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Communication

Conserving Tropical Forests: Can Sustainable Livelihoods Outperform Artisanal or Informal Mining?

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Abstract: The viability of conservation efforts, including protected areas and buffer zones, depends on finding ways to make those strategies more attractive and viable for local populations. This paper presents a pilot study utilizing a rapid rural appraisal of livelihoods in the buffer zone of Tambopata National Reserve in Madre de Dios, Peru, threatened by illegal gold mining and logging. We evaluated three predominant economic activities—artisanal gold mining, Brazil nut harvesting, and fish farming—in terms of potential economic returns. The main research question we ask is whether the latter two potentially sustainable land uses can match or exceed the returns from mining. Contrary to popular belief, we find that enhancing value creation at product origin could make existing forest-friendly livelihoods as or more lucrative than extractive ones. This has implications on local conservation policy encouraging implementable strategies incentivizing sustainable livelihoods in tandem with, and in support of, conservation goals.

Keywords: Brazil nuts; conservation strategies; deforestation; fish farming; half-earth; income analysis; informal gold mining; Madre de Dios; Payments for Ecosystem Services; sustainable livelihoods

1. Introduction

Globally, intact forests provide a variety of provisioning and regulating services essential to social and ecological integrity on multiple spatial scales [1,2]. For instance, forest ecosystem services provide climate regulation, carbon storage and sequestration, pollution control, nutrient cycling, and hydrologic regulation [3]. Forests also provide socio-cultural value for certain groups, as well as economic consumptive use and non-use (e.g., aesthetic) values [4]. Locally, forest landscapes are witness to the multiple land uses which balance these ecological, socio-cultural, and economic services. Yet, despite ecosystem resilience depending on landscape heterogeneity and continuity [4], many of the world's remaining intact forests are threatened by deforestation or fragmentation by human activities including logging, fishing, and mineral extraction, for consumptive use at the loss of crucial social and ecological services. The rapid expansion of destroyed or altered landscapes, particularly in tropical forests, has resulted in calls for conservation measures ranging from the creation of protected areas, landscape corridors, and buffer zones [5,6], to community forest management and payments for ecosystem services [7].

Out of these potential conservation strategies, one line of thought posits that in order to conserve the world's biodiversity and ecosystems, we need to protect up to half of the terrestrial surface of the planet in protected areas [8,9]. However, there remains an inherent tension between human use of ecosystem services like natural resources [10] and conservation of the forests that produce

them. Despite decades of innovative science and policy, local-scale demand for consumption of forest services often outweighs the needs and desires to conserve intact ecosystems. While the conservation community suggests that protected area landscapes be selected "in a way that will be supported, and not just tolerated, by the people living within and around them" [11], experience has shown that in fact, many communities don't yet support conservation efforts—particularly those with valuable natural resources, weak governance, and vulnerable human populations.

With increasing recognition that threats to biologically important landscapes are linked to social and economic pressures [12–14], some argue that forest management and sustainable livelihood perspectives should be combined [15]. As such, a challenge that arises is how to make conservation a more attractive and viable option for individuals and local communities, in service of both ecological and consumptive economic values.

This paper further explores how such conservation goals can be achieved while accounting for local demands. Our main research question—whether sustainable land uses could provide economic returns that match or exceed those from mining in Peru—was examined via two sub-questions:

Q1 *Does informal mining provide higher wages than either fish farming or Brazil nut harvesting as individual activities for the average person?*

Q2 *Can fish farming and Brazil nut harvesting practices can be modified to equal or surpass wages from informal mining, either as individual activities or as components of a mosaic of livelihood choices?*

We examine potential returns from informal gold mining, which is the principal threat to forest ecosystems in Peru's Madre de Dios region [16–18], and two existing forest-based livelihood choices [19]—Brazil nut harvesting and fish farming—which are both practiced by communities in the region. In order to assess whether an individual actor in the study site could pursue economic interests with less negative impacts on the surrounding forest landscape, we compare actual and potential incomes from existing alternative value chains associated with forest-friendly economic activities, with the aim of debunking the myth that forest destructive livelihoods are always more lucrative [20]. Current literature has primarily focused on payments for ecosystem services (PES) for reforestation or prevention of deforestation. Such programs in Peru are frequently rendered ineffective due to greater revenue from illegal activities (such as logging) on program lands [21]. By exploring whether conservation-friendly, forest-based livelihood choices can provide economic returns on par or above those of forest-destructive livelihoods, this research not only offers an innovative analysis of local conservation incentives, but also provides a basis for integrated sustainability that goes beyond economic outcomes to include social and environmental elements [22].

Study Area

Madre de Dios (MDD), Peru, located in the Tropical Andes Biodiversity Hotspot [23], contains large tracts of intact forest that host some of the world's highest levels of terrestrial species endemism and diversity [24], globally important stocks of carbon, and significant cultural diversity including over 40 ethnic groups and indigenous peoples in voluntary isolation [25]. The Peruvian government has established several protected areas, including the Tambopata National Reserve, created in the year 2000 in order to protect an intact forest landscape of 274,690 hectares [26] (Figure 1). In 2001, a buffer zone of 186,450 hectares was established to protect the reserve from the threats of illegal gold mining illegal, logging, agricultural expansion, and road construction [27].

However, the drastic increase in gold price during the last two decades caused a boom in small-scale illegal and informal alluvial gold mining that has remained rampant [28]. Likewise, the completion of the interoceanic highway in 2011 increased migration and connectivity, rapidly exacerbating the drivers of forest loss and land cover conversion. According to Peru's National Institute for Statistical Information, the migrant population in the region has more than doubled in the past 30 years [29]. Notably, migrant populations hold different cultural and economic ties to the area than

indigenous populations, resulting in dramatic changes to the mosaic of economic land uses, and the introduction and expansion of a cash-based economy.

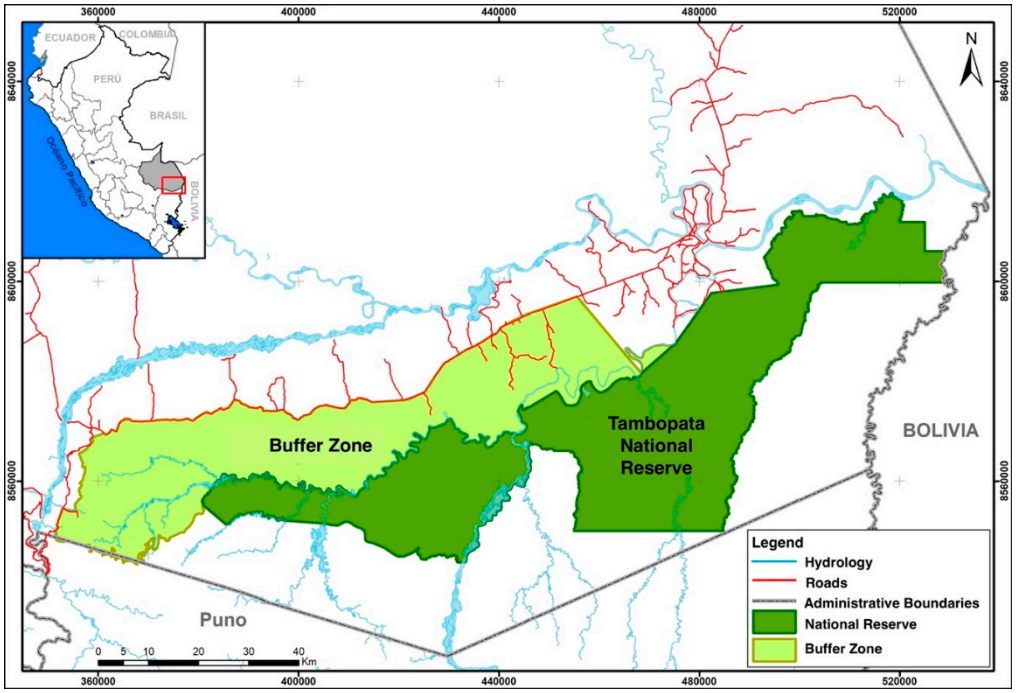

Figure 1. A map of Tambopata National Reserve (dark green) and its Buffer Zone (light green) located in the Madre de Dios region of Southeast Peru, and their connectivity in relation to encroaching roads.

2. Methods

A pilot study utilizing an adaptation of a rapid rural appraisal of livelihoods was conducted in the buffer zone of Tambopata National Reserve, in Madre de Dios, Peru. While rapid rural appraisals are inherently limited in terms of the quality and resolution of data generated, studies have shown they can provide useful information for conservation policy [30,31]. They are particularly useful in areas where social, environmental, and logistical constraints prohibit more thorough and detailed assessments.

Our rapid rural appraisal innovatively utilized a multi-method approach to assess the viability of alternative livelihoods that both leverage intact forests and are economically comparable to informal gold mining in the Madre De Dios (MDD) region of Peru. We began with a comprehensive review of the literature and an analytical re-assessment of existing livelihood data (desk study). Mining was the most commonly cited livelihood, distinguished between small scale (organized mining with 10+ individuals who legally mine on an area of 1000–2000 hectares), artisanal (individual or small groups of 2–5 people who legally mine on land totaling less than 1000 hectares), and informal (individuals or pairs who mine on small tracts of land typically without a full permit). Other livelihoods that allowed for or required intact forests included Brazil nut harvesting, fish farming, agroforestry, logging, eco-tourism, and cash crops such as cacao. Based on their comparable economic returns, three predominant economic activities were chosen for further exploration: informal gold mining, Brazil nut harvesting, and fish farming. Further data analysis was conducted to qualitatively and quantitatively compare inputs, cost structures, supply chains, market sizes, returns, and impacts across all three livelihoods.

Findings from the desk study were used to create interview guides for subsequent qualitative interviews with experts, practitioners, and site visits, allowing for corroboration and triangulation of all data used in our analysis. Qualitative interviews were conducted with experts at the United Nations Development Program (UNDP) in Lima, US Consulate in Lima, SERNAP (Servicio Nacional de Áreas Naturales Protegidas) at the Ministry of Environment in Lima, and project and program

managers at ACCA (Asociación para la Conservación de la Cuenca Amazónica) in MDD. Interviews with experts were conducted in their respective offices, either in Lima or in MDD, in English or Spanish, whichever language was most comfortable for the expert. When the language of the interviews was Spanish, native speakers translated to ensure all researchers understood the content.

Expert interview goals were to confirm the validity of the economic data and trends obtained from the desk study, develop a deeper understanding of the local socio-economic and environmental context in which to ground field interviews and site visits, and, to understand the economic incentives as well as the environmental and social consequences of choosing to informally mine (or not mine) as a livelihood. The UNDP interview provided corroboration for the potential environmental contamination caused by mining, specifically from the use of mercury, and the implications for sustainable national growth. Interviews with ACCA detailed socio-economic tradeoffs, local norms and expectations. SERNAP officials clarified issues of land usage and rights, challenges to enforcement of legal rights, and barriers to entry and some market size data for alternative livelihoods. Mining permit and labor-related data, as well as some cost data gathered during the desk study phase, was verified with economic and country experts at the US Consulate.

Field work was conducted in May 2017 using a purposive sampling frame consisting of seven qualitative interviews with Brazil nut harvesters and fish farmers and six site visits. The six site visits conducted included two fish farms, one Brazil nut harvesting and shelling facility, one bio- and eco-commerce business, one multi-purpose forestry concession, and one visit to the Instituto de Investigaciones de la Amazonia Peruana (IIAP) campus to understand some of the technical aspects of both fish farming and Brazil nuts. All were located in the MDD area. Interviews were conducted at the ACCA offices while site visits occurred on the premises of the practitioners. Due to issues of safety, no interviews were conducted with informal miners. Practitioner interviews were conducted in Spanish. Native speakers simultaneously translated the conversations, which were also recorded (without any identifying features and with permission). Recordings were translated by native speakers for use by researchers. To ensure consistency between interviews two practitioner interview guides were also developed; one for fish farmers and the other for Brazil nut harvesters and their associations.

Field work goals were to map the supply chain for the two alternative livelihoods, gather practitioner level-data on input costs, prices, and profits sufficient, and understand the factors preventing alternative livelihoods from being more prevalent in the MDD area. Interviews provided a firsthand account of the impact of informal mining on the local environment and the local socio-economic context. They illuminated the experiences of those who had chosen alternative livelihoods, including threats to their economic security. Site visits were essential to observe operational conditions and constraints, supply chain issues, and options for livelihood enhancements. Institutional Review Board approval for interviews was obtained at Manhattan College under the title "*Entender el valor de los bosques intactos en la Amazonía peruana*". For reasons of anonymity, interview recordings have not been placed in an archive but are available upon request.

3. Results

3.1. Exploration of Q1

In 2016, Peru was the 6th largest gold producer in the world with an output of 6.8% [16]. In MDD, informal mining is the livelihood of choice for migrants and unskilled workers due to the low entry barriers and mostly unenforced legal restrictions (Figure 2).

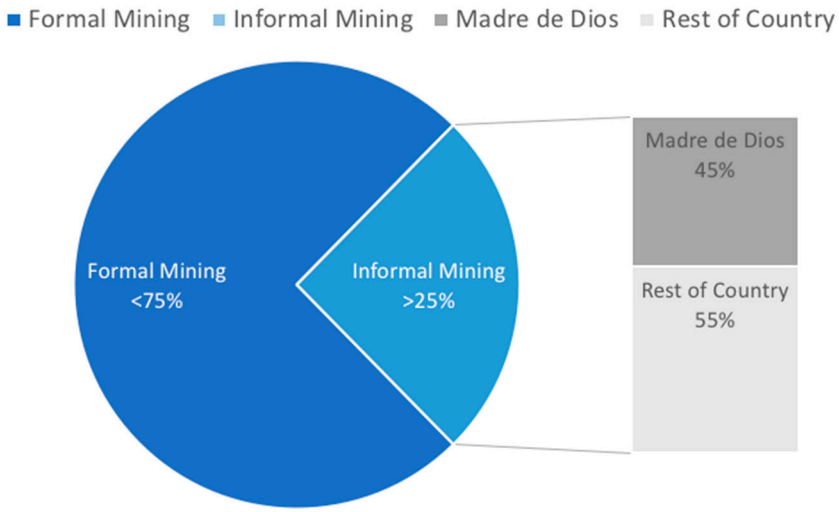

Figure 2. Distinguishing types of mining shows the substantial proportion of informal mining that occurs in Madre de Dios, relative to the total composition of miners in Peru. All artisanal mining in Madre de Dios is informal, employing as many as 180,000 to 280,000 miners and accounting for nearly 45% of the local economy as informed by local experts [32].

Daily gold yield in the mining corridor averages 12–18 g, while the Tambopata buffer zone (60–80 g) and Tambopata National Reserve (150–200 g) yield significantly more [33]. Thus, informal mining is increasing in both the buffer zone and on Reserve land [33,34], resulting in substantial deforestation and increased levels of mercury contamination in the MDD water supply [32]. Efforts to legalize informal mining have not been met with much success as nearly 98% of the 5500 miners who filed papers of intent to become legal miners were unable to complete the process. Reasons included lack of clear access to a land concession or filing on land deemed unsuitable for environmental reasons (according to verbal interviews with experts in Lima). Lack of enforcement and difficulty in obtaining legal permissions has resulted in a strong informal mining culture even outside the mining corridor in MDD.

Table 1 presents the data used to calculate the potential baseline range of income from Brazil nuts and fish farming in MDD. The data, based on the desk study findings, were corroborated via practitioner interviews. Variables such as shelling (for Brazil nuts) and local versus regional sale (for fish) are highly influential in determining final annual income. There is little objectively collected macro-level data on how much is sold shelled or locally. Thus, estimates from associations and practitioners themselves were used to determine income resulting in a wide potential range.

Table 1. Based on data and assumptions collected from literature and verbal interviews with experts and farmers, this table presents the comparative calculations of average annual income obtained from Brazil nut harvesting and fish farming.

	Brazil Nuts [35]	**Fish Farming [36]**
Average Production	15 kg/hectare	450–550 kg/pond
Average Concession	600–1000 hectares	5–10 ponds * of 2500 ft^3
Cost of Production (per kg)	Shelled: $0.49 Unshelled: $0.17	$2.26
Sales Price (per kg)	Shelled: $3.36 Unshelled: $0.49	Locally (MDD) **: $3.50 Regionally (Cusco) **: $5.15
Average Annual Income	**$8209–13,682 *** **	**$4925–9850**

* Desired number of ponds based on practitioner interviews. ** Local market prices in May 2017 (converted to USD). *** Under the assumption that 30% of nuts are sold shelled based on expert and practitioner interviews.

Figure 3 compares the incomes for Brazil nuts and fish farming as calculated in Table 1 to that of informal mining and the average annual wage in MDD.

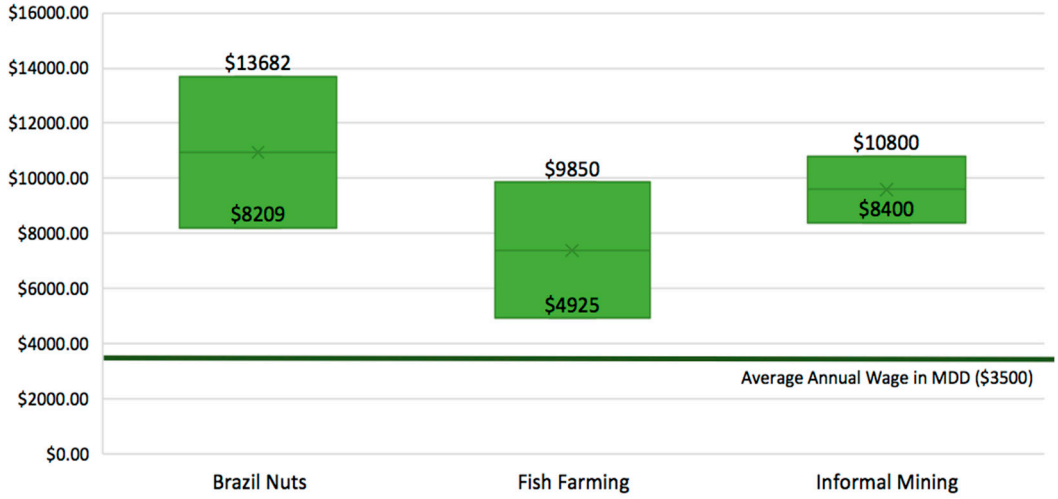

Figure 3. Calculated income ranges from Brazil nut harvesting, fish farming, and informal mining in Madre de Dios, Peru, in comparison to the average annual wage.

These calculations suggest that the assumption that mining always yields higher returns may not be entirely accurate. In fact, Brazil nut harvesting income levels are similar to that of mining. While income from fish farming is lower, it also has the potential to aid in restoration of the natural environment. Given these competitive baseline income ranges, the next step assessed how these alternative livelihoods could be further enhanced to become attractive replacements for mining-based incomes.

3.2. Exploration of Q2

Field interviews were coded to detect barriers to entry for sustainable livelihoods, the processes used by locals to overcome them, and to follow product supply chains (from tree to sellable nut, or pond to sellable fish). This allowed for the identification of suitable income enhancement strategies [37] discussed briefly below.

In the case of Brazil nuts, nuts are sold either unshelled after harvesting to processors for immediate income, or shelled for a higher but delayed income. Shelling capacity in MDD exceeds currently shelled amounts. Thus, shelling could increase substantially without additional investment. To this end, some associations pool member resources to provide joint shelling facilities, while others pool resources to obtain organic certification, both of which command higher market prices [37]. Importantly, shelling and certifications will not raise final prices to the consumers. Rather, they transfer value creation activities from downstream in Lima to upstream in MDD. These processes, however, require additional services from NGOs and governmental agencies for certification training and micro-loans for the upfront costs associated with obtaining certification, as well as the storage of nuts before shelling.

Similarly, fish farming can become more lucrative by addressing operational barriers, including limited distribution, lack of access to building equipment, and operating costs. It can take nearly two years to recoup the cost of building a new pond ($1850), limiting the number of ponds built. We acknowledge the presence of further barriers to entry for those without access to appropriate land and clean water, noting those are beyond the scope of this paper.

Despite higher demand in regional markets, most of the fish is sold locally due to lack of regional transportation, which requires refrigerated vehicles filled to capacity (between 700 and 1000 kg/truck) to be cost-effective. Figure 4 compares profits from selling the total production from one, five and

10 ponds locally in MDD, regionally in Cusco, or 50% per location. Based on local prices (Table 1), selling regionally is profitable as long as transportation costs do not exceed $1.665 per kg/fish for the distance between Puerto Maldonado and Cusco. To amplify returns from fish farming, associations could provide members with the benefits of economies of scale through collective digging of ponds and transportation to regional markets.

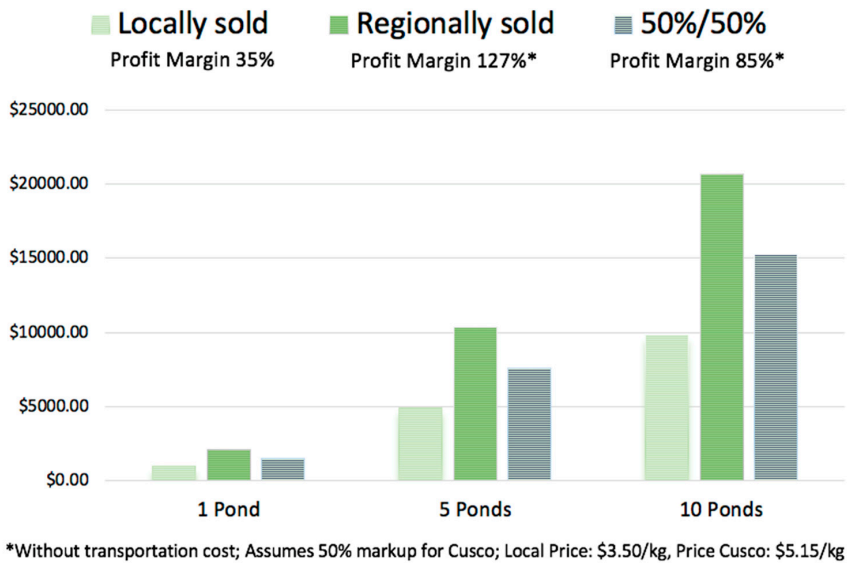

Figure 4. A closer look at the possible returns from fish farming based on pool size and where the fish are sold demonstrate the large gains from selling regionally in new markets (e.g., Cusco).

An obvious synergy is using bruised unsold nuts as fish food. Interviewed fish farmers also grew fruits and cash crops and used unsold portions as fish food. Put together, these strategies of scale and scope suggest that with appropriate NGO and governmental assistance (e.g., capacity building for association management, microcredit for building ponds, refrigerated transportation), fish farming too can achieve returns comparable to informal mining (Figure 5). However, Brazil nut harvesting shows even higher enhanced income levels in scenarios where half of harvested nuts are sold shelled and organically certified (Figure 5).

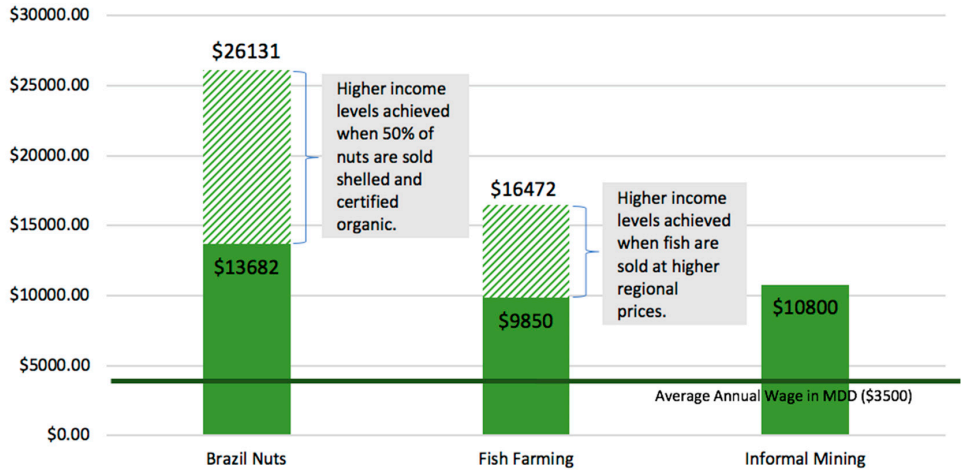

Figure 5. With additional parameters including organic certification, Brazil nut shelling, and regional market access, the potential incomes from Brazil nut harvesting and fish farming surpass that of informal mining.

4. Discussion

In addition to the forest fragmentation from economic and demographic changes, the MDD region of Peru has seen the rise of a political narrative suggesting protected areas are barriers to economic growth. This belief is reinforced by an anti-conservation rhetoric employed by several in the regional political class. At the same time, many communities, indigenous and some recent migrants, embrace a conservation ethic. Current land uses thus include concessions for reforestation, Brazil nuts, and ecotourism, indigenous community territories, smallholder agriculture, alluvial and small-scale mining, logging, and non-timber forest product harvesting. The region has seen considerable communal and local conflict due to weak legal mandates and enforcement, as the same land is targeted for contradictory uses (Brazil nut harvesting and illegal logging).

In this context of weak governance, high-value natural resources, and barriers to entry into the formal cash economy, communities—both migrant and indigenous alike—face the dilemma of how to distribute access to resources to generate income. In game theoretic terms, landscape management often pits conservation against economic development as if in a non-cooperative dilemma [38,39], where development occurs at the cost of conservation and vice-versa. From a conservation perspective, maintaining the ecological integrity of the forest landscape requires that these communities voluntarily comply with existing laws and regulations by choosing livelihood strategies that do not inhibit ecosystem functions. From a sustainable development perspective, this creates the dilemma of incentivizing sustainable economic activities when the informal economy (illegal gold mining and illegal logging) offers comparatively lucrative returns.

Yet, the actual livelihoods and economic returns from any of these activities are often poorly understood by policy makers, civil society organizations, and local residents themselves. Actors operate on assumptions that may or may not be accurate. One such widely held assumption is that mining offers highest returns with relatively low investment compared to other activities. However, little work has been done to calculate the actual wages and cash flow associated with various economic activities and their value chains. It is therefore difficult to know whether alternative livelihoods can in fact be as lucrative, viable, or attractive as unsustainable activities for the average resident of Madre de Dios. Such economic understanding is essential for uncovering ways to promote the ecological health of the landscape while guaranteeing economic stability and achievement of the Sustainable Development Goals for local populations.

This paper suggests that perhaps there is room for conceptualizing the relationship between economic development and forest landscape management as a non-zero-sum game with the potential for a win-win solution. Of course, solutions need to be locally viable in order to be sustainable. Thus, the viability of conservation efforts, including protected areas and buffer zones, depends on finding ways to make conservation strategies more attractive for local populations. This, we propose, is the only way in which local communities will support, and not simply tolerate (or ignore) cornerstones of conservation. Our pilot study demonstrates that enhancing value creation at product origin could make existing forest-friendly livelihoods as or more lucrative than extractive ones.

Communicating such alternatives is crucial for protected areas whose purpose is to safeguard ecological integrity and the landscape as a whole [12,40]. The role of support services is therefore critical in this process; local conservation-oriented communities do not always have the capacity or social capital to connect to markets, understand value-creation scenarios, or develop required skill-sets.

Our proposed approach is locally grounded, requiring local participation and partnerships. Activities that can serve as conservational in some areas may be drivers of deforestation in others; e.g., although some agroforestry can supplement fish farming in parts of MDD, it can be (and often is) a driver of deforestation in other areas [41,42]. Furthermore, changes in policy and services to incentivize sustainable livelihoods in certain local settings may yield unintended consequences (e.g., changes in water streams and deforestation) in others [14].

We propose two streams of future research to promote behavior changes towards conservation goals. First, an understanding of the net local impact of the intact forest livelihoods both in the local

area and the entire Tambopata National Reserve; understanding nested consequences is vital to future conservation efforts, and local impacts should also support total conservation efforts in the area. Second, individual decision-making factors in the area need to be further understood to strategically evaluate interventions [13].

There are many long-term issues, including access to land and clean water, that require substantial policy changes beyond the scope of this paper. While this study is intended only as an initial pilot and not an exhaustive or thorough assessment, it demonstrates a useful approach to understanding the social and economic threats to forest landscapes. It is different from payment for ecosystem services, which pays social actors to not exploit the resource or maintain the intact landscape, often inadvertently reinforcing existing incentive structures leading to exploitation of the very resource they are trying to protect. Our approach differs in that enhancing the value chains for forest-friendly livelihoods not only debunks the myth that extractive livelihoods are always more lucrative, it also creates an environmentally sustainable economic advantage. Here, conservation efforts are less likely to be ignored, and may even increase in visibility, as they now form the basis of a strategic and economic advantage for the local community.

5. Conclusions

As one of the most biodiverse hotspots in the world, the Madre de Dios region in Peru hosts large tropical forests with both ecological and cultural significance. Its forest tracts hold important carbon stocks, and over 40 ethnic groups and indigenous peoples in voluntary isolation live in the region. However, accelerating informal gold mining activities and migration into the region have driven changes to the forest landscape and economic values of the land that increasingly threaten its integrity, often at odds with indigenous land uses.

This study looks at the Tambopata National Reserve within Madre de Dios and its surrounding buffer zone, which was established to protect the reserve from the forces of deforestation, including illegal gold mining, logging, agricultural expansion, and construction. Though there is a prevailing narrative that mining is often the most lucrative use of forest resources, current land uses also include concessions for reforestation, Brazil nuts, and ecotourism, indigenous community territories, smallholder agriculture, and non-timber forest product harvesting. Given the variety of forest-friendly land uses available in Tambopata, particularly within the buffer zone and its environs, this study explored if and how sustainable livelihoods could provide economic returns that match or exceed those from mining, in an attempt to balance local economic interests and conservation goals.

We structured our study around two questions: (1) Does informal mining provide higher wages than either fish farming or Brazil nut harvesting as individual activities for the average person? and; (2) Can fish farming and Brazil nut harvesting practices can be modified to equal or surpass wages from informal mining, either as individual activities or as components of a mosaic of livelihood choices? Using a multi-method approach including a desk study and interviews with government and expert actors, fish farmers, and Brazil nut harvesters, we gained an understanding of the socio-economic and environmental context, incentive structures, values, and supply chain dynamics impacting land use choices. Fieldwork was conducted in May 2017 with six site visits of fish farms, a Brazil nut harvesting and shelling facility, a bio- and eco-commerce business, a forestry concession, and a research institute.

Calculations from prices and scenarios gathered in the methodology suggest mining may not always yield higher returns than other forest-friendly livelihoods. Rather, we found Brazil nut harvesting provides income levels similar to that of mining. In addition, income from fish farming, while not as immediately lucrative, can be enhanced to match similar competitive baseline income ranges.

Strategies to enhance income from Brazil nut harvesting include using associations to pool resources for shelling facilities and obtaining organic certification. A combination of the two strategies (selling a portion of nuts both shelled and organic) is calculated to potentially raise income to levels double that of informal gold mining. Fish farmers should also consider forming associations to

collectively address operational barriers to enlarge distribution scale, access to building equipment, and lower operating costs, which would also significantly raise annual income above informal mining returns.

Enhancing value creation at product origin could make existing forest-friendly livelihoods as or more lucrative than extractive ones. This could be achieved with appropriate NGO and governmental assistance to ensure forest-friendly livelihoods have an environmentally sustainable economic advantage. These findings suggest that conservation-friendly livelihoods can indeed be significantly more attractive than extractive livelihoods, moving towards a locally oriented, conservation-development symbiosis.

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