The Social Injustice of the Belo Monte Dam for the Xingu People of the Amazon: A Remote Sensing Perspective

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***Abstract*—In recent years, the Amazon River basin resources have been exploited disproportionately, resulting in stresses on the people living in the region - especially the indigenous population, who are already victims of social injustice due to a pattern of historical marginalization. One such instance of exploitation of natural resources and marginalization of indigenous communities is the recent completion of the Belo Monte Dam on the Xingu River. The Xingu River holds a high cultural value for the Xingu tribe, but it has now dried up by about 80% following the completion of the Belo Monte dam complex. Using publicly available satellite data and freely available tools (the Reservoir Assessment Tool, RAT), we offer remote-sensing-based solutions to help the affected communities independently monitor dam operations. We believe that this will not only help the communities to back the claims of social injustice with reliable observational data but will also help the dam operators by making it possible to reach a better compromise with the Xingu tribe where both the hydropower needs and the Xingu River's natural flow requirements are met.**

***Index Terms*— Remote Sensing, Reservoirs, Water Resources**

I. Introduction

THE Amazon river basin has a drainage area of more than 60 million km^2 spanning nine countries and represents the world's largest network of rivers [1]. In addition to exceptional biodiversity, dense vegetation, and abundance of surface water, Amazon is also home to ca. 30 million humans. Current estimates indicate that 2.7 million thereof are indigenous people, representing 350 ethnic groups living in more than 3000 indigenous territories [2], Fig. 1.

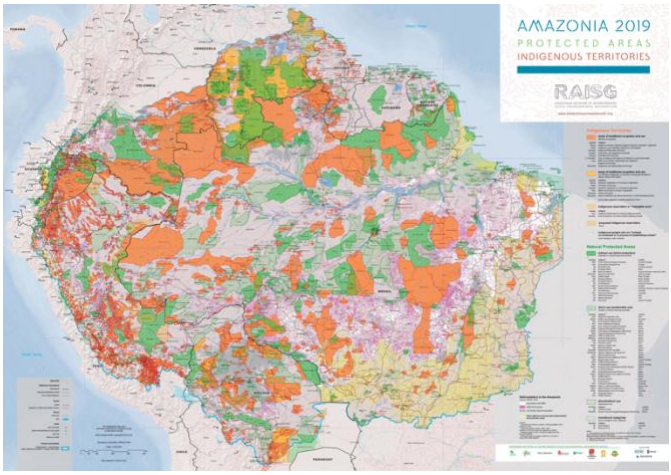

Fig. 1. Map of the Amazon River Basin. Indigenous territories are shown in orange; natural protected areas are shown in green (Source: The Amazonian Geo-referenced Socio-Environmental Information Network (RAISG), 2019 [3]).

In popular literature, the Amazon is widely referred to as the "lungs of the world." There has been extensive research done on how humans have altered the natural landscape of the Amazon River basin [4]. The consequential impacts of these anthropogenic drivers on global hydrology, weather patterns, climate change, and ocean circulation have been well-studied [5]–[7]. However, the impact of these anthropogenic drivers on the social justice of the indigenous population has received relatively little attention.

With a total share of 61%, Brazil has by far the most significant proportion of the Amazon basin within its national boundaries [8]. According to the 2010 census conducted by the Brazilian Institute of Geography and Statistics, 305 distinct ethnic groups are situated in Brazil. There are a total of 505 indigenous lands, which cover about 12.5% of the Brazilian territory. Since colonial times, the Indigenous people of Brazil have been systematically marginalized and victimized by all forms of political parties and administrations [9], [10]. The increasing trend of hostility towards the Indigenous people of Brazil by the Brazilian government is also very well documented. All Indigenous communities are increasingly

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getting more threats from the government in the form of genocidal policies [11].

One such indigenous population that has long suffered social injustice in the name of development is the Xingu population. The Xingu people are an indigenous population of Brazil living near a part of the Xingu River (Fig. 2) called the Big Bend. The origins of the social injustice faced by Xingu people can be traced to 1750 with the arrival of Portuguese slave traders and foreign diseases that systematically decimated the population. According to some estimates, the Xingu population has already reduced to a mere 500 individuals [12].

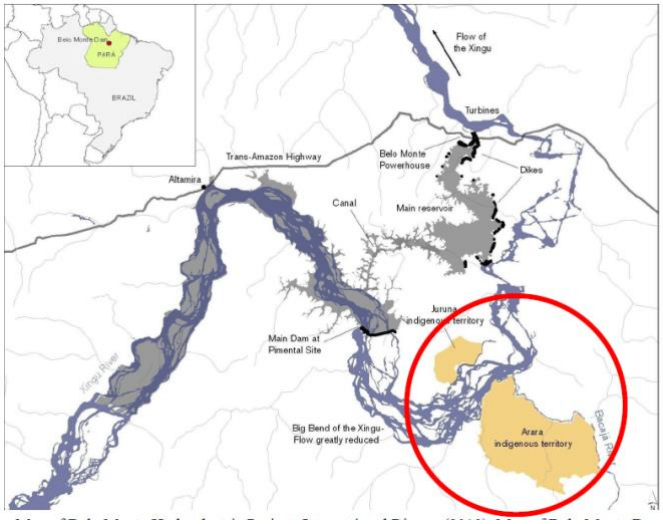

Fig. 2. The Xingu river (right side) in the Brazilian state of Para. The area inside the red circle is where most of the Xingu population lives along the Xingu river. The general direction of flow is from left to right along the river. The shaded gray region indicates the inundation due to the filling of the Belo Monte dam by short-cutting the flow through a canal and embankment. (Source: https://www.internationalrivers.org/resources/map-of-belo-monte-dam-4595)

In addition to the existing disadvantages faced by the Xingu tribe due to historical reasons, a more recent and rapid onslaught of social injustice has affected the tribe over the past decade. The entire Belo Monte dam project has been highly controversial since its inception. Concerns such as incursion into indigenous territories by illegal miners and loggers are becoming a reality ever since the project began taking shape [11].

With the construction of the Belo Monte Dam in 2010 [13], the Xingu River – specifically, the Big Bend portion of the river, which is revered as the 'House of God' by the Xingu population, has now dried up by as much as 80%. This has further marginalized the Xingu people's essential religious and cultural way of life (Fig. 2). The reservoir covers about 200 sq. miles of lowlands and forested areas, and estimates of uprooted populations are 20,000-25,000 [14]. In a project of this scale, where the end-product was going to be among the largest hydropower structures ever built by humans, the Indigenous people whose land and water sources were most affected were never consulted [11]. The construction was even ruled illegal by a federal judge because of the disregard of consultation from Indigenous people, and still, the construction was allowed [14].

In this commentary, we discuss how the Belo Monte Dam has dramatically altered the hydrology of the Xingu River using satellite remote sensing observations. We offer a potential and interim solution based on satellite remote sensing for revising the operation procedure of the Belo Monte Dam to keep the Xingu River flowing at essential times for cultural needs. Finally, we offer our perspectives on how the vast array of remote sensing data could be more comprehensively applied to better characterize the baseline of social injustice due to dam building in the Amazon today.

II. TRACKING THE CHOKING OF THE "HOUSE OF GOD" BY THE BELO MONTE DAM FROM SPACE

The Belo Monte Dam is located on the Xingu River in the Brazilian state of Pará (Figure 3). The dam was managed by *Norte Energia* and started in 2011 and finished in 2016 with an estimated cost of $6.5 Billion [15]. Although the declared motivation for building the Belo Monte Dam as the World's fourth largest (by installed capacity) was to provide power to 23 million households, it is thought that the actual beneficiaries were various private sector companies [16], [17].

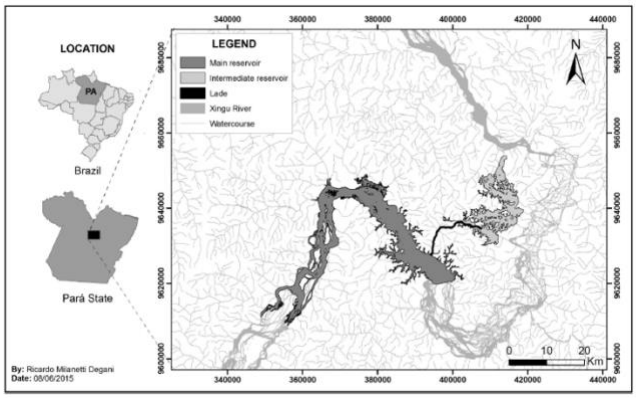

Fig. 3. The Belo Monte Power Plant reservoir on the Xingu River (Source: Norte Energia S.A., 2010).

NASA Landsat observations over the past decade indicate how the Xingu River has systematically drained and dried while the Belo Monte reservoir was filled up through an artificial canal (bypassing the natural flow gradient along the Xingu river, Fig. 4).

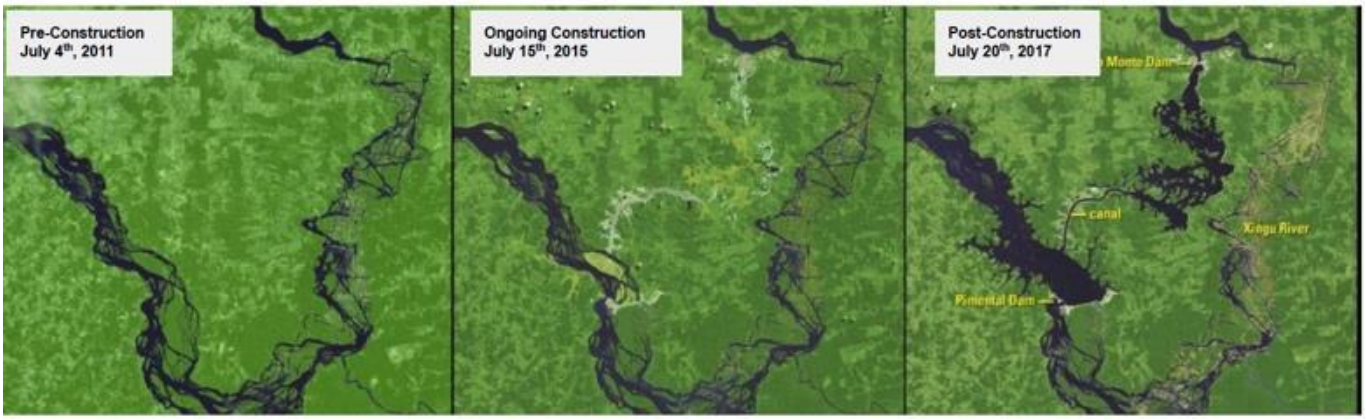

Fig. 4. The gradual drying up of the Xingu river (right side) as observed by the Landsat mission with the construction of a dam to stop flow along the natural gradient and divert it through a canal to the Belo Monte reservoir. (Source: United States Geological Survey - https://www.usgs.gov/media/images/belo-monte-dam-complex-brazil Public-access image.)

III. REMOTE SENSING CAN EMPOWER THE XINGU POPULATION

The fact that satellite observation of surface water of the Xingu river can be tied to the construction and operation of the Belo Monte Dam offers hope that such information can no longer be hidden from the public eye. We argue that satellite observations today can level the playing field and empower those working to restore the cultural rights of the Xingu population, and as a result, the Xingu population itself.

By piecing together vast amounts of satellite remote sensing data from multiple platforms, we can now reconstruct historical patterns and predict current and future trends of reservoir operations around the world in terms of storage change, inflow, outflow, residence time, and rule curves [18], Fig. 5. One such satellite-based tool is the global **Reservoir Assessment Tool (RAT),** which is customizable and updates reservoirs' water quantity condition (flux and storage) for 1598 (and growing) reservoirs of the world [18] (see www.satellitedams.net).

In the Amazon, such an eye on reservoirs can empower marginalized communities such as the Xingu population, who currently lack tools to understand dam impacts (Fig. 6) either due to restrictions related to data-sharing policies of the dam operators or due to the lack of required infrastructure for monitoring and studying the impacts at a relevant scale. Although the RAT currently does not include the Belo Monte Dam (the database that was used while building the RAT tool, Belo Monte was listed as 'Future Dam'), there are several nearby dams that are already monitored routinely from satellite data (such as Caruna Uma, Fig. 7). Furthermore, it is feasible to add Belo Monte Dam to the RAT framework and initiate high-frequency monitoring of the reservoir states such as outflow, inflow, storage change, surface area variations. Our current work using all satellite sensors over the Mekong River indicated that RAT might be able to monitor reservoir state for Belo Monte Dam every 2-5 days with even an outflow forecasting capability, thus providing unprecedented insight into the dam operations for the Xingu people.

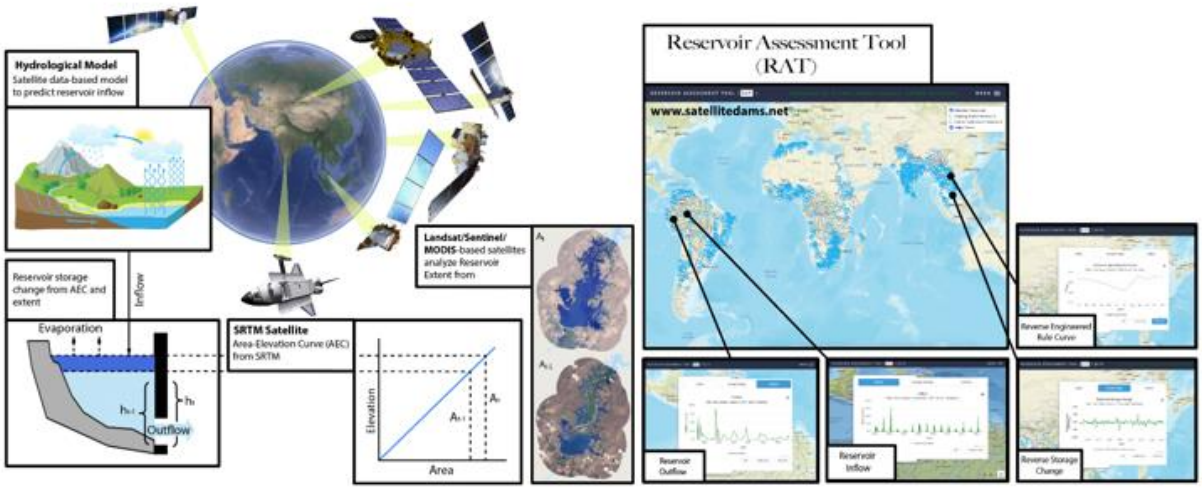

Fig. 5. Front end of the RAT's scalable and customizable platform that provides nowcast and hindcast state of 1598 reservoirs. **Left side**: use of multiple NASA satellites spanning optical, near-infrared, and microwave wavelengths synthesized with a distributed hydrologic model to predict reservoir state. The RAT can be accessed at http://www.satellitedams.net

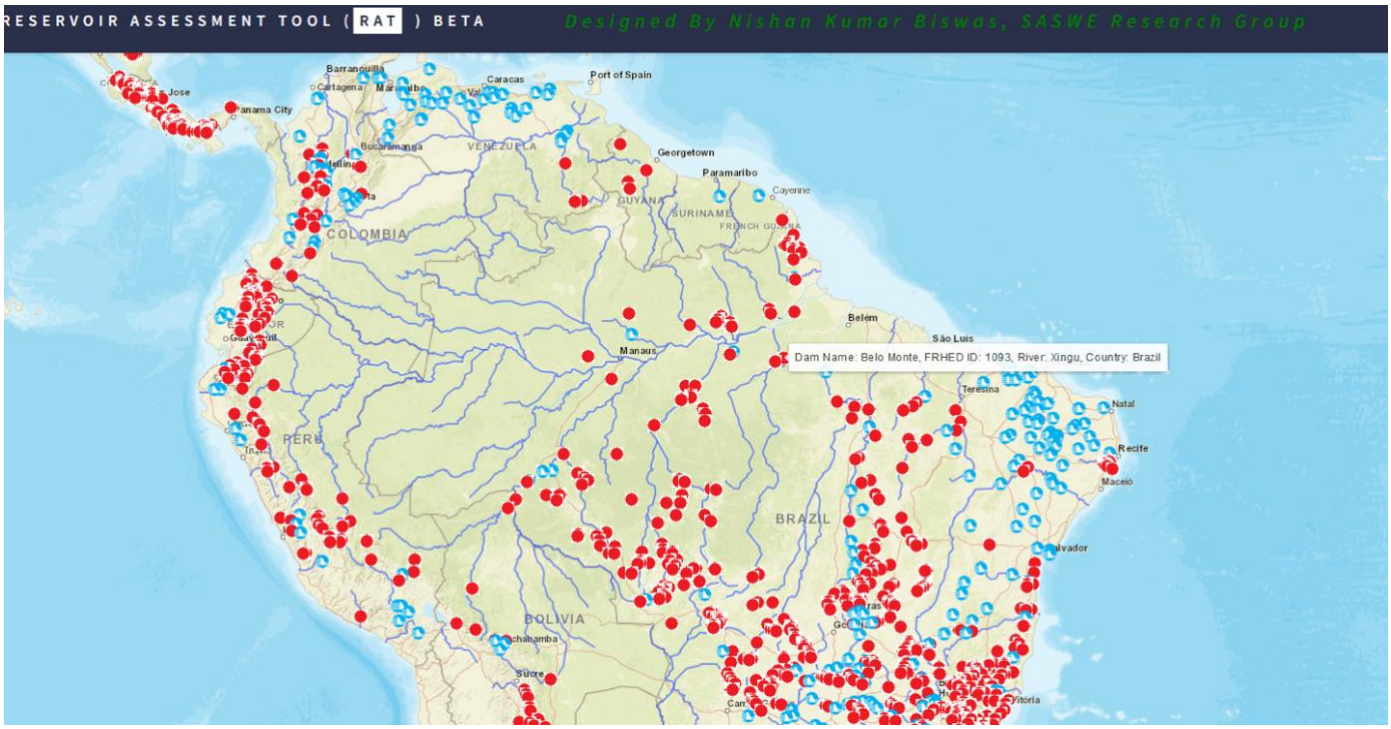

Fig. 6. Dams of the Amazon river basin that are currently modeled in the RAT system (shown in blue) with future dam locations (shown in red). The Belo Monte Dam is shown with a text box. See www.satellitedams.net

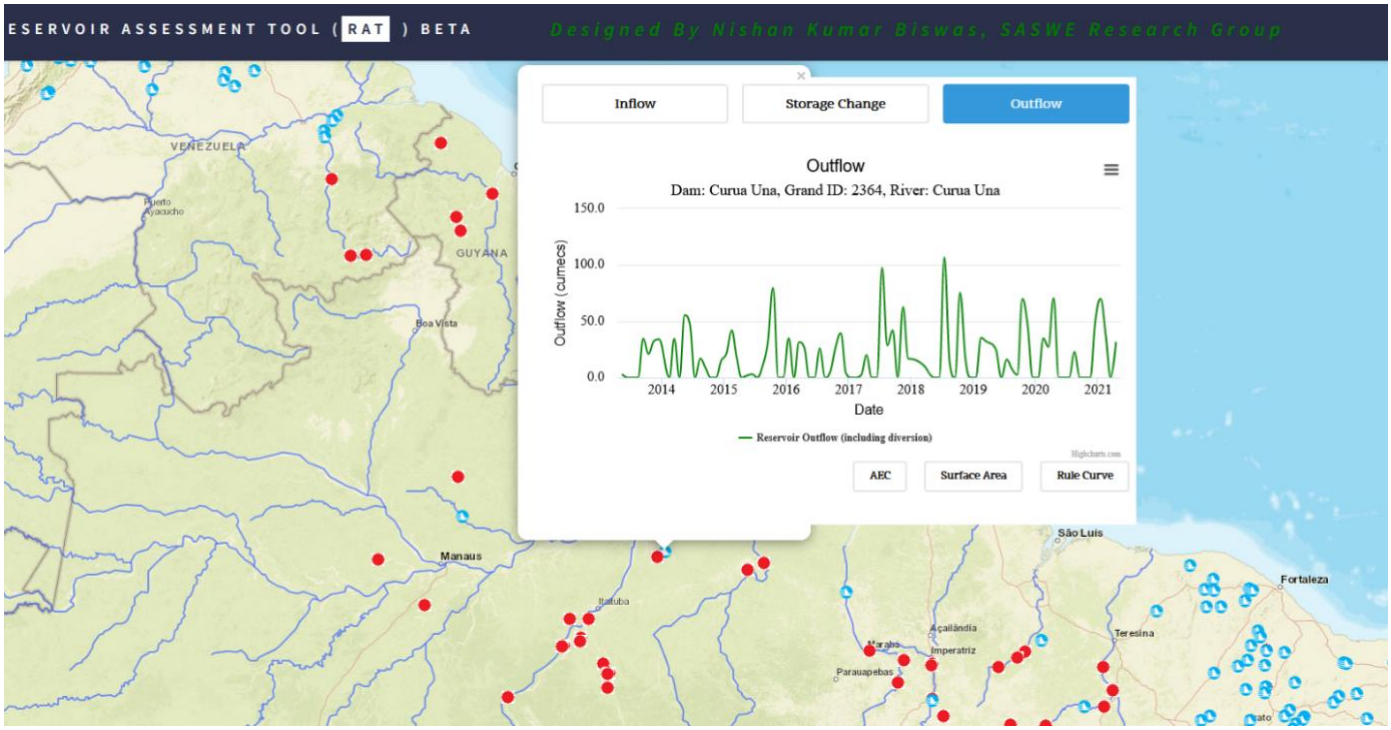

Fig. 7. The Caruna Una dam on the Caruna Una river as modeled in the RAT system. This dam is the nearest to the Belo Monte Dam (see www.satellitedams.net).

Even though dam operators collect extensive in-situ data, these datasets are usually subject to highly restrictive data-sharing policies. On the other hand, remote-sensing-based solutions are freely available. The first benefit RAT offers for the Xingu population that did not exist before is the ability to independently study the recent historical behavior of Belo Monte Dam, track the current state, monitor the operational patterns, and even forecast the likely state of the reservoir – all of which is easily accessible via the internet. While the estimates based on remote sensing have higher uncertainty compared to in-situ data, the unfettered access to this

information via local indigenous government representatives and cellphones can empower the Xingu population to understand the critical pressure factors of the Belo Monte dam operations that cause the Xingu River to dry up during times of most cultural need.

The RAT tool can also be a platform for bringing the population together and helping gather information in preparation for negotiations with Belo Monte dam authorities. Currently, we have a similar tool for bringing the nations of Lower Mekong together via the regional governing body of the Mekong River Commission (see http://depts.washington.edu/saswe/mekong). Access to such independent information levels the playing field for all parties involved. As a result, it empowers the voice of marginalized populations by giving them independent observations that cannot be hidden or modified by those in power.

By providing access to dam operations through independent data sources, dam operators for the Belo Monte Dam are also likely to see the longer-term benefit of seeking feedback from the Xingu population to revise the current release and storage decisions and appear more equitable. Through long-term observations of dam operations with the hydro climatologic records from Landsat spanning 40 years and dynamic programming, we now know that it is possible to revise the standard operating procedure of dams to a more socially just normal [19]. This new standard can ensure emplacement of a compromise, such that the water in Xingu River remains flowing while also providing adequate hydropower benefit within a non-zero-sum framework. Recent studies based on 40 years of Landsat records of reservoirs around the world indicate that it is possible to track reservoir trends in storage accurately [20].

A second benefit offered by RAT is that by making the Belo Monte Dam operations public to the world, governing agencies and the general public who care about indigenous rights and social justice can put pressure on Belo Monte Dam operators and its investor companies during situations when it is clear that withholding water for the Xingu River is morally wrong. By providing a more transparent view of dam operations, imprecise as it may be due to the nature of satellite remote sensing, investor companies may be forced to recognize the Xingu population in its operation of the dam and even reassess the social price they are paying for hydropower production to avoid economically damaging, negative publicity.

IV. Conclusion

Before the modern economic development of the 20th century, indigenous populations of the Amazon were attuned to the ecological realities of their environment from five millennia of iteration. These populations understood how to sustainably manage the rainforest and water resources to suit their needs by maintaining biodiversity through a combination of natural forests, open fields, and managed forests. Sadly, the Amazonian native population has now declined, and so did their sustainable way of life. It is essential to understand the potential drivers (such as the Belo Monte Dam for the Xingu population) that may be accelerating such population declines and the social injustice footprint. With the current hostile stance of the Brazilian government towards indigenous people, access to independent data has become ever so more critical for the survival of the indigenous people and their culture. Remote sensing may not directly solve the problem of social injustice. However, it offers the tools needed to characterize the problems and explore affordable solutions by bringing diverse and competing stakeholders together. Tools such as the Reservoir Assessment Tool that can monitor the near-real-time and historical operations of the dams can help empower the people who are most affected by the changes brought forth by these structures built in the name of development and can help maintain the checks-and-balances required for equitable growth and existence of every involved party.

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