacted by the project because of its location downstream from the dam, and therefore they were not included in the EIA, which is intended to be a mechanism of prevention and restoration, and were not involved either in the participation processes previous to the construction, reflecting procedural issues. These two facts perpetuated the marginalization of this community, leaving them in a desperate situation.

The case of Vila Nova shows how the injustices faced by groups with non-political power are overlooked and hidden by the political and economic interests of the elites. This reflects an intersection between recognition and restorative justice since the impacts of the dam on this riverine community belonging to a historically marginalized group were overlooked, and their voices had not been heard. Nonetheless, affected communities have clear ideas of how they would like to have their lives restored. Unfortunately, they have not been offered any help, perpetuating the injustices riverine communities face.

This study includes capabilities justice, and we showed how it intersects with other types of justices and how capabilities injustice becomes more explicit over time. Most of the work on capabilities and energy justice has focused on energy poverty and how access or lack of access to the resource has expanded or limited people's capabilities (Melin et al., 2021). In this study, we brought capabilities justice to the context of energy production in a community affected by the sitting of infrastructure but also lacking reliable electricity access. By exploring the energy justice issues of Vila Nova locals through capabilities lenses, we were able to get a deep understanding of how local's capabilities were deprived and focus more on the outcomes (emotional well-being, bodily health, control over their own environment) than the resources (e.g., lack of electricity, fisheries declining, etc.). Furthermore, capabilities contributed to the results by bringing a comprehensive well-being approach. This allowed us also to highlight intra-community and gender differences. We explored how the construction of Belo Monte impacted an individual's well-being and found similar trends due to the negative impacts on the social-ecological system. Women described their concerns regarding their emotional well-being and their children's food security, while elders noted how young people use other fishing gear and migrate in case of need, but they felt trapped in the situation without options. These results show how dam developers and governments need to realize that dams generate differentiated impacts, and more importantly, they need to implement ways to alleviate those impacts. This is not an isolated case since development programs frequently misrecognize children, the elderly, the disabled, and people without land (Downing & Garcia-Downing, 2009). This counterbalanced the fact that dam development projects describe affected people as having genderless identities (Mehta & Srinivasan, 2000) rather than people with different identities, values, aspirations, and needs, who will be impacted differently.

Methodologically, our case study exemplifies the need for longitudinal studies to understand the complexity of energy justice issues, highlighting three major trends. First, a temporal dimension: individuals faced multiple and different energy injustices at different stages of the dam construction. We presented how some energy (in)justices were more predominant early in the data collection (e.g., distributional issues from the impacts on fisheries), while others emerged at the end of the study (e.g., capability to resist). Second, the severity of some issues changed over time. For instance, the distributional issues on fisheries generated other (in)justices over time, such as a reduction in fish protein availability, leading to health and loss of emotional well-being in later years. Third, the qualitative research design allowed us to get in-depth information and build trusting relationships with the inhabitants of Vila Nova, which provided the space for participants to share emotional and very personal experiences and fears associated with the dam.

This study provides a clear example of a disconnect between energy policymaking and communities living downstream of construction sites, but also a need to revise the energy sources associated with modern energy transition. Hydroelectric dams could help decarbonize energy systems. However, as this paper shows, dam construction generates multidimensional and multitemporal energy injustices perpetuating structural inequalities in marginalized communities. A just energy transition should look beyond low carbon emissions in energy production. Then, the construction of energy infrastructure should address energy injustices and provide fair and equitable processes that consider aspects of gender, ethnicity, race, and class.

REFERENCES

Adams, C., Murrieta, R., & Neves, W. (2006). Sociedades caboclas amazônicas: modernidade e invisibilidade. Annablume.

Alho, C., Reis, R. E., & Aquino, P. P. U. (2015). Amazonian freshwater habitats experiencing environmental and socioeconomic threats affecting subsistence fisheries. Ambio, 412–425. https://doi.org/10.1007/s13280-014-0610-z

Arantes, C. C., Fitzgerald, D. B., Hoeinghaus, D. J., & Winemiller, K. O. (2019). Impacts of hydroelectric dams on fishes and fisheries in tropical rivers through the lens of functional traits. Current Opinion in Environmental Sustainability, 37, 28–40. https://doi.org/10.1016/j.cosust.2019.04.009

Arantes, C. C., Laufer, J., Pinto, M. D. da S., Moran, E. F., Lopez, M. C., Dutka-Gianelli, J., Pinto, D. M., Chaudhari, S., Pokhrel, Y., & Doria, C. R. C. (2021). Functional responses of fisheries to hydropower dams in the Amazonian Floodplain of the Madeira River. Journal of Applied Ecology, October, 1–13. https://doi.org/10.1111/1365-2664.14082

Athayde, S., Mathews, M., Bohlman, S., Brasil, W., Doria, C. R., Dutka-Gianelli, J., Fearnside, P. M., Loiselle, B., Marques, E. E., Melis, T. S., Millikan, B., Moretto, E. M., Oliver-Smith, A., Rossete, A., Vacca, R., & Kaplan, D. (2019). Mapping research on hydropower and sustainability in the Brazilian Amazon: advances, gaps in knowledge and future directions. Current Opinion in Environmental Sustainability, 37, 50–69. https://doi.org/10.1016/j.cosust.2019.06.004

Atkins, E. (2019a). Damming the Amazon. In Contesting Hydropower in the Brazilian Amazon. Routledge.

Atkins, E. (2019b). Disputing the “National Interest”: The depoliticization and repoliticization of the Belo Monte Dam, Brazil. Water (Switzerland), 11(1). https://doi.org/10.3390/w11010103

Baird, I. G., Silvano, R. A. M., Parlee, B., Poesch, M., Maclean, B., Napoleon, A., Lepine, M., & Hallwass, G. (2021). The Downstream Impacts of Hydropower Dams and Indigenous and Local Knowledge: Examples from the Peace–Athabasca, Mekong, and Amazon. Environmental Management, 67(4), 682–696. https://doi.org/10.1007/s00267-020-01418-x

Barros, T. A., & Ravena, N. (2011). Representações sociais nas audiências públicas de Belo Monte: do palco ao recorte midiático. IV Encontro Da Compolítica, Na Universidade Do Estado Do Rio de Janeiro, 1–20. https://ipea.gov.br/participacao/images/pdfs/thiago-almeida-barros.pdf

Becard, D. S. R., & Macedo, B. V. de. (2014). Corporações multinacionais chinesas no Brasil: Estratégias e implicações nos setores de energia e telecomunicações. Revista Brasileira de Politica Internacional, 57(1), 143–161. https://doi.org/10.1590/0034-7329201400108

Begossi, A., Salivonchyk, S. V., Hallwass, G., Hanazaki, N., Lopes, P. F. M., Silvano, R. A. M., Dumaresq, D., & Pittock, J. (2018). Fish consumption on the amazon: A review of biodiversity, hydropower and food security issues. Brazilian Journal of Biology, 79(2), 345–357. https://doi.org/10.1590/1519-6984.186572

Berno de Almeida, A. W., & Acevedo Marin, R. E. (2014). Pescadores, ribeirinhos e indígenas: mobilizações étnicas na região do Rio Xingu: resolução não negociada dos conflitos na usina hidrelétrica de Belo Monte. In J. Pacheco De Oliveira & C. Cohn (Eds.), Belo Monte e a questão indígena.

Boanada Fuchs, V. (2015). Breaking the walls down: the practice of prior, free, and informed consultation between colonial designs and a new environmental governance framework (The

Belo Monte case). Geneva (CH).

Boanada Fuchs, V. (2016). Blaming the weather, blaming the people: Socio-environmental governance and a crisis attitude in the brazilian electricity sector. Ambiente & Sociedade, 19(2), 221–246. https://doi.org/10.1590/1809-4422ASOC0260R1V1922016

Braun, Y. (2005). Resettlement and Risk: Women's Community Work in Lesotho. Advances in Gender Research, 9, 29–60. https://doi.org/10.1016/S1529-2126(05)09006-5

Bro, A. S., Moran, E., & Calvi, M. F. (2018). Market participation in the age of big dams: The Belo Monte hydroelectric dam and its impact on rural Agrarian households. Sustainability (Switzerland), 10(5). https://doi.org/10.3390/su10051592

Calvi, M. F., Moran, E. F., Silva, R. F. B. da, & Batistella, M. (2019). The construction of the Belo Monte dam in the Brazilian Amazon and its consequences on regional rural labor. Land Use Policy, 90(October 2019), 104327. https://doi.org/10.1016/J.LANDUSEPOL.2019.104327

Castro-Diaz, L., Lopez, M. C., & Moran, E. (2018). Gender-Differentiated Impacts of the Belo Monte Hydroelectric Dam on Downstream Fishers in the Brazilian Amazon. Human Ecology, 46(3), 411–422. https://doi.org/10.1007/s10745-018-9992-z

Cernea, M. (1997). The Risk and Reconstruction Model for Resettling displaced populations. World Development, 25(10), 1569–1587.

Day, R., Walker, G., & Simcock, N. (2016). Conceptualising energy use and energy poverty using a capabilities framework. Energy Policy, 93, 255–264. https://doi.org/10.1016/j.enpol.2016.03.019

Doria, C., Athayde, S., Marques, E. E., Lima, M. A. L., Dutka-Gianelli, J., Ruffino, M. L., Kaplan, D., Freitas, C. E. C. C., & Isaac, V. N. (2017). The invisibility of fisheries in the process of hydropower development across the Amazon. Ambio, 47(4), 453–465. https://doi.org/10.1007/s13280-017-0994-7

Downing, T., & Garcia-Downing, C. (2009). Routine and Dissonant Culture: A theory about the psycho-socio-cultural disruptions of involuntary displacement and ways to mitigate them without inflicting even more damage. In Development and Dispossession: The Anthropology of Displacement and Resettlement (Issue June, pp. 225–253). https://doi.org/10.13140/RG.2.1.1121.7528

Duarte, B., Boelens, R., & Yacoub, C. (2015). Hidroeléctricas, ¿energía limpia o destrucción socioecológica? In C. Yacoub, B. Duarte, & R. Boelens (Eds.), Agua y Ecología Política: El extractivismo en la agroexportación, la minería y las hidroeléctricas en Latinoamerica. Abya-Yala.

Fainguelernt, M. (2016). A trajetoria historica do processo de licenciamento ambiental da usina hidreletica de Belo Monte. Ambiente & Sociedade, XIX(2), 247–265.

Fearnside, P. (2018, March). Belo Monte : Lições da Luta 11 – A farsa da audiência pública. Amazonia Real, 5–8. http://philip.inpa.gov.br/publ_livres/2018/Belo_Monte_Luta-11-A_farsa_da_audiencia_publica.pdf

Fearnside, P. (2020). Environmental justice and Brazil's Amazonian dams. In Landscapes of Inequity: The Quest for Environmental Justice in teh Andes/Amazon Region (pp. 92–96). University of Nebraska Press.

Flecker, A. S., Shi, Q., Almeida, R. M., Angarita, H., Gomes-Selman, J. M., García-Villacorta, R., Sethi, S. A., Thomas, S. A., LeRoy Poff, N., Forsberg, B. R., Heilpern, S. A., Hamilton, S. K., Abad, J. D., Anderson, E. P., Barros, N., Bernal, I. C., Bernstein, R., Cañas, C. M., Dangles, O., … Gomes, C. P. (2022). Reducing adverse impacts of Amazon hydropower expansion. Science, 375(6582), 753–760. https://doi.org/10.1126/science.abj4017

Fraser, N. (1996). Social Justice in the Age of Identity Politics: Redistribution, Recognition, and Participation. The Tanner Lectures on Human Values.

Fraser, N. (2000). Rethinking Recognition. New Left Review, 3.

Fundo Brasil. (2022). Conselho Ribeirinho-Pará. Projetos. https://www.fundobrasil.org.br/projeto/conselho-ribeirinho/

Garcia, M. A., Castro-Díaz, L., Villamayor-tomas, S., & Lopez, C. (2021). Are large-scale hydroelectric dams inherently undemocratic ? Global Environmental Change, 71, 1–11. https://doi.org/10.1016/j.gloenvcha.2021.102395

Goodland, R. (2010). Viewpoint - The World Bank versus the World Commission on Dams. Water Alternatives, 3(2), 384–398.

Gutierrez, G. M., Kelly, S., Cousins, J. J., & Sneddon, C. (2019). What makes a megaproject? A review of global hydropower assemblages. Environment and Society: Advances in Research, 10(1), 101–121. https://doi.org/10.3167/ares.2019.100107

Hay, M., Skinner, J., & Norton, A. (2019). Dam-Induced Displacement and Resettlement : A Literature Review FutureDAMS (Issue September).

Hazrati, M., & Heffron, R. J. (2021). Conceptualising restorative justice in the energy Transition: Changing the perspectives of fossil fuels. Energy Research and Social Science, 78(May). https://doi.org/10.1016/j.erss.2021.102115

Heffron, R. J., & McCauley, D. (2017). The concept of energy justice across the disciplines. Energy Policy, 105(March), 658–667. https://doi.org/10.1016/j.enpol.2017.03.018

Hess, C. E. E., Costa Ribeiro, W., & Wieprecht, S. (2016). Assessing Environmental Justice in Large Hydropower Projects: The Case of São Luiz do Tapajós in Brazil. Desenvolvimento e Meio Ambiente, 37, 91–109. https://doi.org/10.5380/dma.v37i0.45273

Hesse-Biber, Sharlene, N., & Leavey, P. (2006). The Practice of Qualiative Research. Thousand Oaks: Sage Publications.

Hodbod, J., Stevenson, E. G. J., Akall, G., Akuja, T., Angelei, I., Bedasso, E. A., Buffavand, L., Derbyshire, S., Eulenberger, I., Gownaris, N., Kamski, B., Kurewa, A., Lokuruka, M., Mulugeta, M. F., Okenwa, D., Rodgers, C., & Tebbs, E. (2019). Social-ecological change in the Omo-Turkana basin: A synthesis of current developments. Ambio, 48(10), 1099–1115. https://doi.org/10.1007/s13280-018-1139-3

IBGE. (2021). Panorama Altamira. População estimada. Instituto Brasileiro de Geografia e Estatıstica. https://cidades.ibge.gov.br/brasil/pa/altamira/panorama

IEA. (2021). Hydropower Special Market Report - Analysis and forecast to 2030. 126. https://iea.blob.core.windows.net/assets/4d2d4365-08c6-4171-9ea2-8549fabd1c8d/HydropowerSpecialMarketReport_corr.pdf.

Infoamazonia. (2022). Improving the position of hydroelectric plants would reduce impacts on the Pan-Amazon. https://infoamazonia.org/en/2022/02/25/improving-the-position-of-hydroelectric-plants-would-reduce-impacts-on-the-pan-amazon/

IPCC. (2022). Climate Change 2022. Mitigation Climate Change. https://doi.org/10.1201/9781003264705-7

ISA. (2015). Dossiê. Não há condições para a Licença de Operação.

Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. Energy Research & Social Science, 11, 174–182. https://doi.org/dx.doi.org/10.1016/j.erss.2015.10.004

Kelly-Richards, S., Silber-Coats, N., Crootof, A., Tecklin, D., & Bauer, C. (2017). Governing the transition to renewable energy: A review of impacts and policy issues in the small hydropower boom. Energy Policy, 101(November 2016), 251–264. https://doi.org/10.1016/j.enpol.2016.11.035

Kirchherr, J., & Charles, K. J. (2016). The Social Impact of Dams: A New Framework for scholarly Analysis. Environmental Impact Assessment Review, 60, 99–114. https://doi.org/10.1016/j.eiar.2016.02.005

Lacey-Barnacle, M., Robison, R., & Foulds, C. (2020). Energy justice in the developing world: a review of theoretical frameworks, key research themes and policy implications. Energy for Sustainable Development, 55, 122–138. https://doi.org/10.1016/j.esd.2020.01.010

Lukasiewicz, A., & Baldwin, C. (2017). Voice, power, and history: ensuring social justice for all stakeholders in water decision-making. Local Environment, 22(9), 1042–1060. https://doi.org/10.1080/13549839.2014.942261

Manorom, K., Baird, I. G., & Shoemaker, B. (2017). The World Bank, Hydropower-based Poverty Alleviation and Indigenous Peoples: On-the-Ground Realities in the Xe Bang Fai River Basin of Laos. Forum for Development Studies, 44(2), 275–300. https://doi.org/10.1080/08039410.2016.1273850

Mayer, A., Castro-Diaz, L., Lopez, M. C., Leturcq, G., & Moran, E. F. (2021). Is hydropower worth it? Exploring amazonian resettlement, human development and environmental costs with the Belo Monte project in Brazil. Energy Research and Social Science, 78(January), 102129. https://doi.org/10.1016/j.erss.2021.102129

Mayer, A., Garcia, M. A., Castro-Diaz, L., Lopez, M. C., & Moran, E. F. (2022). Pretend participation: Procedural injustices in the Madeira hydroelectric complex. Global and Environmental Change, 75, 102524. https://doi.org/https://doi.org/10.1016/j.gloenvcha.2022.102524

Mayer, A., Lopez, M. C., Leturcq, G., & Moran, E. (2022). Changes in Social Capital Associated with the Construction of the Belo Monte Dam: Comparing a Resettled and a Host Community. Human Organization, 81(1), 22–34. https://doi.org/10.17730/1938-3525-81.1.22

Mayer, A., Lopez, M. C., & Moran, E. F. (2022). Uncompensated losses and damaged livelihoods: Restorative and distributional injustices in Brazilian hydropower. Energy Policy, 167(September 2021), 113048. https://doi.org/10.1016/j.enpol.2022.113048

McCauley, D., Heffron, R., Stephan, H., & Jenkins, K. (2013). Advancing energy justice : the triumvirate of tenets and systems thinking. International Energy Law Review, 32(3), 107–116.

Mehta, L., & Srinivasan, B. (2000). Balancing Pains and Gains. A Perspective Paper on Gender and Large Dams World Commission on Dams Secretariat World Commission on Dams (Vol. 1, Issue March). http://www.dams.org

Melin, A., Day, R., & Jenkins, K. E. H. (2021). Energy Justice and the Capability Approach—Introduction to the Special Issue. Journal of Human Development and Capabilities, 22(2), 185–196. https://doi.org/10.1080/19452829.2021.1909546

Miles, M., Huberman, M., & Saldaña, J. (2014). Research Design and Management. In M. B. Miles,

M. Huberman, & J. Saldaña (Eds.), Qualitative data analysis: A methods sourcebook. SAGE Publications.

Moore, S. (2019). Sustainable Energy Transformations, Power and Politics. Morocco and the Mediterranean. Routledge.

Moran, E. F. (2016). Roads and Dams: Infrastructure-Driven Transformations in the Brazilian Amazon. Ambiente & Sociedade 2016, XIX, 207–220. https://doi.org/10.1590/1809-4422ASOC256V1922016

Moran, E. F., Lopez, M. C., Moore, N., Müller, N., & Hyndman, D. W. (2018). Sustainable hydropower in the 21st century. Proceedings of the National Academy of Sciences, 201809426. https://doi.org/10.1073/pnas.1809426115

Munro, P., van der Horst, G., & Healy, S. (2017). Energy justice for all? Rethinking Sustainable Development Goal 7 through struggles over traditional energy practices in Sierra Leone. Energy Policy, 105(January), 635–641. https://doi.org/10.1016/j.enpol.2017.01.038

Nguyen, H. T., Pham, T. H., & de Bruyn, L. L. (2017). Impact of hydroelectric dam development and resettlement on the natural and social capital of rural livelihoods in bo hon village in central vietnam. Sustainability (Switzerland), 9(8), 1–15. https://doi.org/10.3390/su9081422

Nussbaum, M. (2003). Capabilities as fundamental entitlements: Sen and social justice. Feminist Economics, 9(2–3), 33–59. https://doi.org/10.1080/1354570022000077926

Nussbaum, M. (2007). Social Contracts and Three Unsolved Problems of Justice. In Frontiers of Justice. The Belknap press of Harvard University Press.

Pedroso, F., Bassini, M. T., Horita, M. A. B., Jardini, J. A., Graham, J. F., & Liu, G. (2018). HVDC multi-infeed analysis of the Brazilian transmission system and possible mitigation methods. CSEE Journal of Power and Energy Systems, 4(4), 487–494. https://doi.org/10.17775/cseejpes.2016.01700

Pinto, D. M., Pinto, V., SantAnna, I., Arantes, C. C., & Rodrigues, C. (2022). Mudanças na dinâmica pesqueira em comunidades afetadas por grandes hidrelétricas na Amazônia. Research, Society and Development, 11(6), 1–16. https://doi.org/http://dx.doi.org/10.33448/rsd-v11i6.28775

Raimi, D., Campbell, E., Newell, R., Prest, B., Villanueva, S., & Wingenroth, J. (2022). Global Energy Outlook 2022 : Turning Points and Tension in the Energy Transition (Issue April).

Randell, H. (2016). Structure and agency in development-induced forced migration: the case of Brazil's Belo Monte Dam. Population and Environment, 37(3), 265–287. https://doi.org/10.1007/s11111-015-0245-4

Randell, H., & Klein, P. (2021). Hydropower Development, Collective Action, and Environmental Justice in the Brazilian Amazon. Society and Natural Resources, 34(9), 1232–1249. https://doi.org/10.1080/08941920.2021.1948649

Richter, B. D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., & Chow, M. (2010). Lost in development's shadow: The downstream human consequences of dams. Water Alternatives, 3(2), 14–42.

Robeyns, I. (2009). Capability approach. Handbook of Economics and Ethics, 39–46. https://doi.org/10.4018/ijabim.2011070105

Sayatham, M., & Suhardiman, D. (2015). Hydropower resettlement and livelihood adaptation: The Nam Mang 3 project in Laos. Water Resources and Rural Development, 5, 17–30. https://doi.org/10.1016/j.wrr.2015.01.001

Schlosberg, D. (2007). Distribution and Beyond: Conceptions of Justice in Contemporary Theory and Practice. In Defining Environmental Justice. Theories, Movements, and Nature (pp. 3–45). Oxford University Press.

Scudder, T. (2005). The Future of Large Dams: Dealing with social, environmental, institutional and political costs. Earthscan.

SEforALL. (2021). SEforALL Analysis of SDG7 Progress. In Sustainable Energy For All. https://www.seforall.org/data-stories/seforall-analysis-of-sdg7-progress-2021

Sen, A. (2009). Lives, Freedoms and Capabilities. In The Idea of Justice. Harvard University Press.

Siciliano, G., Del Bene, D., Scheidel, A., Liu, J., & Urban, F. (2019). Environmental justice and Chinese dam-building in the global South. Current Opinion in Environmental Sustainability, 37, 20–27. https://doi.org/10.1016/j.cosust.2019.04.003

Siciliano, G., & Urban, F. (2017). Equity-based Natural Resource Allocation for Infrastructure Development: Evidence From Large Hydropower Dams in Africa and Asia. Ecological Economics, 134, 130–139. https://doi.org/10.1016/j.ecolecon.2016.12.034

Siciliano, G., Urban, F., Tan-Mullins, M., & Mohan, G. (2018). Large dams, energy justice and the divergence between international, national and local developmental needs and priorities in the global South. Energy Research and Social Science, 41(July 2017), 199–209. https://doi.org/10.1016/j.erss.2018.03.029

Sovacool, B., Burke, M., Baker, L., Kotikalapudi, C. K., & Wlokas, H. (2017). New frontiers and conceptual frameworks for energy justice. Energy Policy, 105, 677–691. https://doi.org/10.1016/j.enpol.2017.03.005

Sovacool, B., & Dworkin, M. H. (2014). Global energy justice: Problems, principles, and practices. Cambridge University Press.

Sovacool, B., & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. Applied Energy, 142, 435–444. https://doi.org/10.1016/j.apenergy.2015.01.002

Sultana, F. (2022). Critical climate justice. Geographical Journal, 188(1), 118–124. https://doi.org/10.1111/geoj.12417

Tilt, B., & Gerkey, D. (2016). Dams and population displacement on China's Upper Mekong River: Implications for social capital and social-ecological resilience. Global Environmental Change, 36, 153–162. https://doi.org/10.1016/j.gloenvcha.2015.11.008

Trussart, S., Messier, D., Roquet, V., & Aki, S. (2002). Hydropower projects: A review of most effective mitigation measures. Energy Policy, 30(14), 1251–1259. https://doi.org/10.1016/S0301-4215(02)00087-3

Uprimny, R., & Saffon, M. P. (2005). Transitional Justice, Restorative Justice and Reconciliation. Dejusticia, 2, 1–24. https://bit.ly/3kaVrkm.

von Sperling, E. (2012). Hydropower in Brazil: Overview of positive and negative environmental aspects. Energy Procedia, 18, 110–118. https://doi.org/10.1016/j.egypro.2012.05.023

Winemiller, K. O., McIntyre, P. B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., Baird, I. G., Darwall, W., Lujan, N. K., Harrison, I., Stiassny, M. L. J., Silvano, R. A. M., Fitzgerald, D. B., Pelicice, F. M., Agostinho, A. A., Gomes, L. C., Albert, J. S., Baran, E., Petrere, M., … Saenz, L. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. Science, 351(6269), 128–129. https://doi.org/10.1126/science.aac7082

World Bank. (2008). Environmental Licensing for Hydroeletric Projects in Brazil A Contribution to the Debate Summary Report.

Yankson, P., Asiedu, A. B., Owusu, K., Urban, F., & Siciliano, G. (2018). The livelihood challenges of resettled communities of the Bui dam project in Ghana and the role of Chinese dam-builders. Development Policy Review, 36(October 2016), O476–O494. https://doi.org/10.1111/dpr.12259

Young, I. (1990). Justice and the politics of difference. Princeton University Press. https://doi.org/10.1017/CBO9781107415324.004

Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L., & Tockner, K. (2015). A global boom in hydropower dam construction. Aquatic Sciences, 77(1), 161–170. https://doi.org/10.1007/s00027-014-0377-0

Zehr, H. (2015). The Little Book of Restorative Justice. Revised and Updated. Simon and Schuster. https://www.amazon.com/Big-Book-Restorative-Justice-Peacebuilding/dp/168099056X/ref=sr_1_2?keywords=Restorative+Justice&qid=1555382753&s=books&sr=1-2

APPENDIX 6 CODEBOOK

Table 29. Codebook

Code	Definition	Child Code	Definition	Rule
Distribution	Allocation of outcomes generated by an energy facility, such as electric infrastructure and long-term employment (B. K. Sovacool & Dworkin, 2014a) (Allocation of ills and benefits).	Distribution of adverse effects in fisheries	Distribution of negative impacts focused on fisheries	Use this code in statements describing the ills that the dam has generated in fisheries
		Distribution of negative effects	Distribution of material outcomes generated by the energy facility, such as public and harmful goods (e.g., poverty, pollution) (Sovacool & Dworkin, 2014b)	Use this code to describe the ills of the dam's construction at the individual, household, community, regional or national level.
		Distribution of Benefits	Distribution of material outcomes generated by the facility, such as electricity, jobs, and other (e.g., resources, wealth)	Use this code to describe the benefits of the dam's construction at the individual, household, community, regional or national level.
Recognition	How individuals and communities are recognized. Aspects of equity. Recognition justice calls attention to exploring the context of oppression (Fraser, 2000).	Cultural Domination	being subjected to patterns of interpretation associated with another culture hostile to one's own (Fraser, 1996)	Use statements describing how individuals are subjected to patterns of communication of other cultures or hostile.
		Misrecognition	being invisible; disrespect, being routinely abused (Fraser, 1996)	Use statements related to recognition or misrecognition processes in the context of the dam's construction.
		Disrespect	When there are maligned cultural representations in everyday life interactions.	Use this code to describe how individuals have been disrespected in daily interactions
Procedural	Fairness of institutional decision-making processes (Schlosberg, 2007).	Access to information	All people should have access to high-quality information about energy	To describe if individuals had or did not have access to information about the dam's construction, EIA, SIA, compensation, etc.
		Participation	All people should have access to fair, transparent, and accountable forms of energy decision-making (Sovacool et al., 2015)	Statements regarding the active or no participation of individuals in the processes of decision-making

Table 29 (cont'd)

Restorative	It aims to repair the negative aspects of the dam's construction on society or the environment. It focuses on the victims; this tenet seeks recognition, reparation of their harm, and restoration of their dignity (Uprimny & Saffon, 2005).	Dam developers attempt to put right the harms/ Dam developers take responsibility	"Taking responsibility means saying, 'Yes, I did it and I take responsibility for the harm I caused.' It is the starting point for restorative justice" (Liebmann, 2007)	Statements describing how dam developers are mitigating the impacts generated
		Members have been or have not been compensated	Compensation provided to individuals, households, or communities due to the impacts generated by the dam	Statements claiming whether individuals were compensated
		How individuals would like to be restored	Actions, items, and strategies that the impacted communities want to get due to the impacts generated by the dam	Use this code in statements where respondents describe how they would like to be repaired by the losses generated by the construction of the dam
Capabilities	The capabilities approach broadens the idea of justice by considering how the distribution of in(justices) affects people's well-being (Schlosberg, 2007) or their freedom to do things they value and the ability to achieve valuable functionings (Sen, 2009).	Capabilities		Use this code in sentences describing how inhabitants have lost or gained the freedom to do things they value. That fear and anxiety do not disrupt their lives and emotions (Nussbaum, 2007)
Electricity Access	Electricity access	Electricity access	People deserve sufficient energy resources of high quality (Sovacool, 2017)	Use this code in statements referring to the reliability of the electricity service, the challenges accessing electricity, and the affordability of electricity

Chapter 4: Responses to hydropower development: analytical insights through a qualitative lens for resilience

Introduction

Hydropower is the largest source of global renewable energy, with 30% of worldwide energy production (IRENA, 2022). The hydropower capacity globally is set to increase by 17% between 2021 and 2030, with most of the construction taking place in Africa and the Middle East (IEA, 2021). These nations are building dams to provide a stable energy source for their growing populations, fuel their economies, and reduce their dependence on imported energy (Zarfl et al., 2015). Brazil is one of the most hydropower-dependent nations on earth, where hydropower represents 67% of domestic energy consumption (IEA, 2021). About 200 dams are in operation in the Amazon basin alone, and more than 350 are planned (Flecker et al., 2022; Winemiller et al., 2016). The adverse effects of dam construction on social-ecological systems range from the loss of river connectivity (Grill et al., 2019) to the loss of aquatic and terrestrial biodiversity (Arantes et al., 2021; Benchimol & Peres, 2015; Winemiller et al., 2016), alteration of sediment dynamics and water quality (Forsberg et al. 2017); to the displacement and resettlement of human populations (Cernea, 1997; Égré & Senécal, 2003; Kirchherr et al., 2016).

Resettlement is one of the most visible impacts of dam development. If done correctly, it should prevent impoverishment by restoring and improving the livelihoods of resettled, but it seldom, if ever, does (Cernea, 1997). However, studies have shown that other populations are impacted by dams even if they are not resettled, and studies about these populations are less frequently found in the literature. This is the case for host[3] (Mayer et al., 2021), upstream (M. B. Fainguelernt, 2020), and downstream communities (Baird et al., 2021; Castro-Diaz et al., 2018; Owusu et al., 2017; Richter et al., 2010). Despite this, by 2010, large dams had affected more than 472 million people downstream (Richter et al., 2010). Dam developers have also systematically overlooked the downstream impacts of dams (Baird et al., 2021; Richter et al., 2010; Runde et al., 2020; Scudder, 2005); unsurprisingly, few efforts have been made to mitigate and compensate these communities for dam construction (Baird et al., 2021). The literature points out that some of the social-ecological impacts downstream communities experience include disruption of the flooding patterns, increased erosion, and impact on fisheries diversity and distribution (Baird et al., 2021; Forsberg et al., 2017; Richter et al., 2010; Runde et al., 2020). Riverine communities, who depend on fisheries for their livelihoods, are also impacted since fish yield is reduced (Doria et al., 2021; Runde et al., 2020).

[3] Human populations that receive/host those who were resettled by dam development.

Scholars have described strategies followed by affected communities to respond to the effects associated with dam development. After resettlement, some households lose agricultural farmland, increasing land intensification and using fertilizers to sustain their families (Legese et al., 2018; Loker, 2003), while others have diversified by changing their crops (Rousseau, 2017). The literature also shows that, in some cases, males have migrated to other communities to provide for their families (Dao, 2011). On the other hand, communities downstream from dams have responded by shifting to alternative livelihood strategies (Owusu et al., 2019) or overfishing rates (Doria et al., 2021). Nevertheless, to our knowledge, no studies are exploring the responses of local actors in communities impacted by dams from a social-ecological resilience lens considering the three core resilience capacities: absorptive/coping, adaptive, and transformative capacity.

Few studies have assessed the individual, household, and community responses to the construction of dams (Scudder, 1993; Scudder & Gay, 2011), but in most cases, the authors do not have information from the moment the dam is being constructed. We conducted a qualitative study that started during the final stages of the dam construction (2016) to when the turbines were under operation (2017 and 2019). It befitted from studies by scholars from the beginning of Belo Monte (Boanada Fuchs, 2015; Calvi et al., 2019; M. Fainguelernt, 2016; Grisotti, 2016; Leturcq, 2016; Moran, 2016).

In this study, we are adapting Béné's (2012) resilience framework to explore the responses of individuals and households in a community downstream from the Belo Monte hydroelectric dam in the Brazilian Amazon. As mentioned in Chapter 3, riverine communities are from different ethnicities and are often overlooked by official programs, policies, and decision-making processes (Adams et al., 2006; Boanada Fuchs, 2015; Doria et al., 2017). Specifically, we are exploring the absorptive, adaptive, and transformative responses associated with the effects generated by the construction of the dam over a four-year period. Methodologically, we are not measuring resilience as others have done through the resilience capacity indexes. We are qualitatively assessing the responses associated with dam development used by locals and identifying their potential consequences. Our qualitative study considers the complexities related to hydropower development at different stages of the dam construction, which will inform the design of better policies for preventing and mitigating the effects.

Theoretical Background.

Social-ecological resilience

Resilience is an emergent property of social-ecological systems (Berkes et al., 2008); it is a dynamic concept that explores the complexity, uncertainty, and changes across temporal, spatial, institutional, and knowledge scales (Berkes et al., 2008; Folke, 2016). In particular, social-ecological resilience explores individuals', households,' and communities' capacity to absorb, adapt, and transform into new stages in the face of dynamic change (Béné et al., 2012; Folke, 2016; Folke et al., 2010).

Resilience scholars have identified three core resilience capacities: coping, adaptive, and transformative (Béné et al., 2012; Brown, 2016; Folke, 2016; Olsson & Galaz, 2012; Walker et al., 2004, 2006). (1) Coping capacity is the ability of social-ecological systems to buffer or absorb the shocks (Béné et al., 2012; Cutter et al., 2008). Adaptive capacity is the ability of social-ecological systems to adjust their responses to shocks to allow stability (Folke et al., 2010; Walker et al., 2004), and transformative capacity is the ability of a system to create new stages for development (Folke et al., 2010; Walker et al., 2004). Then, coping, adaptive, and transformative capacities are part of a continuum that reflects different levels of responses in the face of change (Béné & Doyen, 2018).

Figure 12 presents a framework developed by Béné et al. (2013; 2012) to measure resilience. It combines the three capacities, the shocks' intensity, and the responses' cost. The figure shows show how depending on the intensity of a shock, the capacities described above led to diverse responses from absorbing/coping, adapting, and transforming that have incremental transactional costs (Béné, 2013; Béné et al., 2012).

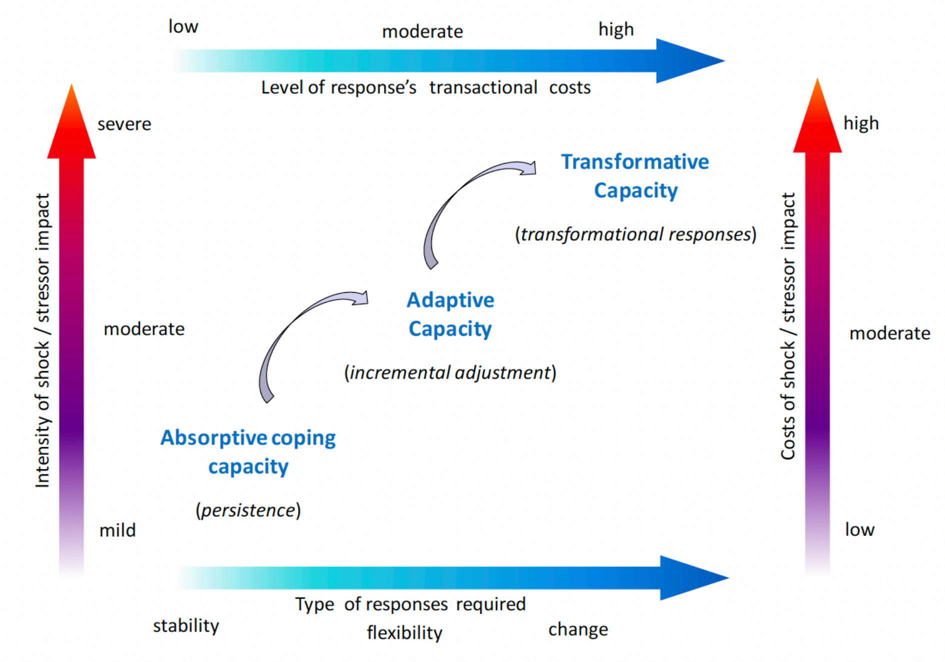


Figure 12. Resilience responses associated with shock intensity (Béné, 2013, p. 10)

Shocks or perturbations are unexpected, intense, and dramatic occurrences beyond the variability range of the system (Marschke & Berkes, 2006). For instance, a natural disaster like a hurricane or an earthquake, but a shock can also be generated by anthropogenic activities such as violent conflict (Marschke & Berkes, 2006), failure to evacuate, institutional failure in delivering assistance, or the construction of dams.

The first capacity included in the framework is *absorptive* capacity. It aims to minimize exposure to shocks and to recover quickly by using predetermined coping strategies (Barrett et al., 2021; Cutter et al., 2008; L. Smith & Frankenberger, 2018). Coping strategies are immediate responses that individuals, households, or communities use within existing structures (Berman et al., 2012). In the face of a low-intensity shock, an individual, a household, a community, or a system, would be able to resist it by absorbing the shock's impacts without changing its function or status (Béné et al., 2016). The threshold of absorptive capacity can be exceeded if the intensity of the shock is too large and overwhelms the capacity or if the coping strategies are insufficient to handle the shock (Cutter et al., 2008).

However, suppose the shock has higher intensity. In that case, the household will need to use its *adaptive* capacity to reorganize and learn in response to a shock to be able to maintain some structure, function, and identity (Béné, 2013; Béné et al., 2012; Cutter et al., 2008). Adaptive capacity is one of the key attributes of resilience (Béné et al., 2012; L. Smith & Frankenberger, 2018), which reflects learning and flexibility to try solutions in response to shocks (Walker et al., 2002). Adaptive strategies are how "individuals, households, and communities change their productive activities and modify local rules and institutions to secure livelihoods" (Berkes & Jolly, 2002, p. 2).

Lastly, suppose the intensity of the shock overwhelms the system. In that case, transformation may occur, and the individual, household, or community will have to change the structure and identity of the system (Béné & Doyen, 2018). *Transformative* capacity is the ability to create a new system (Walker et al., 2004) by changing the underlying structures and dynamics (Barrett et al., 2021), or it can fail altogether, and the system will be overwhelmed and fail. It can be a deliberate process, incentivized by those involved, or it can also be forced on them by changing social, environmental, or economic conditions (Folke et al., 2010). For instance, a system could be transformed by changing power dynamics and empowering women (Barrett et al., 2021) or adopting a new livelihood activity (Béné et al., 2012). All responses include the use of capital (e.g., natural, social, human, financial, and physical) that is available to them (Barrett et al., 2021).

Resilience as a capacity has usually been operationalized as a set of indicators or reduced as an index focused on coping strategies (Barrett et al., 2021). On the other hand, Béné's framework allows seeing the interaction between the three capacities presented above. Based on the three resilience capacities, organizations like FAO (2016) have developed resilience capacity indexes such as the Resilience Indicators for Measurement and Analysis (RIMA). Based on the framework, Smith and Frankenberg (2018) created a set of indicators to measure resilience capacity associated with severe flooding. The framework has also been used in food security (Béné et al., 2016; L. Smith & Frankenberger, 2018) and water governance (Fallon et al., 2022). A limitation of these indicators is that they do not include the local social-cultural dynamics (Barrett et al., 2021). In this study, we assess individuals' responses using a qualitative approach to integrate those dynamics and explore the context-specific resilience implications. There are few studies about the responses of local communities to dam development, so we contribute a qualitative exploratory case study and understanding of how locals respond to the construction of a hydroelectric dam.

It is important to note that Béné's framework is not explicit about the role of temporality, but it is acknowledged elsewhere in the literature that coping strategies are more reactionary and short-term responses to situations that threaten social-ecological systems (Berkes & Jolly, 2002). In comparison, adaptive and transformative strategies are more planned and involve more medium to long-term responses that help systems to develop robustness against shocks (Ansah et al., 2019). Nonetheless, people can rely on coping strategies for the long term if they do not have enough resources (capital) for adaptation. An innovation of this study is to use the framework in a qualitative study that allows us to study the shock of Belo Monte and its effects on resilience capacities over different stages of dam construction and early operation in one community.

Responses to dam construction

To our knowledge, in the context of hydropower development, researchers have not used Béné's framework to understand the shocks and responses of individuals and households. Nevertheless, this topic has been explored since the 1950s with other frameworks (Hay et al., 2019; Scudder, 1993, 2005). For 37 years, Scudder followed displaced individuals through the construction of the Kariba Gorge dam in Zambia, the oldest long-term study of resettled people due to dam construction (Scudder, 1993). Based on those findings and others that the author gathered in his empirical studies of dam displacement, Scudder & Colson (1982) published a framework describing how communities respond after resettlement.

The *Four-Stages framework* Scudder proposed outlines how resettlers respond if a well-implemented resettlement program is successfully operationalized (Scudder, 2005). This framework is unique because it considers the temporal scale, including a second generation of people after resettlement. According to Scudder (2005), resettled communities will respond in the following four stages (*i*) *Planning and Recruitment*, which happens during the pre-resettlement period; people who will be relocated are expected to become concerned as their removal approaches. (*ii*) *Adjustment and Coping* start with the initiation of physical removal. During this stage, living standards are expected to decrease. Most resettlers will be risk averse to the stress and uncertainty associated with the resettlement process (*iii*) *Community Formation and Economic Development* will happen if a successful resettlement process is conducted (Scudder, 2005). During this stage, governments and planners should provide appropriate development opportunities and create economic diversification among the resettled communities; with that support, community members will invest time and effort in forming associations and cooperatives. Consequently, living standards will improve, and people will change their risk preferences into risk-taking behavior (Scudder & Gay, 2011). (*iv*) *Handing Over and Incorporation* is the successful end of a resettlement process. It involves the second generation of resettled people. Three conditions must be met: government should hand processes to settler organizations, living standards must continue to improve, and community members must have the institutional and political strength to get national resources.

Nevertheless, when applying the framework in a systematic review of 44 dams. Scudder and Gay (2011) found that in only three cases, people improved their living standards: *Aswan* in Egypt (42 years after construction), *Arenal* in Costa Rica (3 years after construction), and *Pimburetewa* in Sri Lanka (30 years after construction). In five cases, people restored their living standards. In 36 cases, the living standards of the majority decreased (including the case that he followed: *Kariba* in Zambia and Zimbabwe, even 44 years after construction). Nevertheless, the authors focused only on resettled communities, based on the conditions provided or not by dam authorities, overlooking individual and household agencies and responses.

Other scholars have used elements of a resilience framework (mostly coping and adaptive capacity) to explore the responses of individuals and households to dam development through other frameworks such as human behavior, risk analysis, and political ecology. For example, Xi and Hwang (2011) studied the responses used by resettled households to face stress and depression. The authors included problem-focused and emotion-focused coping strategies in their survey, finding that those who used problem-solving coping strategies (accepted resettlement) were less depressed than those who used emotion-focused strategies (resisted and negotiated relocation). They concluded that their survey instrument included a limited number of coping strategies, which could have overlooked other strategies used by resettlers. In social-ecological resilience terms, we could say that the measurement of depression reflects an effect of the shock; however, there is not enough information to consider the responses described by the authors in any of the three capacities we will study here.

In another study, Owusu et al. (2019) conducted surveys, interviews, and focus groups to study the impacts of dams a year after the inauguration of the Bui dam in Ghana. The study reveals that non-resettled communities were also affected by the dam's construction and that its inhabitants were using a mix of coping and adaptation strategies based on farming, trading, and migration to cope with that adversity (Owusu et al., 2019). Respondents reported that they changed their main activity from fisheries to farming (Owusu et al., 2019), which could be seen as a transformative strategy since they changed the dynamics and structure of the system.

As presented above, scholars studying the social impacts of dams have explored through diverse lenses and, in different cases of studies, how locals have responded to the effects of dam development. No studies explore the short-term responses of hydropower development considering absorptive, adaptive, and transformative capacity. This case study provides an opportunity to get exploratory information about the responses associated with dam development in one community from a social-ecological resilience approach.

The Belo Monte Hydroelectric dam

The Belo Monte Hydroelectric dam on the Xingú river in the Amazon region of Brazil is the fourth largest dam in the world, with an installed capacity of 11,233 megawatts produced by 18 turbines. However, the literature reports that the dam has not generated that potential capacity (Higgins, 2020). In fact, the turbines were stopped due to the low flow and level of the reservoir in August 2022.

The dam's construction began in 2011 by *Norte Energia,* even though it had been under consideration since the 1970s. The dam was built by a consortium formed of private and public companies. It became infamous due to corruption uncovered by the Odebrecht scandal, the lead company in the consortium, which paid bribes to the President's Workers Party (Atkins, 2017; P. Fearnside, 2018). Belo Monte had been a focus of social resistance for over thirty years. Its origins date from the 70s, when Brazil was under a military dictatorship that saw hydropower as the way to power Brazilian economic development. Since then, social movements and local actors have opposed the project due to its immense adverse effects (Atkins, 2019; Bratman, 2015; Garcia et al., 2021). However, dam developers and the government presented Belo Monte as essential for the country's energy supply, a framing strengthened by the 2001 energy crisis and frequent blackouts (Fleury & Almeida, 2013). However, the presidential approval of the construction took place without considering the environmental agency's recommendations (Mayer et al., 2021) or scholars' concerns (Painel de Especialistas, 2009), never mind opposition from civil society.

For the dam's construction, over 20,000 people were displaced (Randell, 2016) without consultation or negotiation for compensation (Boanada Fuchs, 2016; Mayer et al., 2021). After displacement, these communities were relocated to urban resettlement areas that lacked access to public transportation, where electricity prices increased (Mayer et al., 2021), and where people experienced a loss in their social capital (Mayer et al., 2022). Furthermore, these communities perceive that Belo Monte did not benefit them, but they adopted the discourse of the government and the media that the dam generates benefits for Brazil (Mayer et al., 2021; Mourão et al., 2022). Communities downstream from Belo Monte that were not resettled by the project have also faced challenges due to the dam construction in their livelihoods (Castro-Diaz et al., 2018). Fieldwork for this study was conducted in Vila Nova, a riverine community located downstream from the dam. Riverine people are diverse, including individuals of different ethnicities with no titles over their lands (Boanada Fuchs, 2015). They have been ignored in decision-making processes and rarely benefit from official programs and policies (Adams et al., 2006; Boanada Fuchs, 2015; Doria et al., 2017).

Riverine communities depend on the river for their livelihoods. Flooded forests are essential for maintaining Amazonian biodiversity and fishery yield. The forests and their seasonal flooding (between four and ten months yearly) are necessary for fish migration, reproduction, and the productivity of food webs (Alho et al., 2015; Goulding, 1980, 1990; Goulding et al., 1996). Previous research has shown that the construction of Belo Monte generated impacts on the flooded forest of the area, which led to the loss of fishing areas frequently used by locals and a decline in the fisheries yield (Boanada, 2015; Castro-Diaz et al., 2018; M. B. Fainguelernt, 2020). The impacts of dam construction in riverine communities are immense (Arantes et al., 2019; Baird et al., 2021; Doria et al., 2017); however, there are no studies on the responses of locals from a social-ecological resilience approach.

Methods

Data Collection

Vila Nova is a community located at the riverside of the Xingu River, a tributary of the Amazon River, in the municipality of Senador José Porfírio, state of Pará. Approximately 200 families live in the community. Vila Nova's inhabitants are riverine people or *ribeirinhos,* and most depend on fisheries for their source of protein and income (Castro-Diaz et al., 2018). Vila Nova dwellers do not have a tradition of farming (Castro-Diaz et al., 2018) because, during the Rubber Era (from 1870 to 1920), locals were forced to work tapping the wild rubber trees and were prohibited from cultivating their food to force them to buy products from the rubber barons (Moran, 1974; Wagley, 1953). This tradition has continued to influence many traditional areas of the Amazon.

The community was chosen mainly because of its location (See Figure 13), downstream from the Belo Monte hydroelectric dam, because of its size, since it is one of the largest communities in the area, and because men and women are fishers. As was presented in the introduction, the downstream impacts of hydroelectric dams are still understudied (Baird et al., 2021; Richter et al., 2010).

Figure 13. Area of study

This qualitative study adds to the literature on dam development by describing the responses associated with the effects generated by hydroelectric dam construction at late construction and early operation. The temporal dynamics of dam development are often ignored (Kirchherr & Charles, 2016; Scudder, 2005), and because of the complexity both in terms of time and expenses of conducting a longitudinal study, most of the studies are done in one period of time (Braun, 2005). In this study, we explore the effects of dam construction (the shock) and its associated responses over a four-year period. To understand the responses to the effects generated by the construction of Belo Monte in the lives and livelihoods of the inhabitants of Vila Nova, we conducted fieldwork in three data collection points. In 2016, the first author visited the community for the first time after the dam reservoir had just been filled. The aim was to have a baseline to understand the community dynamics and the challenges and opportunities that the construction of Belo Monte generated in the lives and livelihoods of Vila Nova dwellers. The second visit was in 2017 when five of the eighteen turbines were operating. The last visit was in 2019; at that time, 13 turbines were in operation. The goal of the last two visits was to follow up on the constraints and opportunities generated by the dam's construction and its associated responses.

We collected information through in-depth interviews with men and women. The interview guide for 2016 explored the community's context, the perceptions of locals about the dam, and the constraints and opportunities associated with it. We also asked about the ways that locals were responding to the effects of the dam. The interview guides for the following were modified to consider the information already collected related to the effects of dam development and the responses of local actors.

Over the years, we interviewed 22 women and 17 men. We interviewed eight individuals during all three years of data collection, 13 at two years and 20 at one year. All 70 interviews were conducted in Portuguese by the first author. Table 30 summarizes the number of participants per year of data collection. In 2017, we interviewed a group of fishers composed of 1 woman and two men; this is counted as one interview.

Table 30. Interview sample size

Participants	2016	2017	2019
Women	14	9	15
Men	14	8	11
Total	28	17	26

Data analysis

For each interview, we have audio recordings, verbatim transcriptions (conducted by a local research assistant), expanded notes, and a contact summary page based on Miles and Huberman (1994). The contact summary page is a one-page format that includes: 1) information about the main issues or themes discussed in the interview; 2) a summary of the information that we failed to get on each of the target questions; 3) other information that we consider essential to highlight; 4) and what new questions/ themes appeared as a result of interview and that we would need to follow up (either with the same person or the next interviewee).

We followed an interactive process for data analysis that includes: data condensation, data display, and conclusions (M. Miles et al., 2014). Data condensation is the process by which authors organize, select, abstract, and transform the data (Creswell, 2014; M. Miles et al., 2014). It includes the coding of data. We created a two-section codebook. The first section aims to understand the effects associated with the construction of Belo Monte and is based on deductive codes from the literature on the social-ecological impacts of dams (Appendix 7). The second section is a mixed codebook that includes emerging and deductive codes from the literature on the social impacts of dams and the responses of locals that aim to understand the responses to the effects associated with dam construction (Appendix 8). We used NVivo 12 and coded the data for 2016, followed by data for 2017 and 2019. After coding, we extracted excerpts for each code and summarized them in memos. We organized the memos in matrices for data display to compare them across data collection points through the lens of coping, adaptation, or transformation.

We used two strategies for data validity or checking the accuracy of the research (Creswell, 2014). First, we triangulated the information; this allowed us to corroborate evidence from different individuals and methods (interviews and observation). The second strategy was to develop an in-depth understanding of the research context by spending a prolonged time in the field (Creswell, 2014).

Results

The shock generated by the construction and early operation of Belo Monte brought many effects over the years. We will start this section by describing the main effects. Then, we explain how individuals and households responded.

The shock of Belo Monte and its associated effects

Over the years, the construction and operation of the Belo Monte dam brought many negative impacts to the lives of Vila Nova dwellers with direct consequences for their livelihoods. Fishing is one of the most important livelihood activities in the Amazon region, providing the primary source of protein for riverine communities, particularly those in the floodplains (Coomes et al., 2010; Doria & Lima, 2015; Isaac & Barthem, 1995; N. Smith, 1981). Vila Nova is located in the floodplain of the Xingú River, and fisheries were indeed the main activity that supported locals' livelihoods. Many of the effects that the construction of Belo Monte generated in the area were associated with fisheries.

In 2016, just after the reservoir of Belo Monte was filled, an effect identified by locals was the decrease in the river water quality. Interviewees noted that the decline in water quality was noticeable in the color of the water since the water used to be completely clear, and women also associated water consumption with human health issues, such as digestive problems that they did not have before. In contrast to the literature, data in 2016 did not reveal that the reduction in water quality was associated with the blocking of sediment movement (Baird et al., 2021), which occurs when the floodgates are closed, but to the increase of sediments due to the construction of the dam, land removal and heavy machinery in the river.

One of the potential benefits of hydroelectric dams for downstream communities is flood protection (Cernea, 2004). However, the literature has shown that one of the immense negative impacts of dam development is the change in the flood pulse, especially for communities that depend on river ecosystems (Latrubesse et al., 2017; Richter et al., 2010). Fisheries depend on the flood pulse and its seasonality, which is essential for fish ecology (e.g., reproduction, habitat). Since 2016, participants noted that Belo Monte generated changes in the river flow and caused the loss of flooded forests, fishing spots, and species, which led to fish scarcity. As mentioned above, the flooded forest is essential to sustain the fisheries; fish enter the flooded forest in the rainy season, looking for shelter, food, and spawning. However, due to the dam's construction, particularly after the reservoir impoundment, the river flow was disrupted, directly affecting the flooded forest. As a result, other effects emerged, such as losing fishing spots and fish species and low returns from the fisheries. The following quote provides a general explanation of how the impacts of the dam on the ecosystem and fisheries.

> Before the dam was built, the river had a yearly flow. In the winter here, oh, it was all full of water, now it's like this [pointing at the soil], it's all dry if you go in there [to the forest] to take a walk, you will see the fruits that fell on top, on the ground. Dry! It is really dry! This year there was no winter to enter the *Igapó* [flooded forest]. The *Igapo* did not have water, so there would be changes; fish will die of starvation, and we would find lean fish because there was nothing for them to eat, just that shabby grass on the shore. (Woman, 2016).

An impact identified in the literature on resettled and host communities was the rise in the price of goods, especially food, due to insufficient food production and the high migration of workers to the construction area (Moran, 2016; Yankson et al., 2018). In Vila Nova, women identified the increase in food prices as a negative effect associated with the construction of Belo Monte. Even though workers did not arrive in the community, Vila Nova inhabitants felt the effect of workers' migration because most of the goods sold in the community come from both urban centers that received most of the migrant workers: Vitoria do Xingú and Altamira. Added to the rise in food prices, both men and women noted the high gas prices, which consequently affected their mobility and fisheries.

In 2016, locals argued that adding to the effects that Belo Monte generated in their lives and livelihoods, their living situation was more challenging since, in the last closed fishing season, they did not receive the *Defeso*. The Defeso is a federal unemployment benefit provided to artisanal fishers since 1991. It aims to conserve fisheries by restricting fishing activities during spawning while providing fishers with a cash benefit. Vila Nova fishers use this cash transfer to buy and fix their fishing gear, particularly motors, boats, and coolers. It is important to note that the lack of this cash transfer in the closed season of 2015-2016 was not related to the construction of Belo Monte, but it increased the constraints locals were facing.

In 2017, participants noted that the flood pulse was still irregular, adding to the previous effects (change in water quality, loss of flooded forest, inflation). They reported more substantial periods of drought during the dry season (June to November), limiting their mobility and affecting their fisheries. Furthermore, women described new challenges in accessing food due to fish scarcity at the household level. At the same time, men noted how challenging it was for them to provide for their families after the construction of Belo Monte.

> Every time we went [to the river pre-dam], we caught a lot of fish. I think this is why we find it so difficult today because we had it so easy at that time, not today! Today it is tough for us to fish. We trusted that we could and could support our family just by fishing. But then, after the dam, fishing became difficult for us. We already know where it is best to fish, but it is no longer possible for us to make a catch. It is not feasible for us to buy an appliance and be sure we will be able to pay for it. It is tricky because we are not catching fish. Some days we go and bring nothing- Man, 2017

Surprisingly, hydroelectric dam construction does not always address the lack of a reliable electricity source and unaffordable electricity prices in communities nearby the construction sites (P. M. Fearnside, 1999; Green & Baird, 2016). In 2019, interviewees noted that the electricity service has not switched to Belo Monte and continues to come from the Tucurui dam, which is unreliable. Additionally, locals reported an increase in the price of electricity, which was generating issues at the household level. The following quote portrays the local's disappointment due to the cost of the electricity despite their closeness to Belo Monte.

> We expected that at least the energy would be cheaper for us. It is a terrible curse because a state like Pará, the state of Pará is a state that, produces a lot of energy, and I think that it is the state where energy is the most expensive. Man, 2019.

Responses to the effects of Belo Monte.

As noted above, most of the effects of the Belo Monte identified by Vila Nova inhabitants are related to the loss of fishing areas and fish species, resulting in fish scarcity. Responses to these effects are along the spectrum of coping to adaptation to transformation and are differentiated by gender, mainly because women and men have different household responsibilities. Our analysis showed that responses are grouped into four main themes: fisheries diversification, livelihoods diversification, dependence on safety programs, and migration.

In this study, we consider that individuals respond to the shock of Belo Monte along the spectrum from coping to adaptation to transformation (Béné & Doyen, 2018). Coping strategies respond to low-intensity shocks without changing the system's function (Béné et al., 2016). Recall that we include a temporal element to the framework; then, coping strategies are also the short-term responses (Berkes & Jolly, 2002; Berman et al., 2012), the initial responses associated with the construction and early operation of Belo Monte. Adaptive responses are those in which individuals or households reorganize and learn to maintain the structure of the system (Béné, 2013; Béné et al., 2012; Cutter et al., 2008). These responses include the change of livelihood activities that require the investment/use of capital, reflecting proactive planning. Transformative responses include strategies that reorganize systems into different structures (Béné & Doyen, 2018), such as changing livelihood strategies and social norms. As mentioned above, adaptive and transformative strategies are more planned and involve more medium to long-term responses that help systems to develop robustness against shocks (Ansah et al., 2019).

Fisheries diversification

One of the main themes that emerged from the interviews associated with responses to the effects of Belo Monte is based on local's fisheries and their diversification in terms of fishing grounds, time effort, and fishing gear.

In 2016, women and men described changing the amount of fishing time as a response to the effects of Belo Monte. Men noted how they increased their fishing effort by traveling to new and remote fishing areas, thus increasing their time effort and fishing expenses. This reflects a coping strategy since they use the available capital without making substantial changes. There are associated risks due to fish scarcity. Locals are starting to fish in prohibited areas where they never fish before, with the potential of being discovered by the authorities, who can confiscate all their fishing gear and fine them. In contrast, partnered women coped by reducing their time fishing while women head of the household continued fishing daily in the fishing spots available near the community. Even though women used their absorptive capacity, the consequences of this strategy are immense. Women's economic dependence on their male counterparts increased since women decreased their fishing effort due to fish scarcity, and women's fisheries have now been exclusively for household consumption (Castro-Diaz et al., 2018).

It is important to mention that social norms differentiate the responses of men and women. It has already been reported (Castro-Diaz et al., 2021) fisherwomen are spatially constrained compared to fishermen. Thus, mobility constraints make fisherwomen more vulnerable to the effects of the Belo Monte dam. For instance, they lost access to half of their fishing spots due to higher water levels and flooding, constraining their food security (Castro-Diaz et al., 2018). Mobility is related to fishing vessel access and the fact that men can stay away from home because they do not have domestic obligations. Fishermen have motorboats that allow access to more fishing spots and superior equipment needed to harvest commercially valued species. Fisherwomen, in contrast, use paddle canoes and simple handlines.

An adaptive response used by men since 2016 was to increase the use of resource-intensive fishing gear like nets and decrease the use of traditional gear such as bows and arrows. The use of new gear required financial resources to procure them and human capital to learn how to use them. This adaptive strategy continued to be used in 2017 when younger fishermen included diving masks and harpoons, which required further financial investment in equipment and learning new techniques.

> I didn't fish with diving masks and harpoons. I used nets and handlines. Then, after the dam, it became difficult to catch fish, and diving appeared. I started to see people fishing. I found it interesting, I thought it would be better to catch fish, and that's when I decided to dive too, to learn. Man, 2017.

In 2017, as the effects of Belo Monte continued, women's absorptive capacity was overwhelmed. They also adapted and started to use other fishing gear (i.e., nets) to increase their catch and maintain their livelihoods. The use of fishing nets, as described above, requires an economic investment, but also, depending on the type of net, it requires the support of others to operate the net, increasing the use of social capital. The use of nets also involves the use of time for fixing the damages caused by their use.

In 2019, locals continued diversifying their fisheries by traveling to other fishing spots and adding fishing gear. Men notably increased the use of large nets with smaller mesh sizes, which can be seen as an adaptive strategy that could potentially change the system's structure (transformative) due to the unsustainability of catching fish of smaller sizes, as noted by the following quote,

> It is difficult because there are too many fishermen. There are fishermen fishing in this river day and night. People fish with that monstrous blocking net that catches a lot of fish, and of course, fish is getting smaller. Now they have invented another type of net with a smaller mesh, which captures the little ones too. Man, 2019.

Local's fisheries diversification is a short-term strategy that mixes coping and adaptation and enables locals to see the returns immediately. However, the long-term effects could be immense due to the use of capital to support these responses (which will then not necessarily be replenished to respond to future shocks) and the unsustainable methods adopted, and the risk of fishing in prohibited places.

Livelihoods diversification

Locals responded to the effects associated with the construction and early operation of Belo Monte by diversifying their livelihoods and changing their primary livelihood strategy.

In 2016, men and women used their adaptive capacity to include other traditional strategies to maintain their livelihoods. Women raise chickens for consumption and bake bread for sale to provide for their families and support their food security. In times of need, when fisheries were not supporting their families, men described how they diversified their livelihoods by doing manual labor on farms near the community.

> Sometimes we work as day laborers for other people. We go to the countryside to help with our finances. I don't have any land to plant. I wanted to have land but never could buy it. Man, 2016

However, in 2017, as the effects of Belo Monte continued, men used their adaptive capacity by looking for seasonal opportunities in other municipalities. These activities include working in plantations and leaving for a season with their families in Vila Nova. This is a temporal form of adaptation that does not change the structure of their livelihoods. However, it requires financial capital to move from the community to the job area, human capital to learn work skills, and social capital since men reported having relatives nearby the plantations. This adaptive strategy also generates moderate consequences since they invest more capital, and women are left in charge of their households.

In 2019, interviewees indicated a change in their livelihood strategies as men transitioned from fisheries to farming as their primary livelihood strategy, using transformative capacity to create a different interaction and dynamics with the social-ecological system and relying on different functions within it. This response has high consequences since there are no farming lands in the community, and families have decided to invade lands to plant their crops. This response is a long-term investment with high risks because of three main factors. First, there is no farming tradition in the community, so families have to learn other skills and acquire knowledge for planting their crops. Second, planting crops is a long-term investment, and the returns are not immediate. Third, they could lose their plantations since they do not have rights over their land.

> She [his wife] always fishes more than I do. I don't fish every day. To tell you the truth, now there are weeks in which I don't go to the river. I am fishing only during the wintertime. Now I have other things to do, and I am not going to the river. We are working on an area where we will plant cocoa; we want to grow cocoa this year. We hope to farm a cocoa plantation, to experiment with other crops…We are investing in something that will give something back in the future. Before, if we had some money, we didn't have where to invest, now we have, we could buy an animal or seeds, and our land will increase its value. Man, 2019

Dependence on Safety Net Programs

The Brazilian government provides three main national safety programs that households from Vila Nova receive, none of these programs are associated with the construction of Belo Monte and all existed before the construction of the dam started. The first is an unemployment benefit associated with a yearly closed fishing season or *Defeso*. The second one is *Bolsa Família,* a cash transfer the Brazilian government provides to low-income families to ensure the families send their children to school. The third is a retirement program. However, because of the construction and operation of Belo Monte, households changed how they used these cash transfers. The Defeso, as was mentioned above, is a cash transfer provided to artisanal fishers. In 2016, locals did not get the transfer; then, as a coping response, locals fished during the closed season.

The second safety program that families get in this community is *Bolsa Familia*, the largest conditional cash transfer in the world (De Brauw et al., 2014), which aims to assist low-income families by providing a cash transfer to the household caregiver, particularly women (Holmes et al., 2010). The transfer is made for families that are registered in a National system and meet the following criteria: are under a certain income level, all children attend schools (6-15 years old), if women are pregnant, they must receive prenatal care, and children should receive timely vaccinations (De Brauw et al., 2014; Lemos et al., 2016). Households in Vila Nova accessed this cash transfer before the construction of Belo Monte. Still, to respond to the shock of the dam and its associated effects, they are using it to buy food and pay for the household's needs, not for schooling materials and children's health. In other words, they rearranged capital use, which could have long-term effects on children's well-being. Our analysis shows that this benefit has been critical for sustaining local livelihoods while coping with the effects generated by the construction of Belo Monte, as portrayed in the following quote.

> Oh, many people here don't go hungry thanks to *Bolsa Família* because the fish is not giving anything anymore. For example, today, you saw how much fish the boys caught. … for those with three children or even more, because the boy here [one of the fishermen who went with her husband] has five children, it's too hard; if it weren't for the *Bolsa Familia* here, many people would go hungry. Woman, 2016.

The Defeso and Bolsa Familia continued to emerge as essential programs for helping families coping the effects of Belo Monte. In 2017, our analysis showed that locals were given access to the Defeso for 2016-2017. However, they used cash transfers for household goods and food instead of repairing and buying fisheries supplies. This response is an example of a coping strategy, redistributing forms of capital to ensure stability.

In 2019, locals continued to receive and rely on the Defeso and Bolsa Familia to support their families. Added to these two cash transfers, some elderly participants began receiving retirement cash because they reached retirement age. Those affiliated with the fishermen's association, registered with the National Institute of Social Security (INSS), and at least 60 years old (men) or 55 (women), could access the retirement program (Ministério do Trabalho e Previdência, 2022).

This is an adaptive strategy used to maintain the system's identity and function; it is a long-term response because it requires planning and investment of financial capital over the years. Households are using safety net programs to support their families. This response has allowed them to cope and adapt to maintain the function, structure, and identity of the social-ecological system through the effects of the construction and early operation of Belo Monte in their livelihoods. Social safety programs, such as retirement and Bolsa Familia, are critical for rural households. While *Bolsa Família* has been shown in other contexts to be insufficient to respond to effects related to food insecurity (Lemos et al., 2016), here it was critical in supporting food security. However, this coping response could generate high consequences since the cash transfers are not used to support their intended goals: Defeso for sustaining the fisheries and Bolsa Familia for ensuring children stay in school by supporting their education and health. Due to the construction of Belo Monte, families are using these as coping strategies to maintain their food security. Still, this strategy has long-term impacts on the future responses of Vila Nova inhabitants because they reduced their natural and human capital to rely on for future shocks.

Migration

Two primary responses emerged from the data related to migration: household and male migration. To illustrate, we will describe the case of three families and how their responses changed over time The first family (A) comprises a fisherman, his wife, and three children. In the second family (B), the husband and wife are recognized by other community members as knowledgeable fishers. They had eleven children and lived with three of them and two granddaughters. The third family (C) is composed of fisherwomen: a grandmother, two of her daughters, and five grandchildren.

In 2016, these three families and other interviewees noted that if there were no improvements in the fisheries, despite their attachment to the community, they would have to consider migrating to a different area to support their families. For example, the husband of Family A described the challenges he faced in providing for his family and noted the possibility of migration.

> I was born here. I was born here, and for now, I am right here. Now, lately, I'm thinking of looking for another place, precisely because of this lack of fish, right? of fish. The fish today are no longer enough to feed a family. Today it is more complicated. Man, 2016

By 2017, our data collection revealed that family A used their transformative capacity to leave the community. On the other hand, because of fish scarcity, family B adapted to the effects by dividing household labor but maintaining a presence in Vila Nova, a more adaptive strategy. The husband would migrate and work for a month on a cocoa plantation. And the wife will stay in the community in charge of the household and continue fishing., maintaining the livelihood and function of their

Social-ecological system. They were able to use this response since they had family in the area where the male was going to migrate to; as described by the man:

> Well, now, since we are not catching any fish, the way is to look for another job for me to work, or we will starve... I will go, I will go after a job there [Brasil Novo] to work, I will work in cocoa, in any job that appears there. I have a son who works and lives there, and I will go to their house to work there. I will spend about 30 days working there and earn money for my wife. I'll go back again [to Brasil Novo] until the fish gets better. I think many people are trying to get out. Yes, many people are not doing very well because of the lack of fish, they are not catching fish, and they have to look for another job to work; otherwise, they will get sick and go hungry. – Man, 2017

Also, in 2017, family C adapted to the stresses of Belo Monte by migrating to an island close to Vila Nova; fishing is still their primary livelihood activity, carried out in the same social-ecological system. By 2019, family A had not returned to the community. After the experiences that the husband of Family B had working on the cocoa plantation, and with the money they got from the fisherwoman's retirement, they bought a house in *Brasil Novo*, another municipality. They were getting ready to move there and transform their social-ecological system, shifting their main livelihood strategies and living in a new area.

In 2019, the head of the household of Family C moved from the island to Vitoria do Xingú (the closest urban area). One of the family members returned to Vila Nova. However, in the interview, she noted that because of the impacts on fisheries and the lack of employment in Vila Nova, they were ready to migrate to the municipality of Anapu, closer to her husband's family. Then he will be able to work in construction to provide for the family.

In sum, among households, migration is one of the responses to the effects that the dam generated on lives and livelihoods. The examples above portray how these responses changed from considering migrating in 2016, male migration in 2017 (adaptation), and household migration in 2019 (transformation). Also, our results show that these responses differ due to the heterogeneity of the households.

Other responses

In 2016, women reported that in case of need, for instance, when they do not have the means to access food for their families, they ask for support from their neighbors and family members. This coping strategy relies on an existing resource (their social capital) that doesn't decline upon use and therefore has a low cost while allowing them to stay in a stability stage.

Another coping response that has been used even before Belo Monte is to buy food and fishing supplies with credit at specific locations in the community. The owner of these stores keeps a record of the purchases made by everyone, and debts are usually paid once per month. After Belo Monte, data revealed that payments were typically made after women had received the cash transfer from *Bolsa Familia.* Another coping strategy to buy fishing supplies or access cash is asking middlemen for an "advance payment."

In 2019, locals coping strategies associated with the high electricity prices included paying the bills in installments. In other cases, families have stopped paying for the service and tapped into the grid illegally.

> I, now, right now, to tell you the truth, I'm not paying for electricity. I'm not paying. We had it turned off; it was too expensive, too expensive, it was coming from R$100,00, R$120,00, and it was only these two light bulbs, a fridge, and the TV. I thought it was too expensive. So, I went and had it turned off. Now I am not paying for it. Man, 2019.

Discussion and conclusions

This study focuses on the effects of constructing a mega hydroelectric dam in a downstream community and how individuals and households respond. We presented the short-term resilience responses associated with these effects and how they change over time as a response to the accumulated effects.

In this study, we showed how individuals' and households' responses to hydropower development could be seen along the spectrum from coping to adaptation to transformation and how these have different levels of consequences (See Figure 14, 15, and 16). These responses differ by gender and household. In 2016 (see Figure 14), their livelihoods were broadly dependent on coping strategies, reflecting the lack of adaptive actions and flexibility. Households focused on maintaining fishing as the primary livelihood through diversification, even though that seemed insufficient to maintain food security in response to the effects that Belo Monte generated. In our first data collection point, 2016, it is worth mentioning that most households seem very homogeneous. They depended on fisheries, without farmland, and were affected by the dam's construction. In the following years, the heterogeneity between households started to emerge since they responded in diverse ways.

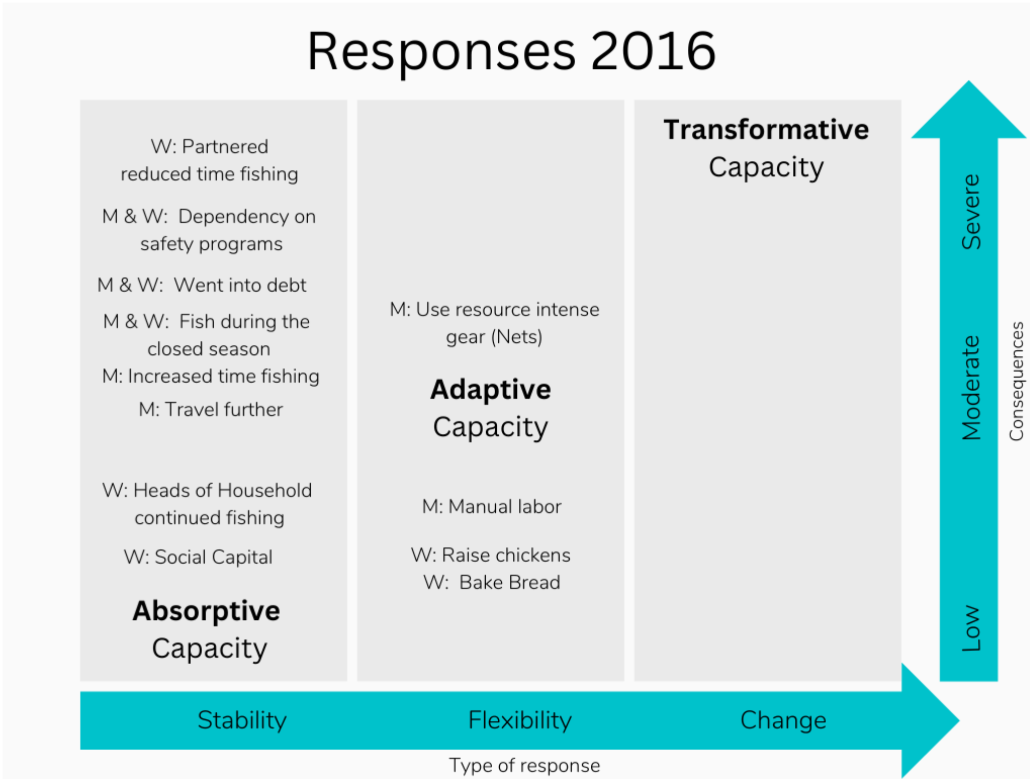


Figure 14. Responses to the effects of Belo Monte in 2016

Rural communities with a high dependency on fishing, such as Vila Nova, find it challenging to turn into non-fishing activities because they do not have the knowledge or the resources to do so (Allison & Ellis, 2001). This lack of flexibility is particularly noticeable in the coping strategies used by women. On one side, women heads of households continue fishing daily in the same fishing spots while catching lower quantities than before the dam's construction. On the other hand, partnered women's strategy to reduce their time fishing is already generating consequences on the independence and agency of women.

In 2016, the initial responses of men were adaptation strategies; compared to women, these responses showed higher flexibility. They diversified their fisheries by including more gear and traveling to fishing spots away from the community. These responses required incremental changes and the use of financial (i.e., for buying new gear and paying for gas), physical (having suitable vessels for transportation and fisheries), and human assets (having the skills to use the new fishing gear in the new fishing spots). As a consequence of this diversification, men started to use resource-intensive fishing gear allowing fishermen to catch smaller species and fish that have not spawned yet, which can compromise the sustainability of fisheries, as happened in communities with high dependence on fisheries (Allison & Ellis, 2001). Then, a future consequence of this response is the pressure on the fisheries' resources due to their rates of overfishing (Doria et al., 2021) and added to the effects of the dam on fish migration and reproduction (Arantes et al., 2021; Doria et al., 2018, 2021), which can lead the social-ecological system to collapse.

Another immediate response used by locals in Vila Nova, associated with the construction of Belo Monte, was the dependency on safety net programs. These safety programs support coping and stability as they allow locals to redirect the funds to buy goods for their households and cope with the low returns from the fisheries. However, not all households in Vila Nova have access to these safety net programs. The safety net aid portfolio differs in each household; some receive the Defeso, others Bolsa Familia or both, and others have access to the retirement program.

Diversity is essential to resilient systems (Hodbod & Eakin, 2015) and rural livelihoods in the Global South (Ellis, 2000) because diversification creates redundancy and therefore reduces the risk of total livelihood failure by providing alternatives for responding to shocks (Allison & Ellis, 2001; Biggs et al., 2015). In our study, we showed how diversification emerged as a response to the effects of the construction of Belo Monte to support adaptive capacity. Firstly, men used their coping and adaptive capacity to diversify in the fisheries, Vila Nova's primary livelihood strategy. By 2017, as presented in Figure 15, men further diversified by adding other livelihood activities, such as farming and manual labor, to sustain their families (Allison & Ellis, 2001) and their opportunities to respond to shocks (Biggs et al., 2015). However, as shown in Figure 16, in 2019, locals had to use their transformative capacity to sustain their families. They shifted their primary livelihood strategy from fisheries to farming, which required the investment of different capital; this comes with risks, for example, invading other terrains to plant their crops.

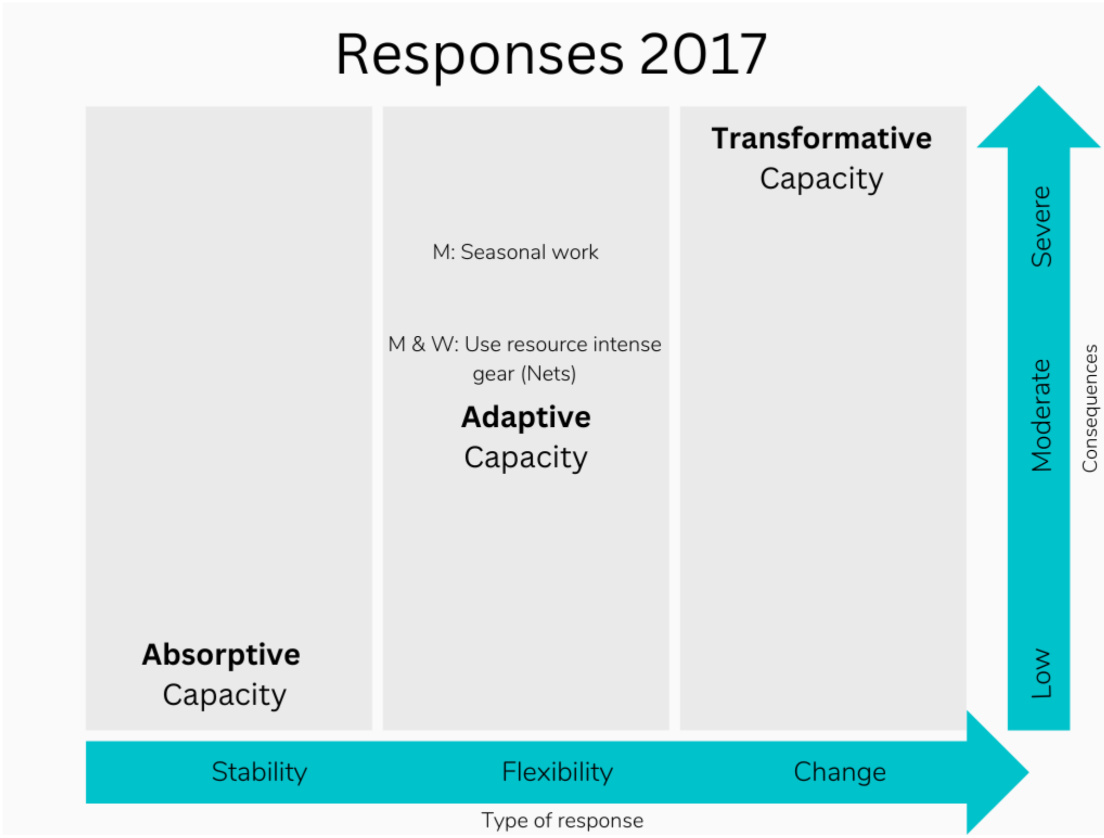


Figure 15. Responses to the effects of Belo Monte in 2017

Shifting livelihood activities (Owusu et al., 2019) and male seasonal migration (Marschke & Berkes, 2006) have been identified elsewhere as a response to changes and uncertainties, such as the effects generated by dam construction (Dao, 2011). In this study, we noticed how seasonal migration was a household adaptation response in which men travel to other communities for manual labor. At the same time, women stayed with their families in the community. This strategy reflected the flexibility of households to maintain the structure, function, and identity of the Vila Nova social-ecological system. However, the consequences of this and the burdens on women should be further explored.

By 2019, the immense adverse effects that the construction of Belo Monte generated in the community overwhelmed locals' absorptive and adaptive capacity and required transformative responses (See Figure 16). Despite the attachment to the community, some families have left the community permanently, significantly changing the household dynamics and its interaction with the Vila Nova SES. It is important to note that households and men who migrated had social support in the places where they traveled, indicating a level of social capital outside the community that supported their response. Those with strong ties to the community and a lack of connectivity with other regions could be less likely to migrate. Nevertheless, in the resilience literature, migration could be considered a failure of the adaptation (Warner, 2010) since, just like resettlement, it could have vast consequences, such as marginalization, food insecurity, and health issues, among others (Cernea, 1997).

This qualitative study, conducted during the late stages of construction (2016) and early operation (2017 and 2019) of the Belo Monte hydroelectric dam, shows how locals' responses rapidly shifted from coping to adaptation to transformation. The study also indicates that local capacities quickly become overwhelmed due to the dam's construction and the system's pre-conditions.

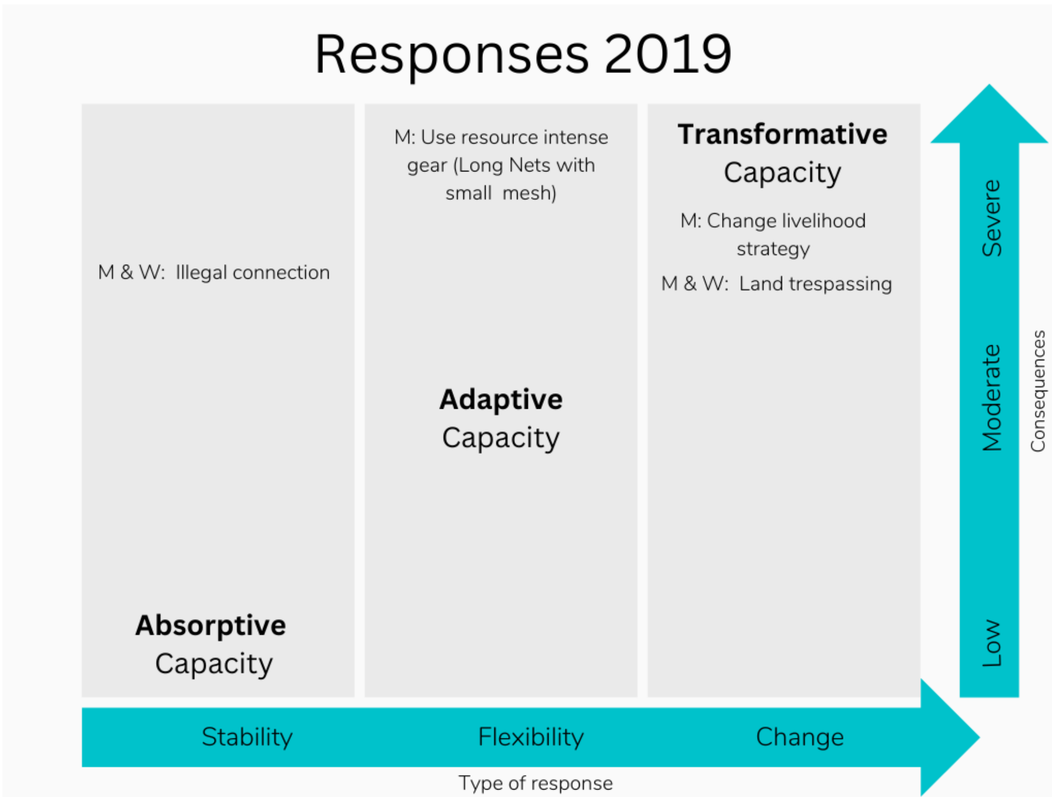


Figure 16. Responses to the effects of Belo Monte in 2019

Understanding the effects of dam development and its cumulative effects on downstream communities can inform dam developers how to improve their assessments. Knowledge of the social-ecological conditions in which local populations exist before the construction of a mega-dam should be a priority since these conditions are the basis for the local's absorptive, adaptive, and transformative capacity. In this case, it could have allowed dam developers to better plan and prevent adverse effects such as the loss of critical ecosystems such as the flooded forest and help households to respond to the potential impacts of dam development. If there is a low capacity of locals to respond to shocks, constructing a hydroelectric dam could generate disruptive effects and collapse peoples' livelihoods, just as we have documented in Vila Nova. As presented in chapter 1, by including local communities' participation in decision-making processes, the adverse effects of dam construction on people's livelihoods could be minimized. For example, just compensation measurements will enhance people's capacities to resist shocks, like training opportunities, affordable electricity prices, etc.

It is important to recall that dam authorities did not consider this community impacted by the construction of Belo Monte. Its inhabitants did not participate in any process or decision-making or receive compensation. Then, locals were not prepared and did not have sufficient support or information to anticipate, absorb, maintain, and recover from the effects of the construction of Belo Monte, as seen by the eventual use of transformative capacity.

Our results show how effects and responses to dam construction vary over time within a local community. Future research should continue exploring gender aspects since dam development projects describe affected people as having genderless identities (Mehta & Srinivasan, 2000) rather than people with different identities, values, aspirations, and needs, and yet our results found the opposite. We recommend dam developers revise their top-down decision-making processes with a focus on solid and influential groups (Hay et al., 2019) to understand the impacts on marginalized groups based on race, ethnicity, and gender. Also, future research should explore how the livelihoods of the migrated households have changed and if this strategy allowed them to transform their livelihoods to a desirable state or if it was a failure.

REFERENCES

Adams, C., Murrieta, R., & Neves, W. (2006). Sociedades caboclas amazônicas: modernidade e invisibilidade. Annablume.

Agostinho, A. A., Pelicice, F. M., & Gomes, L. C. (2008). Dams and the fish fauna of the Neotropical region: impacts and management related to diversity and fisheries. Brazilian Journal of Biology, 68(4), 1119–1132. https://doi.org/10.1590/S1519-69842008000500019

Alho, C. (2011). Environmental Effects of Hydropower Reservoirs on Wild Mammals and Freshwater Turtles in Amazonia: A Review. Oecologia Australis, 15(3), 593–604. https://doi.org/10.4257/oeco.2011.1503.11

Alho, C., Reis, R. E., & Aquino, P. P. U. (2015). Amazonian freshwater habitats experiencing environmental and socioeconomic threats affecting subsistence fisheries. Ambio, 412–425. https://doi.org/10.1007/s13280-014-0610-z

Allison, E. H., & Ellis, F. (2001). The livelihoods approach and management of small-scale fisheries. Marine Policy, 25(5), 377–388. https://doi.org/10.1016/S0308-597X(01)00023-9

Ansah, I., Gardebroek, C., & Ihle, R. (2019). Resilience and household food security: a review of concepts, methodological approaches and empirical evidence. Food Security, 11(6), 1187–1203. https://doi.org/10.1007/s12571-019-00968-1

Arantes, C. C., Fitzgerald, D. B., Hoeinghaus, D. J., & Winemiller, K. O. (2019). Impacts of hydroelectric dams on fishes and fisheries in tropical rivers through the lens of functional traits. Current Opinion in Environmental Sustainability, 37, 28–40. https://doi.org/10.1016/j.cosust.2019.04.009

Arantes, C. C., Laufer, J., Pinto, M. D. da S., Moran, E. F., Lopez, M. C., Dutka-Gianelli, J., Pinto, D. M., Chaudhari, S., Pokhrel, Y., & Doria, C. R. C. (2021). Functional responses of fisheries to hydropower dams in the Amazonian Floodplain of the Madeira River. Journal of Applied Ecology, October, 1–13. https://doi.org/10.1111/1365-2664.14082

Atkins, E. (2017). Dammed and diversionary: The multi-dimensional framing of Brazil's Belo Monte dam. Singapore Journal of Tropical Geography, 38(3), 276–292. https://doi.org/10.1111/sjtg.12206

Atkins, E. (2019). Disputing the "National Interest": The depoliticization and repoliticization of the Belo Monte Dam, Brazil. Water (Switzerland), 11(1). https://doi.org/10.3390/w11010103

Baird, I. G., Silvano, R. A. M., Parlee, B., Poesch, M., Maclean, B., Napoleon, A., Lepine, M., & Hallwass, G. (2021). The Downstream Impacts of Hydropower Dams and Indigenous and Local Knowledge: Examples from the Peace–Athabasca, Mekong, and Amazon. Environmental Management, 67(4), 682–696. https://doi.org/10.1007/s00267-020-01418-x

Baran, E., & Myschowoda, C. (2009). Dams and fisheries in the Mekong Basin. Aquatic Ecosystem Health & Management, 12(3), 227–234. https://doi.org/10.1080/14634980903149902

Barrett, C. B., Ghezzi-Kopel, K., Hoddinott, J., Homami, N., Tennant, E., Upton, J., & Wu, T. (2021). A scoping review of the development resilience literature: Theory, methods and evidence. World Development, 146. https://doi.org/10.1016/j.worlddev.2021.105612

Beck, M. W., Claassen, A. H., & Hundt, P. J. (2012). Environmental and livelihood impacts of dams: common lessons across development gradients that challenge sustainability. International Journal of River Basin Management, 10(1), 73–92.

Benchimol, M., & Peres, C. A. (2015). Widespread forest vertebrate extinctions induced by a mega hydroelectric dam in lowland Amazonia. PLoS ONE, 10(7), 1–15.

https://doi.org/10.1371/journal.pone.0129818

Béné, C. (2013). Towards a Quantifiable Measure of Resilience (Vol. 2013, Issue 434, pp. 1–27). Institute of Development Studies.

Béné, C., & Doyen, L. (2018). From Resistance to Transformation: A Generic Metric of Resilience Through Viability. Earth's Future, 6(7), 979–996. https://doi.org/10.1002/2017EF000660

Béné, C., Headey, D., Haddad, L., & von Grebmer, K. (2016). Is resilience a useful concept in the context of food security and nutrition programmes? Some conceptual and practical considerations. Food Security, 8(1), 123–138. https://doi.org/10.1007/s12571-015-0526-x

Béné, C., Wood, R. G., Newsham, A., & Davies, M. (2012). Resilience: New Utopia or New Tyranny? Reflection about the Potentials and Limits of the Concept of Resilience in Relation to Vulnerability Reduction Programmes. In IDS Working Papers (Vol. 2012, Issue 405). https://doi.org/10.1111/j.2040-0209.2012.00405.x

Berkes, F., Colding, J., & Folke, C. (2008). Introduction. In F. Berkes, J. Colding, & C. Folke (Eds.), Navigating Social-Ecological Systems: Building Resilience for Complexity and Change. Cambridge University Press.

Berkes, F., & Jolly, D. (2002). Adapting to climate change: Social-ecological resilience in a Canadian western arctic community. Ecology and Society, 5(2). https://doi.org/10.5751/es-00342-050218

Berman, R., Quinn, C., & Paavola, J. (2012). The role of institutions in the transformation of coping capacity to sustainable adaptive capacity. Environmental Development, 2(1), 86–100. https://doi.org/10.1016/j.envdev.2012.03.017

Biggs, R., Schlüter, M., & Schoon, M. (2015). Principles for Building Resilience. Sustaining Ecosystem Services in Socio-Ecological Systems (R. Biggs, M. Schlüter, & M. Schoon (eds.)). Cambridge University Press.

Boanada Fuchs, V. (2015). Breaking the walls down: the practice of prior, free, and informed consultation between colonial designs and a new environmental governance framework (The Belo Monte case). Geneva (CH).

Boanada Fuchs, V. (2016). Blaming the weather, blaming the people: Socio-environmental governance and a crisis attitude in the brazilian electricity sector. Ambiente & Sociedade, 19(2), 221–246. https://doi.org/10.1590/1809-4422ASOC0260R1V1922016

Boanada, V. (2015). Breaking the walls down: The practice of prior, free and informed consultation between colonial designs and a new environmental governance framework in Brazil (the Belo Monte case) (Vol. 4, Issue 1).

Bratman, E. (2015). Passive revolution in the green economy: activism and the Belo Monte dam. International Environmental Agreements: Politics, Law and Economics, 15(1), 61–77. https://doi.org/10.1007/s10784-014-9268-z

Braun, Y. (2005). Resettlement and Risk: Women's Community Work in Lesotho. Advances in Gender Research, 9, 29–60. https://doi.org/10.1016/S1529-2126(05)09006-5

Brown, K. (2016). Resilience, Development and Global Change. In Transactions of the Royal Society of South Africa (Vol. 71). Routledge. https://doi.org/10.1080/0035919X.2016.1218374

Calvi, M. F., Moran, E. F., Silva, R. F. B. da, & Batistella, M. (2019). The construction of the Belo Monte dam in the Brazilian Amazon and its consequences on regional rural labor. Land Use Policy, 90(October 2019), 104327. https://doi.org/10.1016/J.LANDUSEPOL.2019.104327

Castro-Diaz, L., Lopez, M. C., Chung, K., & Radonic, L. (2021). Gender norms, institutions, and fishing practices in an Amazonian community. Unpublished Manuscript.

Castro-Diaz, L., Lopez, M. C., & Moran, E. (2018). Gender-Differentiated Impacts of the Belo Monte Hydroelectric Dam on Downstream Fishers in the Brazilian Amazon. Human Ecology, 46(3), 411–422. https://doi.org/10.1007/s10745-018-9992-z

Cernea, M. (1997). The Risk and Reconstruction Model for Resettling displaced populations. World Development, 25(10), 1569–1587.

Cernea, M. (2000). Risks, Safeguards and Reconstruction: A model for population displacement and resettlement. Economic And Political Weekly, 35(41), 3659–3678. https://doi.org/10.2307/4409836

Cernea, M. (2004). Social impacts and social risks in hydropower programs: preemptive planning and counter-risk measures. Proceedings of United Nations Symposium on Hydropower and Sustainable Development, 1–22. http://www.un.org/esa/sustdev/sdissues/energy/op/hydro_cernea_social impacts_backgroundpaper.pdf

Coomes, O., Takasaky, Y., Abizaid, C., & Barham, B. L. (2010). Floodplain fisheries as natural insurance for the rural poor in tropical forest environments : evidence from Amazonia. Fisheries Management and Ecology, 6, 1–9.

Creswell, J. (2014). Research Design. Qualitative, Quantitative, and Mixed Methods Approaches (J. Creswell (ed.); Fourth Edi). SAGE Publications.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. Global Environmental Change, 18(4), 598–606. https://doi.org/10.1016/j.gloenvcha.2008.07.013

Dao, N. (2011). Damming Rivers in Vietnam: A Lesson Learned in the Tây Bắc Region. Journal of Vietnamese Studies, 6(2), 106–140. https://doi.org/10.1525/vs.2011.6.2.106

De Brauw, A., Gilligan, D. O., Hoddinott, J., & Roy, S. (2014). The Impact of Bolsa Família on Women's Decision-Making Power. World Development, 59, 487–504. https://doi.org/10.1016/j.worlddev.2013.02.003

Doria, C., Athayde, S., Marques, E. E., Lima, M. A. L., Dutka-Gianelli, J., Ruffino, M. L., Kaplan, D., Freitas, C. E. C. C., & Isaac, V. N. (2017). The invisibility of fisheries in the process of hydropower development across the Amazon. Ambio, 47(4), 453–465. https://doi.org/10.1007/s13280-017-0994-7

Doria, C., Dutka-Gianelli, J., Athayde, S., Luiz, A. M. M. T., Brasil, W., Estupiñán, G. M. B., Hauser, M., Damme, P. A. Van, & Torrente-Vilara, G. (2018). Grandes hidrelétricas na Amazônia: impactos no recurso pesqueiro e na pesca artesanal, desafios e lições aprendidas na bacia do Rio Madeira. Revista Ciências Da Sociedade, 2(4), 79–106. https://doi.org/10.30810/rcs.v2i4.904

Doria, C., Dutka-Gianelli, J., Brasil de Sousa, S. T., Chu, J., & Garlock, T. M. (2021). Understanding impacts of dams on the small-scale fisheries of the Madeira River through the lens of the Fisheries Performance Indicators. Marine Policy, 125(May 2020), 104261. https://doi.org/10.1016/j.marpol.2020.104261

Doria, C., & Lima, M. A. L. (2015). Rio Madeira, Seus peixes e sua pesca. RiMa Editora.

Égré, D., & Senécal, P. (2003). Social impact assessments of large dams throughout the world: lessons learned over two decades. Impact Assessment and Project Appraisal, 21(3), 215–

224. https://doi.org/10.3152/147154603781766310

Ellis, F. (2000). Rural Livelihoods and Diversity in Developing Countries. Oxford University Press.

Fainguelernt, M. (2016). A trajetoria historica do processo de licenciamento ambiental da usina hidreletica de Belo Monte. Ambiente & Sociedade, XIX(2), 247–265.

Fainguelernt, M. B. (2020). Impactos da Usina Hidrelétrica de Belo Monte: uma análise da visão das populações ribeirinhas das reservas extrativistas da Terra do Meio. Civitas - Revista de Ciências Sociais, 20(1), 43. https://doi.org/10.15448/1984-7289.2020.1.35906

Fallon, A., Jones, R. W., & Keskinen, M. (2022). Bringing resilience-thinking into water governance: Two illustrative case studies from South Africa and Cambodia. Global Environmental Change, 75(March), 102542. https://doi.org/10.1016/j.gloenvcha.2022.102542

FAO. (2016). AnalysIng Resilience for better targeting and action Resilience Index Measurement and Analysis-II. http://www.fao.org/3/a-i5665e.pdf

FAO, IDAD, UNICEF, WFP, & WHO. (2022). The State of Food security and nutrition in the world 2022. In Repurposing food and agricultural policies to make healthy diets more affordable. FAO. https://doi.org/10.1016/S2213-8587(22)00220-0

Fearnside, P. (2018). Represando a Amazônia sem restrições por mudanças no setor elétrico brasileiro. Amazonia Real.

Fearnside, P. M. (1999). Social impacts of Brazil's Tucurui Dam. Environmental Management, 24(4), 483–495. https://doi.org/10.1007/s002679900248

Fearnside, P. M. (2014). Brazil's Madeira River dams: A setback for environmental policy in Amazonian development. Water Alternatives, 71(1), 54–167.

Fearnside, P. M. (2016a). Environmental and Social Impacts of Hydroelectric Dams in Brazilian Amazonia: Implications for the Aluminum Industry. World Development, 77, 48–65. https://doi.org/10.1016/j.worlddev.2015.08.015

Fearnside, P. M. (2016b). Tropical dams: to build or not to build? Science, 351(6272), 1456–1457. http://www.sciencemag.org/content/327/5966/642.1.short

Flecker, A. S., Shi, Q., Almeida, R. M., Angarita, H., Gomes-Selman, J. M., García-Villacorta, R., Sethi, S. A., Thomas, S. A., LeRoy Poff, N., Forsberg, B. R., Heilpern, S. A., Hamilton, S. K., Abad, J. D., Anderson, E. P., Barros, N., Bernal, I. C., Bernstein, R., Cañas, C. M., Dangles, O., … Gomes, C. P. (2022). Reducing adverse impacts of Amazon hydropower expansion. Science, 375(6582), 753–760. https://doi.org/10.1126/science.abj4017

Fleury, L. C., & Almeida, J. (2013). A construção da usina hidrelétrica de Belo Monte: Conflito ambiental e o dilema do desenvolvimento. Ambiente & Sociedade, 16(4), 141–158.

Folke, C. (2016). Resilience (Republished). Ecology and Society. https://doi.org/10.5751/ES-09088-210444

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chappin, T., & Rockstrom, J. (2010). Resilience thinking: Integrating resiliencem adaptability and transformability. Ecology and Society, 15(4), 20–28. https://doi.org/10.5751/ES-03610-150420

Forsberg, B. R., Melack, J. M., Dunne, T., Barthem, R. B., Goulding, M., Paiva, R. C. D., Sorribas, M. V., Silva, U. L., & Weisser, S. (2017). The potential impact of new Andean dams on Amazon fluvial ecosystems. In Plos One (Vol. 12, Issue 8). https://doi.org/10.1371/journal.pone.0182254

Garcia, M. A., Castro-Díaz, L., Villamayor-tomas, S., & Lopez, C. (2021). Are large-scale hydroelectric dams inherently undemocratic ? Global Environmental Change, 71, 1–11. https://doi.org/10.1016/j.gloenvcha.2021.102395

Goulding, M. (1980). The fishes and the forest, explorations in Amazonian natural history. University of California Press.

Goulding, M. (1990). Amazon. The Flooded Forest. Sterling Publishing Company.

Goulding, M., Smith, N., & Mahar, D. J. (1996). Floods of Fortune. Ecology & Economy Along the Amazon. Columbia University Press.

Green, N., & Baird, I. G. (2016). Capitalizing on compensation: Hydropower resettlement and the commodification and decommodification of nature-society relations in Southern Laos. Annals of the American Association of Geographers, 106(4), 853–873. https://doi.org/10.1080/24694452.2016.1146570

Grill, G., Lehner, B., Thieme, M., Geenen, B., Tickner, D., Antonelli, F., Babu, S., Borrelli, P., Cheng, L., Crochetiere, H., Ehalt Macedo, H., Filgueiras, R., Goichot, M., Higgins, J., Hogan, Z., Lip, B., McClain, M. E., Meng, J., Mulligan, M., … Zarfl, C. (2019). Mapping the world's free-flowing rivers. Nature, 569(7755), 215–221. https://doi.org/10.1038/s41586-019-1111-9

Grisotti, M. (2016). The Construction of Health Causal Relations in the Belo Monte Dam Context. Ambiente & Sociedade, 19(2), 287–304. https://doi.org/10.1590/1809-4422ASOC0252V1922016

Hay, M., Skinner, J., & Norton, A. (2019). Dam-Induced Displacement and Resettlement : A Literature Review FutureDAMS (Issue September).

Higgins, T. (2020). Belo Monte boondoggle: Brazil's biggest costiest dam may be unviable. Mongabay Series: Amazon Infrstructure.

Hodbod, J., & Eakin, H. (2015). Adapting a social-ecological resilience framework for food systems. Journal of Environmental Studies and Sciences, 5(3), 474–484. https://doi.org/10.1007/s13412-015-0280-6

Holmes, B. R., Jones, N., Vargas, R., & Veras, F. (2010). Cash transfers and gendered risks and vulnerabilities: lessons from Latin America - Background paper - ODI Background Notes published by ODI, DFID and the International Policy Centre for Inclusive Growth. Development, October.

IEA. (2021). Hydropower Special Market Report - Analysis and forecast to 2030. 126. https://iea.blob.core.windows.net/assets/4d2d4365-08c6-4171-9ea2-8549fabd1c8d/HydropowerSpecialMarketReport_corr.pdf.

IPCC. (2014). Mitigation of Climate Change - Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (O. Edenhofer, R. Pichs-Madruga, Y. Sokona, J. C. Minx, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Shlömer, C. Von Stechow, & T. Zwickel (eds.)). Cambridge University Press. http://report.mitigation2014.org/spm/ipcc_wg3_ar5_summary-for-policymakers_approved.pdf

IRENA. (2022). Renewable Capacity Highlights (Issue April).

Isaac, V. J., & Barthem, R. (1995). Os Recursos Pesqueiros da amâzonia brasileira. Boletim Do Museu Paraense Emílio Goeldi. Série Antropologia, 11(2), 295–339.

Kirchherr, J., & Charles, K. J. (2016). The Social Impact of Dams: A New Framework for scholarly Analysis. Environmental Impact Assessment Review, 60, 99–114. https://doi.org/10.1016/j.eiar.2016.02.005

Kirchherr, J., Pohlner, H., & Charles, K. J. (2016). Cleaning up the big muddy: A meta-synthesis of the research on the social impact of dams. Environmental Impact Assessment Review, 60, 115–125.

Latrubesse, E. M., Arima, E. Y., Dunne, T., Park, E., Baker, V. R., D'Horta, F. M., Wight, C., Wittmann, F., Zuanon, J., Baker, P. A., Ribas, C. C., Norgaard, R. B., Filizola, N., Ansar, A., Flyvbjerg, B., & Stevaux, J. C. (2017). Damming the rivers of the Amazon basin. Nature, 546(7658), 363–369. https://doi.org/10.1038/nature22333

Legese, G., Van Assche, K., Stelmacher, T., Tekleworld, H., & Kelboro, G. (2018). Land for food or power? Risk governance of dams and family farms in Southwest Ethiopia. Land Use Policy, 75, 50–59.

Lemos, M. C., Lo, Y. J., Nelson, D. R., Eakin, H., & Bedran-Martins, A. M. (2016). Linking development to climate adaptation: Leveraging generic and specific capacities to reduce vulnerability to drought in NE Brazil. Global Environmental Change, 39, 170–179. https://doi.org/10.1016/j.gloenvcha.2016.05.001

Leturcq, G. (2016). Differences and similarities in impacts of hydroeletric dams between North and South of Brazil. Ambiente e Sociedade, 19(2), 265–286. https://doi.org/10.1590/1809-4422ASOC0254R1V1922016

Loker, W. (2003). The University of Chicago Press Research http://www.jstor.org/stable/10.1086/340282 . Wenner-Gren Foundation for Anthropological. Current Anthropology, 43(1), 509–510.

Manyari, W. V., & de Carvalho, O. A. (2007). Environmental considerations in energy planning for the Amazon region: Downstream effects of dams. Energy Policy, 35(12), 6526–6534. https://doi.org/10.1016/j.enpol.2007.07.031

Marschke, M. J., & Berkes, F. (2006). Exploring strategies that build livelihood resilience: A case from Cambodia. Ecology and Society, 11(1). https://doi.org/10.5751/ES-01730-110142

Mayer, A., Castro-Diaz, L., Lopez, M. C., Leturcq, G., & Moran, E. F. (2021). Is hydropower worth it? Exploring amazonian resettlement, human development and environmental costs with the Belo Monte project in Brazil. Energy Research and Social Science, 78(January), 102129. https://doi.org/10.1016/j.erss.2021.102129

Mayer, A., Lopez, M. C., Leturcq, G., & Moran, E. (2022). Changes in Social Capital Associated with the Construction of the Belo Monte Dam: Comparing a Resettled and a Host Community. Human Organization, 81(1), 22–34. https://doi.org/10.17730/1938-3525-81.1.22

Mehta, L., & Srinivasan, B. (2000). Balancing Pains and Gains. A Perspective Paper on Gender and Large Dams World Commission on Dams Secretariat World Commission on Dams (Vol. 1, Issue March). http://www.dams.org

Miles, M., & Huberman, A. (1994). Qualitative Data Analysis: an expanded sourcebook (2nd. ed). Thousand Oaks: Sage Publications.

Miles, M., Huberman, M., & Saldaña, J. (2014). Qualitative Data Analysis. A Methods Source Book (M. B. Miles, M. Huberman, & J. Saldaña (eds.); Third). Sage Publications.

Ministério do Trabalho e Previdência. (2022). Solicitar Aposentadoria por Idade para Trabalhador

Rural — Português (Brasil). (2022). Retrieved 30 September 2022, from. Instituto Nacional Do Seguro Social - INSS. https://www.gov.br/pt-br/servicos/solicitar-aposentadoria-por-idade-para-trabalhador-rural

Moran, E. F. (1974). The adaptive system of the Amazonian caboclo. In C. Wagley (Ed.), Man in the Amazon (pp. 136–159). University of Florida Press.

Moran, E. F. (2016). Roads and Dams: Infrastructure-Driven Transformations in the Brazilian Amazon. Ambiente & Sociedade 2016, XIX, 207–220. https://doi.org/10.1590/1809-4422ASOC256V1922016

Mourão, R. R., Neuls, G. S., & Ninni, K. (2022). Hydropower in the News : how Journalists do (not) Cover the Environmental and Socioeconomic Costs of Dams in Brazil. Environmental Communication, 0(0), 1–14. https://doi.org/10.1080/17524032.2022.2115095

Olsson, P., & Galaz, V. (2012). Social-ecological innovation and transformation. In A. Nicholls & A. Murdock (Eds.), Social Innovation. Blurring Boundaries to Reconfigure Markets (pp. 223–247). Palgrave macmillan. https://doi.org/10.1016/j.paid.2011.03.037

Orr, S., Pittock, J., Chapagain, A., & Dumaresq, D. (2012). Dams on the Mekong River : Lost fish protein and the implications for land and water resources. Global Environmental Change, 22(4), 925–932. https://doi.org/10.1016/j.gloenvcha.2012.06.002

Owusu, K., Asiedu, A. B., Yankson, P. W. K., & Boafo, Y. A. (2019). Impacts of Ghana's Bui dam hydroelectricity project on the livelihood of downstream non-resettled communities. Sustainability Science, 14(2), 487–499. https://doi.org/10.1007/s11625-018-0588-8

Owusu, K., Obour, P. B., & Nkansah, M. A. (2017). Downstream effects of dams on livelihoods of river-dependent communities: the case of Ghana's Kpong Dam. Geografisk Tidsskrift - Danish Journal of Geography, 117(1), 1–10. https://doi.org/10.1080/00167223.2016.1258318

Painel de Especialistas. (2009). Análise Crítica do Estudo de Impacto Ambiental do Aproveitamento Hidrelétrico de Belo Monte.

Randell, H. (2016). Structure and agency in development-induced forced migration: the case of Brazil's Belo Monte Dam. Population and Environment, 37(3), 265–287. https://doi.org/10.1007/s11111-015-0245-4

Richter, B. D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., & Chow, M. (2010). Lost in development's shadow: The downstream human consequences of dams. Water Alternatives, 3(2), 14–42. https://doi.org/10.1007/s11195-009-9131-2

Rousseau, J. F. (2017). Does carbon finance make a sustainable difference? Hydropower expansion and livelihood trade-offs in the Red River valley, Yunnan Province, China. Singapore Journal of Tropical Geography, 38(1), 90–107. https://doi.org/10.1111/sjtg.12176

Runde, A., Hallwass, G., & Silvano, R. A. M. (2020). Fishers' Knowledge Indicates Extensive Socioecological Impacts Downstream of Proposed Dams in a Tropical River. One Earth, 2(3), 255–268. https://doi.org/10.1016/j.oneear.2020.02.012

Scudder, T. (1993). Development-induced relocation and refugee studies: 37 years of change and continuity among zambia's gwembe tonga. Journal of Refugee Studies, 6(2), 123–152. https://doi.org/10.1093/jrs/6.2.123

Scudder, T. (2005). The Future of Large Dams: Dealing with social, environmental, institutional and political costs. Earthscan.

Scudder, T., & Colson, E. (1982). From welfare to development: A conceptual framework for the analysis of dislocated people. In A. Oliver-Smith & A. Hansen (Eds.), Involuntary Migration and Resettlement: The Problems and Responses of Dislocated People (pp. 267–287).

Scudder, T., & Gay, J. (2011). A Comparative Survey of Dam-induced Resettlement in 50 Cases With the Statistical Assistance of John Gay. In The Future of Large Dams: Dealing with Social, Environmental. Institutional and Political Costs (pp. 56–86).

Smith, L., & Frankenberger, T. (2018). Does Resilience Capacity Reduce the Negative Impact of Shocks on Household Food Security? Evidence from the 2014 Floods in Northern Bangladesh. World Development, 102, 358–376. https://doi.org/10.1016/j.worlddev.2017.07.003

Smith, N. (1981). Man, Fishes, and the Amazon. Columbia University Press.

Stenberg, R. (2006). Damming the river: a changing perspective on altering nature. Renewable and Sustainable Energy Reviews, 10(3), 165–197. https://doi.org/10.1016/j.rser.2004.07.004

Trussart, S., Messier, D., Roquet, V., & Aki, S. (2002). Hydropower projects: A review of most effective mitigation measures. Energy Policy, 30(14), 1251–1259. https://doi.org/10.1016/S0301-4215(02)00087-3

Urban, F., Nordensvard, J., Siciliano, G., & Li, B. (2015). Chinese Overseas Hydropower Dams and Social Sustainability: The Bui Dam in Ghana and the Kamchay Dam in Cambodia. Asia and the Pacific Policy Studies, 2(3), 573–589. https://doi.org/10.1002/app5.103

von Sperling, E. (2012). Hydropower in Brazil: Overview of positive and negative environmental aspects. Energy Procedia, 18, 110–118. https://doi.org/10.1016/j.egypro.2012.05.023

Wagley, C. (1953). Amazon Town. A Study of Man in the Tropics. Macmillan.

Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G. D., & Pritchard, R. (2002). Resilience management in social-ecological systems: A working hypothesis for a participatory approach. Ecology and Society, 6(1). https://doi.org/10.5751/es-00356-060114

Walker, B., Gunderson, L., Kinzig, A., Folke, C., Carpenter, S., & Schultz, L. (2006). A Handful of Heuristics and Some Propositions for Understanding Resilience in Social-Ecological Systems. Ecology and Society, 11 (1)(1).

Walker, B., Holling, C. ., Carpenter, S., & Kinzig, A. (2004). Resilience, adaptability and transformability in social-ecological systems. Ecology and Society, 9(2), 5.

Warner, K. (2010). Global environmental change and migration: Governance challenges. Global Environmental Change, 20(3), 402–413. https://doi.org/10.1016/j.gloenvcha.2009.12.001

Wiejaczka, Ł., Piróg, D., Tamang, L., & Prokop, P. (2018). Local Residents' Perceptions of a Dam and Reservoir Project in the Teesta Basin, Darjeeling Himalayas, India. Mountain Research and Development, 38(3), 203. https://doi.org/10.1659/mrd-journal-d-16-00124.1

Wilmsen, B., Webber, M., & Yuefang, D. (2011). Development for whom? rural to Urban resettlement at the three Gorges Dam, China. Asian Studies Review, 35(1), 21–42. https://doi.org/10.1080/10357823.2011.552707

Winemiller, K. O., McIntyre, P. B., Castello, L., Fluet-Chouinard, E., Giarrizzo, T., Nam, S., Baird, I. G., Darwall, W., Lujan, N. K., Harrison, I., Stiassny, M. L. J., Silvano, R. A. M., Fitzgerald, D. B., Pelicice, F. M., Agostinho, A. A., Gomes, L. C., Albert, J. S., Baran, E., Petrere, M., … Saenz, L. (2016). Balancing hydropower and biodiversity in the Amazon, Congo, and Mekong. Science, 351(6269), 128–129. https://doi.org/10.1126/science.aac7082

Xi, J., & Hwang, S. S. (2011). Relocation Stress, Coping, and Sense of Control Among Resettlers Resulting from China's Three Gorges Dam Project. Social Indicators Research, 104(3), 507–522. https://doi.org/10.1007/s11205-010-9758-5

Yankson, P., Asiedu, A. B., Owusu, K., Urban, F., & Siciliano, G. (2018). The livelihood challenges of resettled communities of the Bui dam project in Ghana and the role of Chinese dam-builders. Development Policy Review, 36(October 2016), O476–O494. https://doi.org/10.1111/dpr.12259

Yüksel, I. (2009). Dams and Hydropower for Sustainable Development. Energy Sources, Part B: Economics, Planning, and Policy, 4(1), 100–110. https://doi.org/10.1080/15567240701425808

Zarfl, C., Lumsdon, A. E., Berlekamp, J., Tydecks, L., & Tockner, K. (2015). A global boom in hydropower dam construction. Aquatic Sciences, 77(1), 161–170. https://doi.org/10.1007/s00027-014-0377-0

APPENDIX 7 EFFECTS OF DAM CONSTRUCTION LOCAL ACTORS' LIVELIHOODS

Table 31. Codebook effects of dam construction

Code	Sub-code	Definition	Rule
Seasonality	Positive Negative	Ecological and fishing seasonality of the region. Hydroelectric dams generate changes in hydrological regimes (Alho, 2011; IPCC, 2014; Trussart et al., 2002; Yüksel, 2009)	Use statements that describe changes in the fisheries, including the river's flood.
Water quality	Positive Negative	Changes perceived by local fishers in the quality of water. Scholars have reported effects on water quality due to dam construction (Baird et al., 2021; Castro-Diaz et al., 2018)	Include statements describing the change in the quality of the river quality. Positve and negative.
Natural system	Positive Negative	Changes in the ecology of the fisheries. Dams block fish migration, increase fish mortality and increase habitat transformation, which generates negative impacts on fish habitat and reproduction (Arantes et al., 2019; Baran & Myschowoda, 2009; Trussart et al., 2002; von Sperling, 2012; Winemiller et al., 2016)	Use this code to describe the fish species' ecology before and after the dam's construction. Include aspects such as reproduction and migration.
Fishing yield	Positive Negative	Social and economic effects associated with dam construction. Since the ecology of fisheries has been affected, scholars have reported a reduction in fish production (Baran & Myschowoda, 2009; Doria et al., 2017, 2018; Orr et al., 2012; Runde et al., 2020)	Use statements from the respondent regarding the quantity and quality of fish they harvest. E.g., kg
Loss of common property/ Fishing spots	Positive Negative	Loss of access to common property - Particularly fishing spots. Dams generate the loss of flooded forests and fishing spots (Castro-Diaz et al., 2018; P. M. Fearnside, 2016a; Manyari & de Carvalho, 2007; von Sperling, 2012)	Use statements regarding the places where fisher fish and how it has changed because of the construction of BM
River navigation	Positive Negative	Obstacles in the navigation. Dams generate blocks in river navigation (Baran & Myschowoda, 2009; Orr et al., 2012; Trussart et al., 2002)	Use statements that include a description of barriers during navigation generated by the construction of the dam.
Inflation rate	Positive Negative	Increased inflation rates of basic food and fishery products (e.g., gas). The construction of hydroelectric dams generates a booming economy in the areas where dams are built (Moran, 2016).	Excerpts from the interviewees that explain the increase in the price level of goods and services after the dam's construction.

Table 31 (cont'd)

Code	Sub-code	Definition	Rule
Morbidity & Mortality	Positive Negative	There are severe declines in health due to dam construction. Social stress and psychological trauma are sometimes related to the outbreak of illnesses such as parasitic and vector-borne diseases. In addition, the lack of water-safe supply and sewage systems increases vulnerability to epidemics (Cernea, 1997, 2000)	Include statements describing changes in health. Include mental health. Include positive and negative.
Food Access	Positive Negative	Whether people have physical and economic access to that food (FAO et al., 2022). Dams have caused significant declines in fish populations and consequently to people's livelihoods and food security (Beck et al., 2012; Urban et al., 2015; Wiejaczka et al., 2018; Wilmsen et al., 2011; Yankson et al., 2018).	Access to food changed (for example, if they used to plant their food but now have to buy food from a store, etc.) after the dam construction. Or if the price of food increased. Fish is considered food. Include positive and negative changes.
Crime	Positive Negative	Cases of crime in the community and region. Researchers have described how criminality increases in the areas where dams are constructed (von Sperling 2012)	Include statements that describe cases of crime in the community and or region
Sense of insecurity	Positive Negative	Perception of insecurity	Statements about the perception of insecurity of the interviewees related to violence.
Marginalization		When families and/or individuals lose economic power, many people cannot use their previous skills at the new locations; therefore, human and financial capital is lost or inactive. (Cernea, 1997)	Use this code when interviewees note that their fishing skills are no longer helpful for sustaining themselves and their families.
Electricity Access		People deserve sufficient energy resources of high quality (Sovacool, 2017). Communities near dams lack access to reliable electricity sources and unaffordable electricity prices (P. M. Fearnside, 1999; Green & Baird, 2016).	Use this code in statements referring to the reliability of the electricity service, the challenges accessing electricity, and the affordability of electricity

APPENDIX 8 RESPONSES ASSOCIATED WITH DAM DEVELOPMENT

Table 32. Responses associated with dam development

Code	Definition	Rule
Fisheries Diversification	Include aspects that describe changes in the visited fishing spots, gear used, or target fishing species. Include gear, time, effort, and distance.	This code should be used when there is a reference regarding a change in fisheries strategies. It is about their practices.
Diversified livelihoods	When individuals and households include more activities to sustain their livelihoods. (Other than fisheries)	Use statements that show that individuals or households are including other activities besides fishing to sustain their livelihoods. Include if other household members started fishing or working in other activities.
Change of livelihood activity	When individuals or households change their primary livelihood activity, affected communities shift their livelihood activities (Owusu et al., 2019).	Use statements describing how individuals pursue different activities than fisheries as the primary strategy. Include if other members of the household start fishing or doing other activities.
Safety net programs new	Individuals and households are enrolling in new safety programs as a result of the construction of the dam	Use to describe that individuals or households are enrolling in new safety programs.
Safety net programs change	Individuals or households have changed the purpose/aim of the safety program to cope/adapt	Use when interviewees describe that they change the use of the subsidies they receive
Change of diet	Individuals or households include or exclude some food from their daily or weekly intake. Research has shown that individuals and households change their diets as a consequence of dam construction (Agostinho et al., 2008; P. M. Fearnside, 2014, 2016b; Stenberg, 2006)	Use this code when a respondent is describing how they have changed their diet due to the impacts generated by the dam
Migrate	Because of the impacts on their lives and livelihoods, individuals or households decide to migrate to other regions. Due to the effects of dam development, communities migrate (Dao, 2011).	Use this code to describe statements regarding migrating from vila nova to other communities because their livelihood strategy is no longer sustaining their lives. *Include seasonal work.
Rule compliance	Some individuals and households are not complying with rules to sustain their families.	This code refers to activities conducted by individuals or households that don't comply with formal or informal rules.

Table 32 (cont'd)

Code	**Definition**	**Rule**
Community networks	Individuals and households ask for support from friends or relatives.	This code should be used when the interviewee describes moments when they ask relatives for support.
Other	Other activities or behaviors of fishers to respond to the changes generated at the individual, household, or community level	Use this code to describe activities or behaviors not included in other codes regarding the response of individuals, households, or the community to shocks generated by Belo Monte

Conclusions: Beyond decarbonization

"*La transición energética no es solamente una cuestión de energía. La supervivencia y el bienestar de la humanidad y de la vida toda dependen de pasar de civilizaciones obsesionadas con el consumo ilimitado de energía a sociedades centradas en la vida*." Arturo Escobar, 2022

This dissertation contributes to the literature on the social impacts of large-scale hydroelectric dam construction in the Global South by exploring the underlying effects and energy injustices through different theoretical frameworks and methodological approaches.

The social-ecological impacts of dams have been studied since the 50s (Hay et al., 2019; Scudder, 1993, 2005). However, there are still some gaps in the literature I addressed in my dissertation. In *Chapter 1*, I present a comparative medium-N study that compiles the effects of dam construction in 33 large-scale dams built in the Global South and emerging economies. I explore dam development's positive and negative impact in the capitals of local communities near these hydroelectric dams. The main results show that natural, social, human, and financial capital are negatively impacted, whereas some physical capital is positively impacted. The analysis also showed a relationship between civil society's lack of participation in decision-making and negative impacts on peoples' capital- a relationship that has not been described in the literature. I also found that mega-dams negatively affect people's capital regardless of the energy security status of a nation. These results are significant given the current energy demand and the need for a fast energy transition. Hydroelectric dams are usually portrayed as cheap and sustainable energy sources. However, as I demonstrate, they affect the livelihoods of those living near construction sites and therefore enhance injustices in communities lacking political power to make project decisions.

Second, the literature has studied the adaptive capacity individuals, households, and communities should have to respond effectively to shocks. However, there were no studies assessing how hydroelectric dams' construction affects local communities' adaptive capacity and how the construction of a dam may have impacted their food and energy security. In *Chapter 2*, I explored how constructing a hydroelectric complex composed of two large-scale dams in the Brazilian Amazon affected the generic adaptive capacity of households in eight communities near the dams and, in turn, how that influenced household well-being, as per food and energy security. I found that the construction of the dams negatively impacted the households' adaptive generic capacity, as well as food security in terms of availability and access. Therefore, the construction of these dams impacted the conditions that support people to respond to shocks, reduce adverse effects, recover, and take advantage of new opportunities. This shows how dams increase the vulnerability of local communities, putting them at risk because they lack the adaptive capacity to respond to future shocks from extreme climate events and anthropogenic activities.

Third, most studies about the effects of hydroelectric dams have focused on resettled communities. Dam authorities overlook the downstream impacts of hydropower development (Baird et al., 2021; Richter et al., 2010; Runde et al., 2020; Scudder, 2005). Fourth, there is a lack of studies exploring the temporal dynamics of dam development; most of the studies are conducted in one period of time (Braun, 2005) and usually takes place 5 to 10 years after dam construction (Kirchherr et al., 2016). In *Chapters 3 and 4.* I conducted a multitemporal qualitative case study of data collected in a community downstream from the *Belo Monte* hydroelectric dam. Data were collected at three points: during the late stage of construction (2016) and early operation (2017, 2019). This methodological approach allowed me to understand the temporal dynamics of energy injustices faced by locals in a community downstream from a mega hydroelectric dam and their responses to the effects associated with dam development over four years.

Chapter 3 presents a systematic overview of the energy injustices experienced in the last stages of construction and early operation by a community located downstream from the Belo Monte dam. The contributions of this chapter go beyond the methodological approach. This study expands the temporal understanding of the justice implications of hydropower development in the Brazilian Amazon. Furthermore, most of the literature on energy justice focuses on integrating distributional and procedural justice (Lacey-Barnacle et al., 2020), downplaying the multidimensionality of energy (in)justices. This misses a deeper understanding of how local actors experience different energy justice issues (distributional, procedural, recognition, restorative, and capabilities justice) and how these interact to further the injustices. I used the distributional, procedural, recognition, restorative, and capabilities energy justice tenets to understand how local actors experience different energy justice issues and how these interact to further the injustices. I find that individuals face multiple and diverse energy injustices at various stages of the dam construction, and its severity changes over time. For instance, distributional issues were more predominant at the beginning of data collection since fisheries, their main livelihood activity, was impacted by dam construction. Then, other justice issues, such as capabilities, emerged in the last years of data collection.

Chapter 4 focuses on the effects of constructing a mega hydroelectric dam in a downstream community and how individuals and households respond to those. Scholars have described strategies followed by affected communities to respond to the effects associated with dam development. Nevertheless, to my knowledge, no studies are exploring the responses of local actors in communities impacted by dams from social-ecological resilience lenses considering the three core resilience capacities: coping, adaptive, and transformative. The study shows dam construction generates immediate negative impacts on downstream communities and how these cause cumulative effects over time. For example, since the first year of data collection, locals' described the adverse effects on the river's flow and how it caused the loss of the flooded forest, fishing spots, and fish species. In the following years, these impacts continued to appear, along with limited access to food. Likewise, I presented the short-term resilience responses associated with these effects and how they rapidly shift from relying on coping to adaptive to transformative capacity in response to the accumulated effects. Men used more adaptive and transformative strategies than women, such as migrating for seasonal jobs or changing livelihood strategies from fisheries to farming.

As a sustainability scholar, I used an interdisciplinary perspective of the social impacts of dams at different scales from different theoretical frameworks and methods. The complexity of the social impacts of dams involves many aspects that I could not cover in the dissertation (e.g., power dynamics, governance, and intersectionality). However, with the findings of this dissertation, we have a better understanding of what happens after the construction of dams.

In this dissertation, I used qualitative, quantitative, and mixed-methods to understand diverse aspects of the social impacts of hydroelectric dams. This approach allowed me to explore the social impacts and energy injustices associated with dam development at different scales using different units of analysis: A Global South scale, comprising 33 large-scale dams; a complex hydroelectric scale, assessing the effects of constructing two hydroelectric dams at the household level in 8 communities; and an individual and household scale, exploring the effects of dam development in a community downstream from dams.

As mentioned above, the qualitative meta-analysis allowed me to understand dams' impacts on the capital comprehensively. This method had limitations since the papers included were only written in English. I acknowledge that science is written in many languages and that researchers in the Global South are conducting critical, high-quality studies. Nonetheless, to highlight the work of Global South researchers throughout my dissertation, I recognize and cite research conducted and published in Portuguese and Spanish by researchers studying the social-ecological impacts of hydroelectric dams.

The second scale I explored was at the level of a hydroelectric dam complex. To assess how the adaptive capacity of households was affected, I used the information from a social survey I helped design. Most studies exploring dams' social impacts are qualitative (Kirchherr et al., 2016); survey data helps advance the literature using quantitative methods. Some issues included the survey design because some responses to one question determine whether a respondent gets the next question.

The qualitative research design for *Chapters 3* and *4* allowed me to get in-depth information and build trusting relationships with the community's inhabitants, which provided the space for participants to share emotional and very personal experiences and fears associated with the dam. Over the years, besides the trust relationship with locals, my expertise using qualitative methods and knowledge about the social impacts and energy injustices increased over time. One limitation of these two papers was that the research protocol was not based on the literature on Energy Justice and Social-Ecological Resilience at the beginning of the study. It is worth mentioning I conducted this research during the Covid pandemic, then my possibility of going to the field was limited. Coming back to an argument that I stated earlier in the introduction of this dissertation, the narrative under the technologies of the energy transition tends to overestimate their benefits and underestimate their drawbacks (Sovacool & Brossmann, 2014). I show how an energy source portrayed as a solution for achieving energy transition can generate immense social-ecological impacts and multidimensional and multitemporal energy injustices perpetuating structural inequities. As energy demand and the need for a clean energy transition are increasing, we must find energy systems that look beyond just low carbon emissions to those that also address energy injustices and provide fair and equitable processes that consider gender, ethnicity, race, and class. Furthermore, this dissertation shows a disconnect between academics, energy policymaking, and communities living nearby construction sites. By now, we know that hydroelectric dam construction negatively affects host, downstream, and resettled communities. This was already demonstrated in the WCD report. Then, why the Environmental and Social Impact Assessments have not been restructured? Why have these assessments not included other affected communities? Why are we letting dam developers conduct the assessments? Who defines and decides who is considered impacted and who is not?

Most scholars argue that the construction of dams generates disturbances; that have been discussed since the 50s. The context continues to be the same, those living in the rural areas, usually poor and who lack political and economic power, are facing the burdens, while the urban elites enjoy the benefits of dams. Then, why are we still building dams? How can we avoid and begin to address these immense injustices?

The recurrent injustices and the rejection of the WCD recommendations lead me to conclude that they are intentional—the cost of development at any expense. My dissertation demonstrates that large-scale hydroelectric dams affect the livelihoods of those living near construction sites and therefore enhance injustices in communities that lack the political power to make project decisions. It suggests that solutions must put people first and that finding other pathways to development is necessary. In Brazil, for example, the government and NGOs have started promoting photovoltaic panels in programs like *Mais Luz para Amazônia* (More light for the Amazon) for communities that lack access to a reliable, clean, and sustainable electricity source.

As mentioned in the introduction of my dissertation, energy transition should consider, among others, the technology, the actors, the social norms, and the context (Geels, 2004). Some initiatives have started to include a systemic approach by co-designing with local communities energy systems tailored to their needs (Brown et al., 2022; Moran et al., in press). A convergence approach like the one proposed by Moran et al. (in press) is based on the engagement of local communities to build decentralized energy systems that, beyond generating low-carbon electricity, are adapted to the social-ecological context. Besides the co-design of the system, the approach recognizes the importance of local communities' self-governance and self-determination, which enhances local actors' empowerment (Moran et al., in press). They propose using hybrid systems of in-stream hydroelectric generators and photovoltaic panels in off-the-grid communities in the Amazon region. We must effectively communicate our findings with our participants, local and national governments, and industry. Let's get out of this zone of comfort in which privileged people are writing papers and communicating with each other. Publishing and conducting "novel studies," as we have seen in the context of dams, is not enough to change or address the structural injustices of society. Calling out these injustices and offering alternatives is one step in the right direction. Let's put this knowledge into practice; let's help improve the lives and well-being of those suffering the negative impacts of dams and avoid future injustices.

REFERENCES

Baird, I. G., Silvano, R. A. M., Parlee, B., Poesch, M., Maclean, B., Napoleon, A., Lepine, M., & Hallwass, G. (2021). The Downstream Impacts of Hydropower Dams and Indigenous and Local Knowledge: Examples from the Peace–Athabasca, Mekong, and Amazon. Environmental Management, 67(4), 682–696. https://doi.org/10.1007/s00267-020-01418-x

Braun, Y. (2005). Resettlement and Risk: Women's Community Work in Lesotho. Advances in Gender Research, 9, 29–60. https://doi.org/10.1016/S1529-2126(05)09006-5

Brown, E., Johansen, I. C., Bortoleto, A. P., Pokhrel, Y., Chaudhari, S., Cak, A., Sulaeman, S., Castro-Diaz, L., Lopez, M. C., Mayer, A., Walgren, J., Müller, N., & Moran, E. (2022). Feasibility of hybrid in-stream generator-photovoltaic systems for Amazonian off-grid communities. PNAS Nexus, June, 1–9. https://doi.org/10.1093/pnasnexus/pgac077

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. Research Policy, 33(6), 897–920. https://doi.org/https://doi.org/10.1016/j.respol.2004.01.015

Hay, M., Skinner, J., & Norton, A. (2019). Dam-Induced Displacement and Resettlement : A Literature Review FutureDAMS (Issue September).

Kirchherr, J., Pohlner, H., & Charles, K. J. (2016). Cleaning up the big muddy: A meta-synthesis of the research on the social impact of dams. Environmental Impact Assessment Review, 60, 115–125.

Moran, E. F., Lopez, M. C., Mourão, R., Erik, B., McCright, A., Walgren, J., Bortoleto, A. P., Mayer, A., Cavallini, I., Ninni, K., Castro-Diaz, L., Garcia, M. A., Lembi, R., & Mueller, N. (in press). Advancing Convergence Research: Renewable Energy Solutions for Off-Grid Communities. PNAS, In Press.

Richter, B. D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., & Chow, M. (2010). Lost in development's shadow: The downstream human consequences of dams. Water Alternatives, 3(2), 14–42. https://doi.org/10.1007/s11195-009-9131-2

Runde, A., Hallwass, G., & Silvano, R. A. M. (2020). Fishers' Knowledge Indicates Extensive Socioecological Impacts Downstream of Proposed Dams in a Tropical River. One Earth, 2(3), 255–268. https://doi.org/10.1016/j.oneear.2020.02.012

Scudder, T. (1993). Development-induced relocation and refugee studies: 37 years of change and continuity among zambia's gwembe tonga. Journal of Refugee Studies, 6(2), 123–152. https://doi.org/10.1093/jrs/6.2.123

Scudder, T. (2005). The Future of Large Dams: Dealing with social, environmental, institutional and political costs. Earthscan.

Sovacool, B. K., & Brossmann, B. (2014). The rhetorical fantasy of energy transitions: implications for energy policy and analysis. Technology Analysis and Strategic Management, 26(7), 837–854. https://doi.org/10.1080/09537325.2014.905674