Journal of Rural Studies 101 (2023) 103045

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Multidimensional poverty and small-scale mining in the shadow of large-scale mines in Papua New Guinea

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ARTICLE INFO

Keywords:
Artisanal and small-scale mining (ASM)
Tolukuma Gold Mine
Mine closure
Oxford Multidimensional Poverty Index
Mine abandonment
Sustainable development

ABSTRACT

In this paper, we introduce the novel concept of a 'residual landscape' to examine the effects of mine closure on local landscapes and lives. Drawing on our study of the abandoned Tolukuma Gold Mine in Papua New Guinea (PNG), we describe the experiences of the people who attempt to make a living from artisanal and small-scale mining (ASM) on this residual landscape. We then present fieldwork data on the poverty status of households in Tolukuma based on the use and modification of the Oxford Multidimensional Poverty Index assessment tool. This data is offered against village level poverty assessments in comparable regions in PNG where mining induced impacts have likewise been studied. By attending to the residual landscape, and the livelihood activities occurring on this landscape, we challenge the large-scale bias evident in the literature on mining and highlight the spatial and temporal features of co-existence models driving debates within academic and policy literature on ASM. Importantly, the significant level of ASM activity occurring on the Tolukuma residual landscape provides an opportunity to re-think assumptions about the drivers and experiences of poverty. Specifically, we ask, is it possible for people who appear to be successfully harvesting gold to be categorically poor? And if so, how does this seemingly impossible situation arise? Our data demonstrates why poor people appear to favour large-scale mining despite the harms generated by these activities. We argue that the history of Tolukuma should be read as a cautionary tale for future resource projects noting the persistence of these residual effects throughout the operational and post-operational phase of the mine.

Author statement

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1. Introduction

The Tolukuma Gold Mine in Central Province of Papua New Guinea (PNG) is, in many respects, a pure example of what scholars refer to as a 'resource enclave' or 'mining enclave' (Sidaway, 2007; Bloch and Owusu, 2012). Prior to the development of a large-scale gold mine in Tolukuma, the area was remote, with access from the nation's capital Port Moresby requiring travellers to walk long distances before completing their journey on a rough road by privately operated motor vehicles. This mode of access was the basis of trade in the years before the development of the mine. During the construction and operation of the mine, logistics were rapidly improved by the use of helicopters which not only opened up supply lines for the mine, but which also enabled local landowners to access markets and government services in the country's capital. Over the course of the mine's productive lifecycle no major investments were made in improving the physical linkages between Tolukuma and the road infrastructure that connects through to Port Moresby. Today, the mine is more or less in a state of abandonment, and the enabling logistics and resources that came with the presence of a large-scale mine are no longer there.

What remains is best described as a 'residual landscape' or what we

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https://doi.org/10.1016/j.jrurstud.2023.103045
Received 30 March 2023; Received in revised form 24 May 2023; Accepted 29 May 2023
Available online 3 June 2023

also term a 'mining residuum'. This is a landscape, constrained by its remoteness and the absence of rehabilitation, that offers few economic alternatives for its resident landowners to pursue. From the vantage point of a large-scale mine, the narrative is almost conventional: few external economic linkages established during construction or cultivated through the operational phase, followed by closure, divestment or abandonment when the economics of the geology were no longer favourable to the owner. These features are true enough for Tolukuma, but there is an important aspect that is easily overlooked if this case is examined solely through a large-scale lens. From a large-scale perspective, the project has ceased. But as our research demonstrates, the area continues to support the activities of small-scale gold miners, an opportunity that, while fraught with its own challenges, nonetheless exists as a livelihood strategy for the landowning community. We argue that the history of Tolukuma should be read as a cautionary tale for future resource projects noting the persistence of these residual effects throughout the operational and post-operational phase of the mine.

The remaining body of the paper is organised into five (5) sections. The next section introduces the Tolukuma case study and the idea of the residual landscape. Section three outlines the research methods, sample and data. Section four contains the findings and showcases the application of both the notion of the mining residuum and the utility of the Oxford Multidimensional Poverty index (MPI). The findings demonstrate the unique livelihood strategies and conditions associated with provisioning in a residual landscape. Our data is offered against village level poverty assessments in comparable regions in PNG where mining induced impacts have likewise been studied. In section five we reflect on case examples in the research literature and discuss the relevance of our insights from Tolukuma for examining LSM-ASM interactions elsewhere. Attending to the residual landscape addresses, in part, the large-scale bias evident in the literature on mining (Hilson, 2019). Section six concludes with summary remarks for scholars and policy makers seeking to understand and improve LSM-ASM interactions and outcomes. Our 'residual' lens draws attention to the specific spatial and temporal features of co-existence models that are driving debates within academic and policy literature on artisanal and small-scale mining (or ASM). Importantly, the significant level of ASM activity occurring on this residual landscape provides an opportunity to re-think normative assumptions about the drivers and experiences of poverty. Specifically, we ask, is it possible for people who appear to be successfully harvesting gold to be categorically poor? And if so, how does this seemingly impossible situation arise?

2. The residual landscape at Tolukuma

PNG is a resource-dependent nation. The mining industry has played a dominant role in the economy since independence was achieved in 1975. By the 1980s Rio Tinto's large-scale Panguna copper mine on the island of Bougainville was in full production, and the giant Ok Tedi mine had been established on the opposite side of the country in the remote Star Mountains of the Western Province. In 1989 the Panguna mine was abandoned because of a local rebellion movement sparked by the social and environmental impacts of the mine (Lasslett 2014). At the same time, the Canadian mining giant Placer invested in the Misima mine in 1989 and then developed the Porgera mine three years later. The Lihir gold mine began commercial production in 1997. Other medium-sized mines such as the Tolukuma Gold Mine, Simberi and Hidden Valley came 'online' a few years after Lihir was developed. In the mid-2000s, China entered PNG's mining scene with the development of the Ramu nickel mine – China's largest overseas direct investment in mining in the Pacific. The prevailing policy and regulatory regimes further augment the view that extraction of mineral resources financed by large multinational corporations will stimulate economic development. However, rather than creating an even form of economic development across regions, these extractive ventures have carved out pockets of development across the landscape, typifying resource enclaves (see for example, Hilson, 2019: 852).

Dependence on mineral wealth has contributed to a resource curse, otherwise known as the 'paradox of plenty'. In the PNG context, the resource curse is expressed in various social, economic and environmental impacts (Mudd et al., 2020). For example, we find intensifying competition over resource rents at the national level, and unmet expectations and aspirations among customary landowners the local level. As the post-colonial state has consistently failed to deliver broad-based development, many rural communities have looked to extractive companies to fill the gap in return for access to their customary lands and natural resources (Bainton and Skrzypek, 2021).

The unmanaged residual effects and legacies of closed or non-operational mines also contribute to the resource curse because the associated risks and impacts affect livelihoods and wellbeing of land-connected people. PNG's mining policy and regulatory framework is geared towards the development of the large-scale mining (LSM) sector as part of an overall economic growth and development strategy. This bias is also a salient feature of PNG's mine closure framework (IISD, 2019). The framework pays scant attention to LSM as an enabler for ASM. For example, when large-scale miners cease operations, small-scale miners may start working areas of the deposit that were previously inaccessible. Thus, the application of the terms 'closed mine site' or 'abandoned mine site' may only apply to LSM. From the perspective of small-scale miners, there is no final point of closure or abandonment of mine sites on residual landscapes (see also Halvaksz, 2008). This paper develops a small-scale perspective of the residual landscape by using the example of the Tolukuma Gold Mine (TGM) in PNG.

The TGM is a medium-sized underground mining project located on the customary lands of the Yulai people who inhabit the headwaters of the Auga River in Tolukuma ward 13 of the Woitape Local Level Government (LLG) area, in the Goilala district of Central Province (Figs. 1 and 2). There is no road or airstrip connecting Tolukuma to the rest of PNG. Occasionally local gold dealers charter helicopters to move people and store goods in and out of the area. The mine was commissioned in 1994 and commenced production in 1997. It was managed by several foreign-owned companies throughout the life of the operation. In 2008, the PNG Government, through its subsidiary Petromin PNG Holdings, purchased the mine from Australian Emperor Mines. In the face of declining gold prices and increasing operating costs, the state decided to have TGM put into care and maintenance. In 2015, TGM was sold to Asidokona Mining Resources, a Singapore-based company. In 2017, Asidokona abandoned the mine when the company went bankrupt. In 2019, the PNG national court ordered TGM to be liquidated for failing to pay its outstanding bills to service providers, amounting to some US$1.5 million ('Tolukuma mine liquidated', 2019). Somewhat confusingly, the national mining regulator, the Mineral Resources Authority (MRA), refers to TGM as a site in 'care and maintenance'. In mid-2021, a local PNG mining company, Lole Mining, applied to re-open TGM and in 2022 the MRA granted them permission. To date, Lole Mining has not provided the state or the landowners with a schedule of key activities to reopen the mine, nor has the company secured consent from the customary landowners of the mine area to restart the operation. The residual effects of mining compounded by historical mining legacy issues have created a landscape of profound uncertainty.

3. Research methods

The research process involved extensive interviews and household surveys (see Table 1). The household survey contained two parts. The first part focused on the composition of local households, their expenses, and their livelihood activities including involvement in ASM and related income and gold sales. A further section dealt with the operators of small businesses that sustain the ASM economy, such as trade store owners, vegetable farmers, gold buyers and other retailers who sell prepaid mobile phone cards. Key informant interviews were conducted to

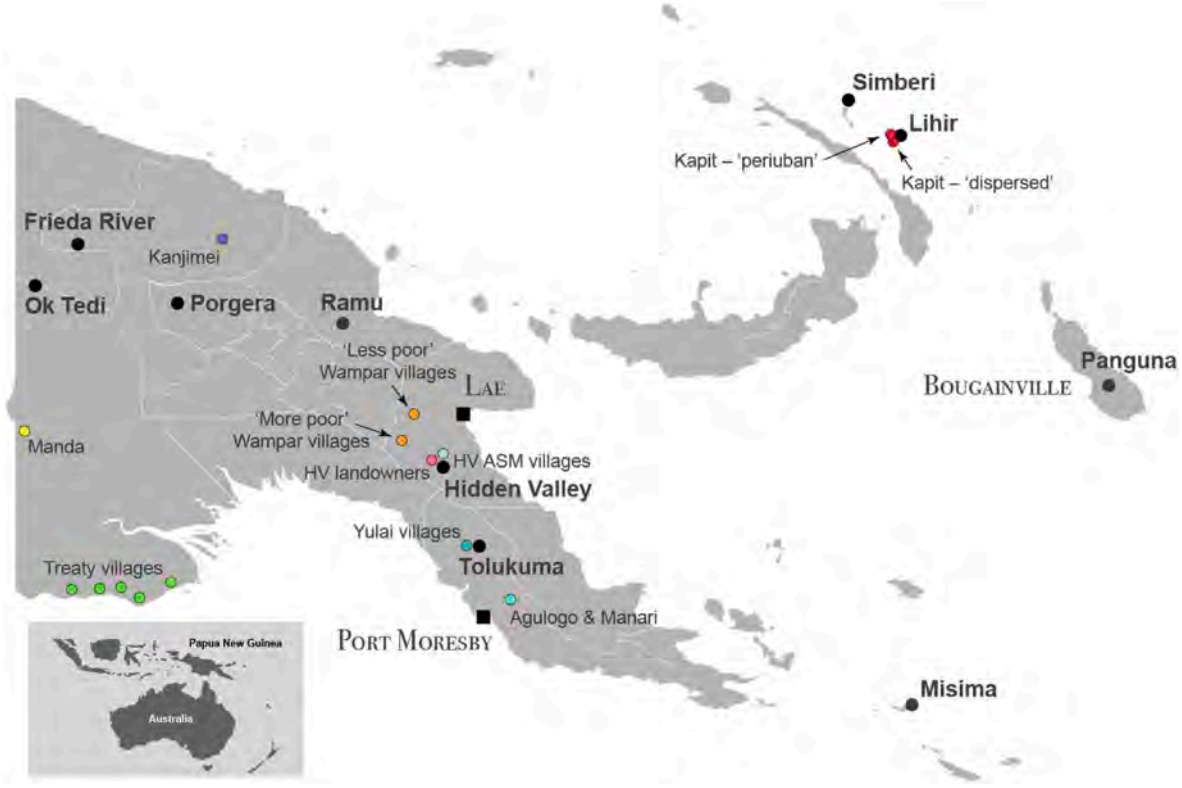

Fig. 1. Mining projects and operations in Papua New Guinea. For key to communities shown in colour, see section 4.3. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Fig. 2. The Tolukuma gold mine in Papua New Guinea (2008). Photo: Rocky Roe.

Table 1
Participant samples.

Sample group	No.
1. Key informants	34
2. Former employees at TGM	8
3. Tolukuma landowners:	47
- Household heads	39
- Trade store owners	5
- Gold traders	3
Total interview participants	89

capture different perspectives on mining activities and other social issues and experiences at Tolukuma.

The second part of the household survey entailed the use of the Oxford Multidimensional Poverty Index (MPI) assessment tool, which we explain in more detail below. We used the MPI tool to test three assumptions about poverty among the Yulai who are the customary landowners of the TGM:

- First, the Yulai landowners have access to adequate cash levels and, therefore, are not income poor.
- Second, landowners are able to use excess cash to facilitate community-level projects in the absence of health and education programs previously subsidised by TGM or which would otherwise be supplied by a government agency.
- Third, the landowners are earning more money from ASM on the mining leases compared to the income received from the operation of TGM.

A total of 39 TGM landowner households, comprising 13 households in each of the three major clan groups, were surveyed for the MPI assessment. This represented about 50 percent of total landowner households.

3.1. Using the MPI tool in Papua New Guinea

The United Nations Development Programme (UNDP) began publishing country-level MPI data in the 2010 Human Development Report (UNDP, 2010), based on work by the Oxford Poverty and Human Development Initiative (Alkire and Santos, 2010; Alkire and Jahan, 2018). The MPI measures a set of direct deprivations that affect households and reveals different drivers, patterns and dependencies when compared with poverty assessments that are primarily based on income. It presents an internationally comparable measure of acute poverty that captures the multiple deprivations poor people experience with respect to three key dimensions: Health, Education and Standards of Living (Fig. 3). These dimensions are measured using a set of 10 indicators. Each dimension is equally weighted; each indicator within a dimension is also equally weighted. The dimensions, indicators, and deprivations are as follows: Health (each indicator weighted equally at 1/6), Education (each indicator weighted equally at 1/6) and Standard of Living (each of the six indicators is weighted equally at 1/18). The method identifies each person as deprived or not deprived using any available information for the household. It then aggregates across all poor people (see Alkire and Santos, 2010; Alkire and Santos, 2014; Alkire et al., 2011). A household is identified as dimensionally poor if, and only if, it is deprived in some combination of indicators whose weighted sum is 30 per cent or more of the dimensions.

Table 2 sets out the 10 indicators we used to identify the MPI with appropriate modifications for rural PNG. The MPI result is the product of multidimensional poverty headcount and the average number of deprivations each multidimensional poor household experiences (intensity of poverty). A summary of the aggregated data compiled for the 10 indicators against the three dimensions makes it possible to ask questions at an individual and household level.

The MPI avoids the obstacles confronting the use of UNDP's better-known measure, the Human Development Index (HDI) in PNG. The first of the three components of the HDI, national per capita income, is inflated because of the presence of capital-intensive mining and energy industries. The second, life expectancy, has not been measured from in-country data for over 30 years (Hayes, 1996). Thirdly, with no reliable census in the 21st century, a number for the last component, mean years of schooling vs expected years of schooling, can be only be estimated from sample surveys. By contrast, because the MPI is based on observations in individual households, nine of the ten indicators needed to calculate an aggregate MPI for a community (Fig. 3) can be recorded quite easily during rapid rural surveys. The exception is the nutrition question, 'Is anyone malnourished in the household'. While high levels of child malnutrition are widely reported (e.g. McGlynn et al., 2018), members of remote communities rarely encounter health staff with the expertise needed to collect accurate data for this indicator (cf. Howes et al., 2012).

Table 3 is an ad hoc scheme that translates MPI scores into categories

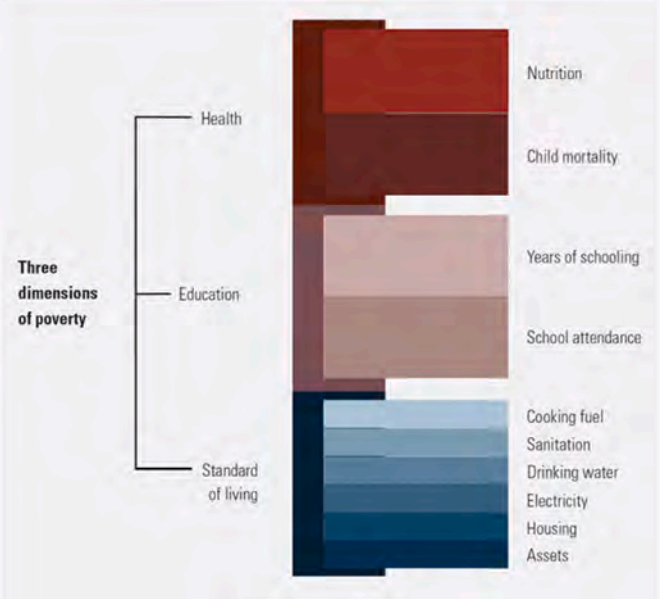

Fig. 3. The Multidimensional Poverty Index: three dimensions of poverty. Source: UNDP (2020, Fig. 1).

Table 2
Indicators used to identify the MPI (modified for rural PNG). Source: Adapted from Burton (2018a).

Dimension	Indicator (recorded by household)
Education	E1 – Deprived if no household member has completed five years of schooling. E2 – Deprived if any school-aged child is not attending school in Years 1–8.
Health	H3 – Deprived if any child has died in the family. H4 – Deprived if any adult or child for whom there is nutritional information is malnourished.
Assets	A5 – Deprived if the household has no electricity. A6 – Deprived if the household does not have access to clean drinking water, or clean water is more than 30 min' walk from home. A7 – Deprived if they do not have an improved toilet or if their toilet is shared. A8 – [International: Deprived if the household has dirt, sand or dung floor] PNG: Deprived if the household does not sleep in an insect vector-proof house. A9 – Deprived if they cook with wood, charcoal or dung. A10 – [International: Deprived if the household does not own more than one of radio, TV, telephone, bike, or motorbike, and does not own a car or tractor] PNG: Deprived if house does not own a car or truck, motorbike, or canoe/dinghy with an outboard motor.

Table 3
Guideline interpretation of MPI scores based on international results. Source: Burton et al. (2012: 46).

MPI Score	Interpretation
0.60 or higher	Catastrophic poverty – remote and isolated communities
0.50–0.60	Extreme poverty – worst nationally reported MPI scores
0.40–0.50	Severe poverty
0.30–0.40	Struggling to achieve development
0.10–0.30	In the process of development
0.00–0.10	Mostly developed

of development status, based on international comparisons. Countries classed as having 'high human development' had scores between zero and 0.039 in 2010 (UNDP, 2010, Table 5) and UNDP has ceased reporting many in this group. 'Mostly developed' countries include Sri Lanka (MPI = 0.011) and El Savador (0.032). Countries 'in the process of development' include Kenya (0.178) and Nigeria (0.254). Countries in the higher brackets are experiencing varying degrees of MPI poverty with only four in what we class here as 'extreme poverty' for nationally reported MPI scores: Burkina Faso (0.519), Chad (0.533), South Sudan (0.580) and Niger (0.590).

Since 2020, UNDP has used the PNG 2016–2018 Demographic and Health Survey (DHS) to report a national MPI score of 0.263 for PNG (NSO, 2019; UNDP, 2020), indicating 'in the process of development' in our scheme. We discuss the plausibility of this score below. The only other Pacific nation for which a national figure has been reported to date is Kiribati (UNDP, 2020), though UNDP has announced training on the collection of MPI data in partnership with the Governments of Samoa, Cook Islands, Niue, Samoa and Tokelau in 2021 (UNDP, 2021). Using field data collection, MPI data has been collected in the Solomon Islands and Vanuatu (Feeny and McDonald, 2016), and in rural parts of PNG, including several ASM communities.[1]

4. Livelihood activities on a residual landscape

In this section we consider ASM as a primary economic livelihood activity among the Yulai landowners. These ASM activities are notable because they occur on a residual mining landscape at Tolukuma. Previously, access to the orebody was impossible. However, large-scale mining activities have exposed the ore body, which can now be accessed via the unrehabilitated open pits, exposed mine tunnels and waste dumps. These unsterilised sites have become the new 'accessible deposit' sites for ASM activities.

The social relations of the Yulai landowning community are underpinned by three dimensions: dependencies, competition and cooperation. These elements provide complementary ways of adjusting to and living on a residual mining landscape that contains limited opportunities. The dependency aspect arises at the household level as parents, spouses, children and kin depend on each other to derive maximum outcomes in the ASM economy. Kin and siblings constantly compete yet cooperate with each other to exploit new opportunities for individual and collective benefit as economic limitations intensify.

There were 75 landowner households spread across the Tolukuma valley at the time of the survey in 2021. The households live in scattered hamlets in their distinct clan groupings. The three main Yulai clans are Yangam, Hameng and Yaulo (see Table 4). Of the 39 households surveyed, only five reported not being involved in any ASM activities. Their reasons for not participating in ASM relate to their rights of access. Instead, they participate in growing vegetables and cash cropping at a small scale to raise income. The survey results showed that there are slightly more women involved in ASM than men, and young and school-aged children work alongside their parents and elder siblings. Household members have described ASM as a full-time 'mining job'.

Unlike other parts of PNG where local miners make use of dredges, water pumps and sluice boxes, the main form of ASM activity at Tolukuma is panning and manual searches. Miners use gold pans, shovels and picks to break up rocks. Gold pans and other tools are bought and transported from outlets in Port Moresby. Often, gold buyers bring in this equipment and resell to local miners at an inflated price. Some miners improvise by using old cooking pots and dishes. Since ASM is more of a family affair, miners lend their tools to their relatives to mine. This rudimentary method of gold extraction requires virtually no start-up capital to mine the residual gold at Tolukuma. There are three main locations where ASM miners spend their time: the mine waste dump, underground mine tunnels and the Iliva creek. An individual or several members of a household may spend up to six days per week on average conducting ASM. At the site of the abandoned stockpile area, large boulders and rocks are broken up into pieces. Mercury is then added to the finely crushed rocks to separate the gold from the fine sand particles. The mercury gold amalgam is then heated to extract the pure gold.

In the survey, individual household members were asked to recall how many times they have worked ASM in the previous week and previous month. They were also asked to recall how many grams of gold they have collected in the previous week and previous month. The results are shown in Table 5.

Table 6 summarises the gold earnings by clan households.[2] There are a range of factors that determine how much individuals or households can recover from working the gold fields. Weather conditions, food supply and personal health status are key factors that influence the decision to mine. Without geological knowledge, mining activities are based on guess work and trial and error. If they can find a spot that is yielding more gold, they may spend more time in this place, exploiting as much as they can before moving onto a new site.

Participants were asked who they sell their gold to. All said that they usually sell their gold to relatives who act as gold buyers. The prevailing gold price set by the gold buyers at Tolukuma is PGK80 per gram (about US$22.4 per gram). Compared to other parts of PNG, the gold price at Tolukuma is very low against the backdrop of rising gold prices on the global market. For example, in the Sepik region, where a similar ASM study was carried out in 2019, gold was sold to village gold buyers for between PGK102 and PGK105 per gram (Bainton et al., 2019).

Table 4
Number of people by clan involved in ASM activities at Tolukuma.

Clan	Households surveyed	Number of people in ASM	Men in ASM	Women in ASM
Yangam	13	37	19	18
Hameng	13	37	17	20
Yaulo	13	39	19	20

Table 5
Summary of ASM activities and production among the three Yulai clans.

Clan households surveyed	Number of people	Total number of days spent on ASM in last 7 days	Total number of days spent on ASM in last month
Yangam	37	222	696
Hameng	37	215	697
Yaulo	39	186	746

[1] See Bainton et al. (2019, 2022), Burton et al. (2012; Burton, 2018a, 2018b), Bussilachi et al. (2018), Hoenigman (n.d.), and (Hamago, 2022).

[2] At the time of the survey, one PNG Kina (PGK) was equivalent to about 0.28 US Dollars.

Table 6
ASM earnings among the landowning clans at Tolukuma.

Clan households surveyed	Grams obtained previous week	Earnings in PGK previous week	Grams obtained previous month	Earnings in PGK previous month
Yangam	97.3	7784	293.9	23,512
Hameng	258.6	20,688	776.5	62,120
Yaulo	112.3	8984	356.7	28,536
Total	468.2	37,456	1427.1	114,168

Overall, these figures indicate a high level of monthly earnings. However, this is a remote community with a low level of self-reliance in food stuffs, and high transportation costs. Popular store goods like rice, tinned fish, noodles, cooking oil and salt sell at an inflated price that drastically erodes the purchasing power of funds generated by mining. For example, a 1 kg packet of rice that costs PGK5 (US$1.4) in the city costs about PGK20 (US$5.6) at Tolukuma. Some families owe trade store owners money for food that was purchased on credit during times of limited gold recovery. When they find gold, they repay their debts. Some households reported being trapped in a cycle of debt. Most of the households reported holding gold rather than cashing it out. Some reasons for retaining gold were for contributing towards a common community or family event such as funerals and church activities or saving for hard times. These saved amounts meant that their reported earnings (in Table 6) may not reflect the quantity of gold they found in the prior week or month and may also represent 'cash on hand/gold on hand'.

Not surprisingly, gold is used as a direct form of currency in Tolukuma. Trade store owners who were interviewed as part of this study confirmed that they prefer to trade their goods for gold. One store owner said that he often offers to accept gold in exchange for goods at a slightly lower price than the prevailing gold price in the village:

> Many villagers spend time mining. They do not have gardens. They rely heavily on rice and other processed food from the trade store. I accept gold in exchange for food items at a price lower than the prevailing price in the village because many of them are my relatives. It is not all the time that they get gold. Sometimes they are not lucky at all. When they don't strike luck, they come to me, and I help them with food and other necessities. So, we have an understanding that even though they traded their gold at a lower price for store goods, there is something for them in return. (Trade store owner number 1).

It is helpful to consider this response through the lens of the moral economy, where the operation of village trade stores remains embedded in local social and cultural relations (see Curry, 1999). The moral economy concept recognises that people's interaction in economic activities generates obligations and interdependencies. The provisioning of human needs is embedded in the nexus of relationships and reciprocity (Booth, 1994). This understanding is particularly useful for thinking about how the Yulai are managing the transition from active mining to a period of uncertainty surrounding the status of the mine. Their ideas and practices around the customary economy and the ASM economy intersect where relationships and mutual obligations become part of the production and circulation of cash and other things in the current state of affairs (see Carrier, 2018). This type of economic transaction in a society like Tolukuma recognises community norms and expectations and provides a type of risk insurance in times of extreme vulnerability. The Yulai landowners are aware that the gold extracted at the TGM has accelerated the national economy, but this has not translated into net positive impacts in their local economy or at their household level.

4.1. Risk and the residual landscape

The use of mercury by miners to extract gold at Tolukuma is a daily occurrence. Mercury is a serious health risk (World Health Organization, 2017). It is procured through illegal channels in Port Moresby city. One informant said that he obtains mercury from other ASM miners and dealers in the district town of Wau, Morobe Province, which can be reached by walking several days across the mountain range from Tolukuma. Mercury has been persistently used in Wau and Bulolo regions since dredge mining activities began in the 1920s (Crispin, 2003; Lole, 2005; Lynas, 2018). The unsafe storage, handling and use of mercury by ASM miners is a concern for the national mining regulator. ASM miners have been described by the regulator as having a 'no care' attitude and carelessly discarding mercury wastes into the bushes and, worse, into streams and rivers (Lole, 2005).

Some Tolukuma miners recalled how they became ill when they encountered ASM sites. Many of them attributed their illnesses to the pollution from TGM's riverine tailings disposal, chemicals in a fuel spill, and the one-tonne box of sodium cyanide that spilled into the river near Tolukuma in 2000 (Oxfam Community Aid Abroad, 2004). Few people acknowledged or demonstrated an awareness of their own use of mercury, which poses a threat to their personal health and safety. The amalgam produced at the ASM sites is usually brought home to be burnt at the common fireplace to extract gold. One participant bemoaned the health condition of his community members:

> Our land is cursed. We get sick all the time. I feel sorry for the women and children. When they are sick, we do not have medicine to treat them. Many of our children have already died. Others who have survived are pale and weak. They are not healthy like children of their age in other villages.

Miners spend significant periods of time involved in ASM activities, often compromising their health and safety. Women bring their children along to pan for gold, often at the mine waste dump areas which are particularly toxic. Since their time is predominantly devoted to ASM, farming vegetables and growing cash crops is less attractive. The villagers also say that the land surface has been disturbed (i.e., made unsuitable for farming) by TGM's mining activities. These impacts are further exacerbated by ASM activities. Consequently, there is less arable land available for farming. Suitable farmlands are in the forest, which require long hours of walking to access. Some clan members have lost their land rights to the forest land and, therefore, had to seek special permission from other landowners to farm there. Land conflicts stem from the problem of not clearly identifying ownership and entitlements to portions of land where the ore body is prior to the commencement of mining. As a result, some individuals and family groups who now own land in the forest have been excluded from the benefits of mining. This current predicament is exactly what anthropologist Colin Filer cautioned in 1994 in his social and economic impact assessment for the mine. He recommended to the mine developer that, given the overlapping rights on parcels of land between 'private' and 'community land', a survey should be conducted on the customary land boundaries within the mine lease area. This was to be augmented by a 'catalogue of rights' developed in conjunction with the landowners so that it could serve as a point of reference for the resolution of subsequent boundary disputes (Filer, 1994). In the end, none of this occurred.

On a mining residuum, these types of customary connections and variables determine livelihood options that households may pursue. Intra-clan land disputes are one the reasons some families turn to ASM – not only for cash but to feed themselves because of a lack of access to garden land. They spend their money on processed store food, typically rice, tinned fish and noodles. These food items are low in nutritional value but have become the staple diet among many households. Store foods are purchased in Port Moresby and transported on chartered flights to Fane, which is the nearest airstrip at Tolukuma. These goods are then carted by paid labourers to Tolukuma, where they are sold at the village canteens at an inflated price considering all the logistical costs. On the other hand, as we noted above, a small number of households have turned to farming and other livelihood strategies because

they are unable to access ASM lands. In a context where there are very few alternatives for provisioning, it's critical to recognise the extent to which customary constraints shape local outcomes and options.

In December 2020, an ASM village called Saki, near Tolukuma, was swept away by a deadly landslide, killing 15 people, including three children. Intensive ASM activities near the base of the mountain was thought to be the main cause of soil instability (Whiting, 2020). Although this incident did not occur within the mining lease area at Tolukuma, this example illustrates the risks surrounding ASM within the vicinity of a residual mining landscape.

4.2. Residual poverty

Yulai landowners clearly depend upon ASM activities to survive on a residual landscape. However, the data we have collected indicates that the Yulai landowners are at risk of losing their major income stream from ASM activities if a new mine operator actively takes over TGM. Their ASM income (according to the survey) is higher than what they were previously receiving through wages, royalties and compensation when TGM was operational. When we posed this possible loss scenario, participants showed little concern: they would prefer a large-scale miner to return to Tolukuma to continue to mine. They are willing to relinquish their ASM economy to the new mine operator. This is a perplexing situation where these same landowners who have denounced the operators of the TGM over environmental destruction, social disintegration and a lack of financial benefits now desire the return of a mining company. The question we ask is whether the money that the households are making from ASM in the period where the mine is un-operational can lift them out of poverty and improve their general wellbeing.

In this section we look at the different dimensions of poverty, with data drawn from the Oxford MPI survey conducted with 39 Yulai landowner households. We sought to understand the livelihood conditions and wellbeing of the Yulai landowners in response to the question arising from the results presented from ASM gold income: if these people appear to be earning generous cash incomes on a mining residuum, are they poor? The MPI allows for a deeper understanding of the disconnection between what appears to be income earned in its most ideal form (i.e gold) and strikingly impoverished conditions. In this regard our work provides a basis for future comparative assessments of ASM communities and how their experience of deprivations is complicated by socio-cultural and geographic factors peculiar to their individual contexts. The villagers in our study are living on a mining residuum and some are earning income in gold, yet plain observation indicates that they are living in extremely impoverished conditions. Gold does not seem to solve the practical challenges of poverty or address the poverty of opportunity. To understand this paradox, we need to understand the multiple dimensions of poverty. We argue that this approach could be advantageous to scholars and policy makers confronting similar such paradoxes.

With an overall MPI score of 0.66, Yulai households are in the 'extreme poverty' category. Deprivations for the surveyed households are shown in Fig. 4. From the data gathered, 100 per cent of the Yulai population surveyed at Tolukuma are multidimensionally poor. For the heavily weighted deprivations, the collected data show that 85 per cent of the households have lost a child, 60 per cent have nobody who has completed 5 years at school, and 40 per cent have children who are out of school. As noted earlier, specialist studies have consistently found high levels of malnutrition in under-fives in rural PNG study areas (e.g. McGlynn et al., 2018). Yulai households will be no different, but nutrition data was not available for this survey. These results also suggest that there is no positive legacy for landowners after 15 years of mine operations at Tolukuma. For example, 60 per cent of the landowner population surveyed have not received education beyond Year 5. This situation is a multigenerational issue that exists beyond the active life of the mine.

The poverty of opportunities that existed in Tolukuma before mining operations started in 1994 has persisted differently on the mining residuum. The scores of deprivations have indicated that while the company, government and community draw benefits from TGM, little attention was given to budgeting and planning for the future at mine closure. It is misleading to suggest that at the end of mine life landowners would return to agriculture and farming since they have security over land tenure. The current scenario at Tolukuma demonstrates this is not the case. The poverty issue at TGM points to a much broader structural problem of differentiation in mining concessions and other economic and political forces that inform the understanding of how the mine functions in the local and regional economy. People are not only poor because they are deprived on indices relating to health, education and standards of living. The residual effects of mining have presented them with a landscape that is constrained of other economic and social means of production.

4.3. Placing Yulai poverty in national and global context

As we have noted above, several studies have now applied the MPI tool at the community level in PNG. In this section we summarise the results of those studies to place Yulai poverty in context. We summarise this data in Fig. 5 which plots MPI scores for individual communities

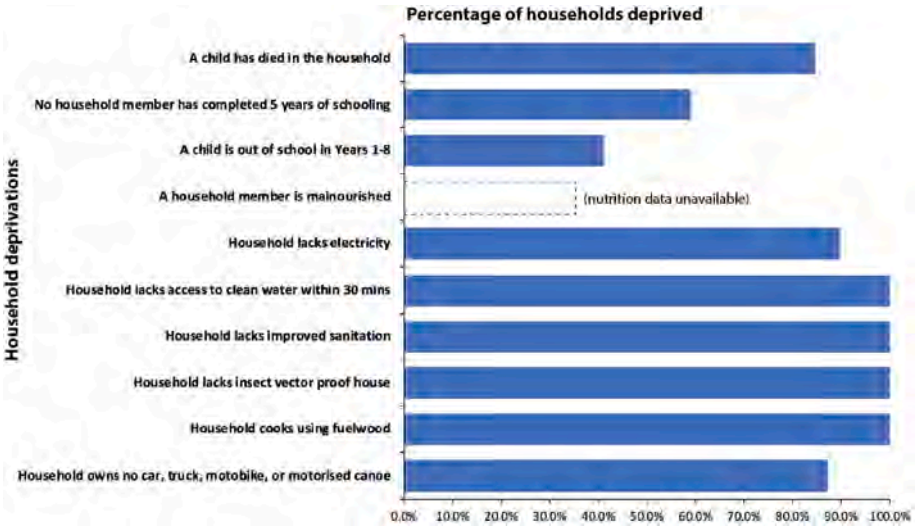

Fig. 4. Percentage of surveyed households with deprivations.

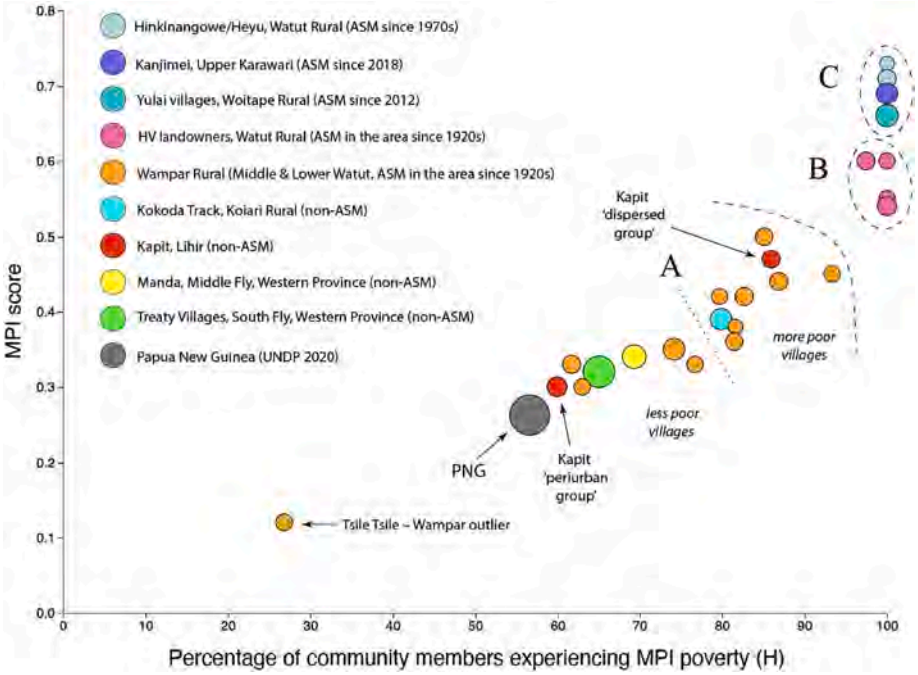

Fig. 5. MPI score and percentage of population experiencing MPI poverty in selected rural communities in Papua New Guinea. Creator: John Burton. Bubbles scaled to logarithm of survey populations.

against the percentage of community members experiencing MPI poverty (the headcount, H, in MPI terminology). All villages where data has been collected, except one, are experiencing high levels of MPI poverty, that is, with scores of 0.30 or higher. Following the scheme in Table 3, the villages can be divided into three rough groups:

A. Villages 'struggling to achieve development'/in 'severe poverty' (MPI = 0.30–0.50)
B. Landowner villages experiencing 'extreme poverty' (MPI = 0.50–0.60)
C. Villages experiencing 'catastrophic poverty' (MPI = >0.60)

4.3.1. (A) Villages 'struggling to achieve development'/in 'severe poverty' (MPI = 0.30–0.50)

The collection of villages in this category is made up of (a) eleven riverine communities along the lower reaches of the Watut River in the Wampar Rural Local Level Government (LLG) area in PNG's Morobe Province, and (b) four other communities from different parts of PNG, and the 79,353 individuals sampled in the 2016–2018 PNG Demographic and Health Survey. In Fig. 5, we make a rough division into 'more poor' and 'less poor' villages around a poverty headcount of 75%.

The Wampar villagers are subsistence farmers with low cash incomes from smallholder cocoa growing. At the same time, ASM has been an opportunistic source of cash income in the area since Australian prospectors exploited the Lower Watut Goldfield from the 1920s to the

Fig. 6. Small-scale miners using informal equipment to sluice for gold at Madzim village, Wampar Rural LLG, on 17 April 2012. Photo: John Burton.

1950s. At the time of the MPI survey in 2011-12, a pulse of sediment had flowed down the river originating with mining activities higher up the river system and was being exploited by villagers in some areas (Burton et al., 2012, Fig. 6). Between 2008 and 2013 the New Zealand Aid Programme supported Bris Kanda ('cane bridge'), a rural livelihood improvement project targeting cocoa growers (Bris Kanda News, 2008). During the survey, assistance to villagers included piped water supplies and tap stands, and household fermentaries purchased with loans facilitated by Bris Kanda.

The key determinant of MPI poverty in the Wampar villages – making some 'more poor' and some 'less poor' relative to each other – is the distance in river kilometres from the junction of the Watut and Markham Rivers. Once across the Markham, a bus can be taken to the provincial capital of Lae. The poorest Wampar village is Wawas, 85 river kilometres from the river mouth, with an MPI score of 0.50. Here a child had died in 46% of families, two-thirds of families had at least one child out of school and no-one had completed primary education in two-thirds of families. An additional Wampar village, Tsile Tsile, is an outlier, with an MPI score of 0.10. It stands out as having a good aid (health) post and a well-resourced primary school. All families had members with at least primary education, and only one family of those sampled had lost a child. The village was notable for its engagement with development initiatives, with several families having invested in cocoa fermentaries.

The other four communities in this group, which may be typical of rural PNG in general, face their own problems of underdevelopment. They are Manda in the Middle Fly, the adjacent villages of Agulogo and Manari on the Kokoda Track, fourteen Treaty Villages on the PNG side of Torres Strait in Western Province, and two sets of families from the mine village of Kapit in the Lihir islands who have been resettled in different locations. None is an ASM community and each has access to a well-funded development program or receives mining benefits: from the Ok Tedi Development Foundation (Manda), the Australia-Papua New Guinea Kokoda Initiative (Agulogo-Manari), Australian aid projects in South Fly (the Treaty Villages), and the Lihir gold mine's Integrated Benefits Package (Kapit). Despite this, the development assistance they receive is incomplete in some aspect or other and they are all still poor by world standards (Burton, 2018a; 2018b; Moran and Curth Bibb, 2020; Bainton et al., 2022). The finding that the two sets of Kapit families, formerly residing in the same village but displaced by the Lihir mine to different locations, should have widely divergent MPI scores after just two decades apart (periurban: 0.30; dispersed to remote locations: 0.47) is confronting (Bainton et al., 2022). It reinforces the observation that distance from schools, health services and town amenities like banks and shops is the critical factor in determining MPI poverty.

4.3.2. (B) Landowner villages experiencing 'extreme poverty' (MPI = 0.50–0.60)

The collection of villages in this category comprises four villages in Watut Rural LLG whose members are landowners of the nearby Hidden Valley gold mine (Nauti, Akikanda, Yokua, Minava). During mining exploration (1984–2005), villagers received small amounts of compensation and allocations of iron roofing sheets for each household. However, all but one was more than an hour's walk from a school or health (aid) post. In the broader Local Government Area, aid posts were poorly staffed and rarely stocked with the required supplies, few women gave birth with a midwife in attendance, and child immunisation rates were low up to the time of the survey in 2012. Most villagers were participants in the cash economy, growing and selling coffee and vegetables. Once the construction of the Hidden Valley mine began in 2005, formal employment opportunities opened up and, after production started, royalty payments began to be received and new infrastructure built: classrooms, an aid post and reticulated water piped to household water taps. ASM activities have been taken up in some stretches of the Watut River. However, an increase in income and better infrastructure does not immediately remove long-lived deprivations in MPI calculations, such as the death of a child or the poor schooling of family members.

To summarise this group:

- only three people out of 1171 were members of a family not experiencing MPI poverty in 2012: on the X axis of Fig. 5 the MPI poverty headcount (H) can be seen to be very close to 100%.
- 100% of families were deprived of improved sanitation
- 100% of families were using fuel wood for cooking
- 0% of families owned a vehicle (car, truck, motorbike)
- 69% of families were deprived of safe water supplies (one village had a water supply)
- 58% of families had no member who had completed five years of schooling
- 52% of families had suffered the death of a child

4.3.3. (C) Villages experiencing 'catastrophic poverty' (MPI = >0.60)

What levels of poverty can be imagined that are more extreme than already described? Only one country has ever reported an MPI score in this bracket – Niger in 2012 (MPI = 0.601; UNDP, 2022, Table 1). However, we now report much higher MPI scores than this for three sets of ASM communities in PNG:

- Yulai hamlets around the closed Tolukuma mine (MPI = 0.66) (Hamago, 2022)
- Kanjimei village (MPI = 0.67), an extremely remote community in Karawari Rural LLG, East Sepik Province (Hoenigman, 2015)
- Hikinangowe (MPI = 0.71) and Heyu (MPI = 0.73), ASM settler villages paying rent to nearby landowners and exploiting alluvial gold in the upper part of the Watut River (Burton et al., 2012)

All these villages are isolated and many hours' walk to the nearest schools and health posts. It is noteworthy that their MPI scores are very close to one another, but not surprising given the convergence of their deprivations. Deprivations for the surveyed households are shown in Fig. 7. Out of 874 family members surveyed in 113 families, all were experiencing MPI poverty.

Some of these indicators conceal horrific levels of suffering. At Heyu, a 51-year-old mother had given birth to fourteen children, losing five of them. Her eldest daughter and first daughter-in-law, aged 34 and 29, had given birth to seven children each, losing 3 and 4 of them respectively. There was no access here to mother-child health services, and the nearest road – the Hidden Valley mine access road, but only built five years before the survey – was several hours distant by foot. Although the term is rarely used today, the four communities come closest to the common understanding of who 'Fourth World' peoples are: subpopulations socially and economically excluded from the broader societies of which they are a part. While none of these communities is economically excluded in the strictest sense because all participate in ASM gold mining, the cash income that this provides is incapable of bringing services any closer or lifting the structural barriers to social and economic development that each community faces.

4.3.4. UNDP's national MPI score for Papua New Guinea

UNDP has published a methodological briefing note for PNG (UNDP, 2022) but this omits significant details. A key problem is that the contribution of the health dimension to overall deprivation was reported as just 4.1%. This was the lowest – best – contribution of the 111 countries for which the MPI was reported in 2022 and contrasts with the contribution of standard of living, which was the highest – worst – of the 111 countries. The health dimension is made up of two indicators, nutrition ('Is anyone malnourished in the family?') and child mortality ('Has a child died in the family?'). The nutrition indicator could not be scored during any of the field surveys nor was it included in UNDP's nationally-reported MPI score, i.e. was left as zero in relevant calculations (no one malnourished). As already noted, though, high levels of child malnutrition are widely reported for PNG. To be locally specific,

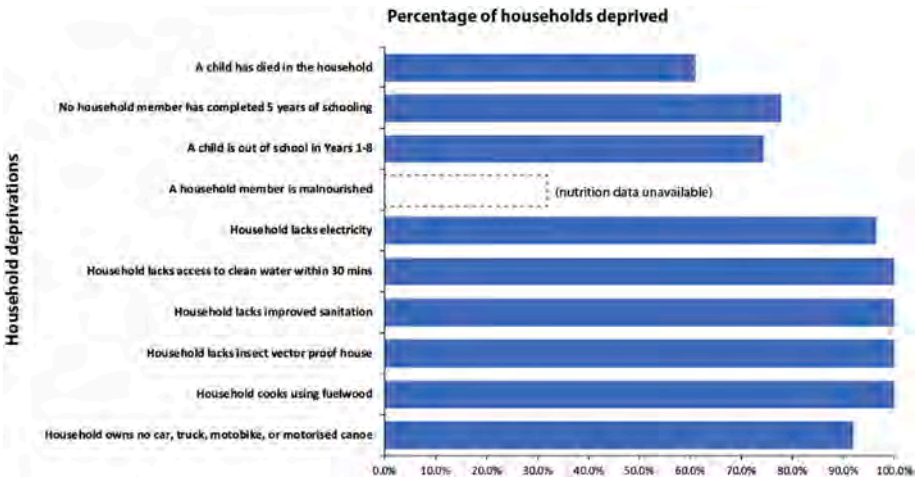

Fig. 7. Percentage of surveyed households from remote ASM communities (Group C) with deprivations.

Bentley (2003) found that 60% of under-fives were stunted and 43% were wasted in a sample of households in and around the villages of Group B, being more than two standard deviations below the US National Center for Health Statistics reference measures of height-for-age and weight-for-age respectively.

A simulation model, using the conservative assumption that 35% of under-fives were malnourished (and no one else in the household was malnourished), suggests that MPI scores with blank nutrition fields should be revised upwards by as much as 0.05. For the four villages in Group B, the model suggests that the true MPI scores should be lifted from the range 0.54–0.60 to 0.59–0.65 (Burton, n.d.). Similarly, it is implausible that there are nationally so few deaths of children in households that PNG is really the best performer of 111 countries on the health dimension. For the time being, UNDP's national MPI score must be treated with suspicion.

4.3.5. *Global comparisons*

Putting the Yulai landowners' MPI score into global context, their MPI score of 0.66 is worse than the rural regions of South Sudan (MPI score of 0.580), Niger (MPI score of 0.601) and Burkina Faso (MPI score of 0.423), which according to 2021 global MPI data, suffer from severe multidimensional poverty (UNDP, 2021, 2022: 5). These are war-torn rural regions experiencing constant and high levels of insecurity on all fronts. The Goilala district where Tolukuma is situated has had no significant political and civil strife, unlike these three countries in the sub-Sahara. Nonetheless, after 15 years of a mine operating on their land, no significant improvements have been made to their general wellbeing and their livelihood conditions are similar to the aforementioned impoverished war-torn countries. Against this national and international backdrop, we now return to Tolukuma to consider how poverty is experienced.

4.4. *The Yulai eat the sugar, and the sugar eats them*

Yulai people talk a lot about their livelihood struggles and the limitations of living on a mining residuum. Stories of impacts and loss linger in their conversation with visitors, government representatives and others who show some interest in them. The effects of TGM's mining activities on the physical and natural environment are clearly visible. ASM is a residuum activity that also presents a complex set of social and environmental consequences. The effects of these circumstances on an unmanaged residual landscape have different impacts on men, women, the elderly and children.

The primary goal of the Yulai miners is to extract as much gold as they possibly can and to make the most of it before a new mining company takes over the TGM and resumes operation. As we have noted above, the residuum activities appear to bring them more income than in the period when the mining company had total control over the lease and restricted ASM and other landowner activities within its boundaries. They are holding onto the hope that the current activity is only short term and when TGM resumes operation, the mine will lift them out of their current state of despair and allow them to realise their development aspirations. As one informant exclaimed in Tok Pisin, 'em taim bilong kaikai', which directly translates as 'now is the time to eat'. But this is also taken to mean 'when the opportunity is limited and while it presents itself, it must be enjoyed'. However, not all Yulai households participate in ASM activities, and the earnings have not resulted in any transformative community initiatives such as school infrastructure or improved health services, although these have been discussed numerous times. Household earnings are usually quickly consumed to survive.

To better understand this situation, here we turn to June Nash's (1979) classic account of Bolivian tin miners. The central focus of her work is on the dependency of the tin miners on the mine. The mine provides the miners with employment, food and other basic resources that they need to live in hard times. The contradiction is that the mine is also the source of their misery, exploitation, and oppression by those who control the mine. The book's title, We eat the mine and the mine eats us, refers to the arduous tasks required of the mine labourers that simply wears them down. This labour eats away their strength, health, and human dignity. They become cheap labour to produce wealth and capital accumulation for the mine owners. During the operational period of TGM, the Yulai landowners were at the periphery of this. The mine was the conduit to the world economy, but their environment was used or eaten away, which they benefited very little from. TGM's operations have ceased, yet the Yulai are still dependent on the capitalistic forces of the market economy. As a consequence, they are drawn into ASM activities to access money to survive. ASM, in place of TGM, connects them to the broader gold economy. Like the tin mine that eats away the Bolivian miners, the ASM sites on the mining residuum eat away at the Yulai miners. ASM wears down their physical strength and health, shortens lives, and reconfigures the natural landscape and environment.

In parts of the Wau-Bulolo gold fields in Morobe Province of PNG, and among the Yulai landowners, people use the Tok Pisin word 'suga' (sugar) to refer to gold. This reference bears a very deep meaning to the Yulai – sugar is an addictive substance, and so is the search for gold in high-risk zones such as the mine tunnels and waste dumps. As our Yulai field assistant commented:

> The grains of gold nuggets that we extract from the gold veins in the mine tunnels are like sugar. Many people refer to this gold as suga. But the true meaning is that we experience euphoria when money lands on the hand after risking our lives to access that sugar. Cash

will always entice us into those risky and hostile places. It controls our lives. Gold, like sugar, is an addiction.

Like the Bolivian tin miners, the Yulai landowners eat the suga and the suga eats them. The sense of urgency to extract and consume as much as they can while they can reveals the uncertainties experienced on a mining residuum.

5. Serialised co-existence

In the previous sections we briefly characterised the history of the large-scale mine and the temporal factors that have conspired to produce a residual landscape at Tolukuma. A careful review of how people enact livelihood strategies in this setting reveals a curious binary and contradictory paradox: a paradox of plenty situated in a paradox of poverty. Our empirical research in villages highlights the importance of institutional actors in driving formal measurements of poverty either up or down. The remoteness of Tolukuma, for instance, is a stronger inhibitor for government investment in services that directly correlate with those factors that determine poverty scores in instruments like the Oxford MPI. The scores at Tolukuma reinforce the limited value of cash, gold or other exchangeables, when the tyranny of distance is so pivotal to the pricing of goods and the high cost to residents in securing educational and health services for themselves and their kin. It is a perverse condition when the means of exchange, and in particular, something as precious as gold, is itself then a contributor to the causes and consequences of poverty for the people who extract and trade in it.

Our study has implications for how scholars and policy makers understand co-existence. A standard approach is to understand co-existence as the product of some kind of shared temporal condition in a defined geographical area. This reading would offer little utility for examining the type of co-existence that has fermented at Tolukuma. Instead, the departure, and indeed the circumstances surrounding the exit of the large-scale miner, has created a situation where both large- and small-scale mining exist in a single location, but in a serialised temporal form. In other words, Tolukuma has hosted both scales of mining at different times, with the existence of one operator directly being causal to the geological opportunities of the other. The prevailing discussion on co-existence, and especially 'autonomous co-existence' (Hilson et al., 2020) emphasizes the co-temporaneous nature of that co-existence, which is to say that the two scales of miner should operate within a single frame of time, but in clearly demarcated and physically separate geographical areas. At Tolukuma, large and small-scale mining have co-existed autonomously on this site, not because of any spatial or geographic factors, but due to temporal and regulatory factors. These actors have co-existed autonomously due to the passing of time and the exclusive use caused by one actor being present while the other is dormant or absent.

The small-scale gold mining sector continues to receive attention from the World Bank and UN level agencies. There are, as the policy literature reveals, poverty alleviation, SDG, and self-determination dimensions driving regional initiatives by these agencies. The central idea advanced by the World Bank, in particular, is that with sufficient planning and zoning on the part of government, and with a more permissive 'live and let live' (Aubynn, 2006) approach by large-scale corporations, it is possible for the two scales to work together harmoniously. This approach has been strongly criticised in the scholarly literature on the basis that, for gold especially, competition for land between the sectors frequently drives conflict and risks to people and projects that large-scale operators are simply not prepared to entertain. To this effect, the case literature is replete with examples of encroachments, claims of human rights violations, environmental damage and 'blame shifting' over the responsible party, as well as concerns about uncoordinated mining by ASM sterilising LSM assets (Kemp and Owen 2019).

The Porgera Gold Mine in the highlands of PNG offers a curious point of contrast that could provide insights into how landowner residents and other community members understand their relationship with large-scale miners and the value they place on their presence compared to the value of livelihood strategies premised primarily on ASM. The interactions between large and small-scale miners at Porgera have not been harmonious (Bainton et al., 2020). Porgera is perhaps the one of the most infamous international cases showcasing the potential hazards of large-scale mining operating in such near proximity to not only villages, but alongside small-scale miners who are actively seeking to utilise the same geological resource base. For decades, small-scale miners, themselves a mix of landowner residents and in-migrants, have operated in the spoils of an antiquated waste management process and in near proximity to blasts and other hazards. This situation is far from ideal and has received considerable criticism globally for the risks the project has imposed on local communities through their environmental and waste management practices, and to confound the matter further, the inability to resettle populations living amongst the mine's waste stream away from these hazards (Kemp and Owen, 2015). These conditions have been contentious for some time, and in the lead up to expiration of the Special Mining Lease (SML) in 2019, were focal points for the government in its decision in April 2020 to not renew the SML (see Burton and Banks 2020). The company then decided to place the mine into care and maintenance, and since then small-scale miners have had more or less free reign over the site. This is the closest thing to the type of autonomous (serialised) co-existence presently experienced at Tolukuma – one scale of miner is active, while the other is dormant.

By early 2023 mine operations at Porgera remained suspended. The social and economic ramifications arising from a sudden halt to operations have been immense. Local households have come under enormous pressure, law and order has dramatically deteriorated, and essential social services are almost non-existent. Calls abound for a return to operations, and negotiations between the government, Barrick Nuigini Limited (the mine operator), and local landowner representatives have progressed slowly. While some landowners celebrated the government's decision to not renew the SML, many have since pleaded with the government to restart the mine, restore essential government services, and resolve outstanding issues. Landowners know that reopening the mine will create an uneasy set of interactions once again. But they have also been reminded of the poverty of opportunities in this region and confronted with their dependency upon the mining operation for access to basic social services and economic development.

The Yulai landowners at Tolukuma have faced a similar double bind, and in the absence of any other significant development activities, they have looked to the reopening of the mine to lift them out their persistent state of poverty. They are willing to relinquish ASM activities and vacate the mining leases because ASM activities in themselves are unable to lift the Yulai landowners out of poverty. As the MPI survey has shown, the community is severely deprived in the health and education dimensions. These services were previously provided and/or subsidised by TGM. From their perspective, to reopen the mine means that the mine operator will agree to subsidise the cost of transport and access to essential services. These examples reveal the messiness of these interfaces and the need to heed some caution in the development of prescriptive policies for managing the interface between large- and small-scale miners.

6. Conclusion

The conditions at Tolukuma, while unique to the extent that the enclave effects are more severely pronounced than in other post-mining landscapes, provides a rich case study from which to examine several prominent themes in contemporary debates about the interface between large- and small-scale mining. Knowledge about this former gold mine, and the presumptions about how its post-mining circumstances function, are most certainly influenced by the 'large-scale' bias identified by other scholars (Hilson 2019). The residual landscape we described at Tolukuma is obviously the result of decades of large-scale mining and its eventual abandonment, but the very fact that mining continues as an

activity in that residuum is evidence that the site should not, from the perspective of ASM, be considered as 'closed' or 'inactive'. Landowner residents, as our empirical research confirms, construct and enact livelihood strategies based on their connection to these landscapes and from the economic possibilities remaining in their residuum. The focus of our paper, and the crux of our argument, is the need to see through the large-scale bias, and once on the other side, to have the necessary perspective to identify and interpret the value that small-scale miners are extracting in these conditions.

Thinking through these opportunities using the idea of the residual landscape not only denies the essentialist proposition that mining has stopped, but it also emphasizes the importance of understanding the value of what has been left in place. Our findings on livelihood strategies and the measurement of poverty using the Oxford Multidimensional Poverty Index (MPI) show that while the immediate exchange value of gold is promising, currency in cash or in precious metal cannot on its own overcome the logistical barriers that restrict access to education and health services. Crucially, the MPI data shows why people have a favourable view of large-scale mining despite social and environmental harms that accompany these activities. Our application of the MPI has also demonstrated the value of this tool in in small communities which otherwise 'disappear' statistically in national reporting of development indicators. The MPI shows a remarkable consistency in being able to group together geographically separated communities whose poverty is drawn from the same set of deprivations, despite wide cultural and regional differences. In this instance, it was able to pick out three sets of isolated ASM-dependent villages in remote parts of PNG as a cluster, set apart from severely poor rural communities with 'better' – yet still compromised – access to services. The ASM-dependent villages simply had no access to health care at all, very limited access to education, and few means of improving the physical assets underpinning their standard of living.

Finally, it is worth reflecting on recent policy initiatives about the co-existence and autonomous co-existence of large- and small-scale mining. Debates rarely construct these dynamics in terms of a choice, such as whether it is better to have one scale of mining activity rather than the other. But in situations where remaining residents are extracting livelihoods based on what has been surrendered in the residuum, these kinds of binary choices can become critical research problems in their own right.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

Acknowledgements

Joel Hamago acknowledges the help of Sebastian Ketava with data collection at Tolukuma. John Burton acknowledges the help of many people involved in field data collection: Rachael Lennie, Theresa Phillips, and the late Walter Pondrelei of the Hidden Valley Social Impact Monitoring Unit; Jane Wiyawa and Obert Foneng of Ok Tedi Mining Ltd; Joyce Onguglo of ANU Enterprise; assistance 2011–2014 from staff and students of the PNG University of Technology, notably the late Ngawae Mitio; Dr Darja Hoenigman of the School of Culture, History and Language, Australian National University for generously sharing her Kanjimei data; and Dr Sara Busilacchi of CSIRO Land and Water and Dr Garrick Hitchcock, Senior Anthropologist, Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation for picking up on the MPI method for use on South Fly in 2012–2013.

References

Aubynn, A., 2006. "Live and Let's Live" – the relationship between artisanal/small-scale and large-scale miners in Ghana: the Abosso Goldfields experience. In: Small-Scale Mining, Rural Subsistence and Poverty in West Africa. Intermediate Technology Publications Ltd, pp. 227–240.

Alkire, S., Santos, M.E., 2010. Acute Multidimensional Poverty: A New Index for Developing Countries. OPHI Working Paper No. 38 & United Nations Development Programme Human Development Report Office Background Paper No. 2010/11.

Alkire, S., Roche, J.M., Santos, M.E., Seth, S., 2011. Multidimensional Poverty Index 2011: Brief Methodological Note. Oxford Poverty and Human Development Initiative, University of Oxford. https://ophi.org.uk/wp-content/uploads/MPI_2011_Methodology_Note_4-11-2011_1500.pdf.

Alkire, S., Santos, M.E., 2014. Measuring acute poverty in the developing world: robustness and scope of the Multidimensional Poverty Index. World Dev. 59, 251–274. https://doi.org/10.1016/j.worlddev.2014.01.026.

Alkire, S., Jahan, S., 2018. The New Global MPI 2018: Aligning with the Sustainable Development Goals. OPHI Working Paper, 121. University of Oxford.

Bainton, N., Kenema, S., Hamago, J., Diya-Sand, A., 2019. The Artisanal and Small-Scale Mining (ASM) Economy at Frieda River, Papua New Guinea: A Pilot Study. Centre for Social Responsibility in Mining, The University of Queensland, Brisbane.

Bainton, N., Owen, J.R., Kenema, S., Burton, J., 2020. Land, labour and capital: small and large-scale miners in Papua New Guinea. Resour. Pol. 68, 101805 https://doi.org/10.1016/j.resourpol.2020.101805.

Bainton, N., Burton, J., Owen, J.R., 2022. Land relations, resource extraction and displacement effects in island Papua New Guinea. J. Peasant Stud. 49 (6), 1295–1315. https://doi.org/10.1080/03066150.2021.1928086.

Bainton, N., Skrzypek, E.E. (Eds.), 2021. The Absent Presence of the State in Large-Scale Resource Extraction Projects. ANU Press, Canberra.

Bentley, K.W., 2003. Hidden Valley Baseline Health Study. Enesar Consulting Pty Ltd.

Bloch, R., Owusu, G., 2012. Linkages in Ghana's gold mining industry: challenging the enclave thesis. Resour. Pol. 37 (4), 434–442. https://doi.org/10.1016/j.resourpol.2012.06.004.

Booth, W.J., 1994. On the idea of the moral economy. Am. Polit. Sci. Rev. 88 (3), 457–463.

Bris Kanda News, 2008. Rural Enterprise Development Programme for the Huon District Funded by New Zealand Aid. Issue Number 1. Lae, Morobe Province.

Burton, J., Banks, G., 2020. The Porgera Mine in PNG: Some Background. 7 May 2020, ANU DevPolicy Blog. https://devpolicy.org/the-porgera-mine-in-png-some-background-20200507-2/.

Burton, J., 2018a. Are the people of Manda in Middle fly poor? A development assessment using the Oxford multidimensional poverty index. Contemporary PNG Studies: DWU Res. J. 28, 84–98.

Burton, J., 2018b. Life expectancy of Kokoda Track authority communities in central Province, Papua New Guinea. Contemporary PNG Studies: DWU Res. J. 29, 34–51.

Burton, J., Pondrelei, W., Phillips, T., Lennie, R., 2012. Hidden Valley +10. Development and Social Mapping in the Hidden Valley Gold Mine Impact Area, 10 Year Re-study – Final Report. Volume 2 Village Profiles and Multidimensional Poverty Index. ANU Enterprise for Hidden Valley Services Limited.

Burton, J. (n.d.). A Monte Carlo Simulation for MPI Calculations when Malnutrition Data Is Missing. (Unpublished working paper).

Busilacchi, S., Butler, J., Van Putten, I., Maru, Y., Posu, J., 2018. Asymmetrical development across transboundary regions: the case of the Torres Strait treaty region (Australia and Papua New Guinea). Sustainability 10 (11), 4200. https://doi.org/10.3390/su10114200.

Carrier, J.G., 2018. Moral economy. What's in a name Anthropol. Theor 18 (1), 18–35. https://doi.org/10.1177//%2F1463499617735259.

Crispin, G., 2003. Environmental management in small scale mining in PNG. J. Clean. Prod. 11 (2), 175–183. https://doi.org/10.1016/S0959-6526(02)00037-9.

Curry, G., 1999. Markets, social embeddedness and precapitalist societies: the case of village tradestores in Papua New Guinea. Geoforum 30 (3), 285–298. https://doi.org/10.1016/S0016-7185(99)00020-2.

Feeny, S., McDonald, L., 2016. Vulnerability to multidimensional poverty: Findings from households in Melanesia. The Journal of Development Studies 52 (3), 447–464. https://doi.org/10.1080/00220388.2015.1075974.

Filer, C., 1994. Socio-economic impact assessment of the Tolukuma gold mine, Central Province. Res. Melanesia 18, 1–84.

Halvaksz II, J.A., 2008. Whose closure? Appearances, temporality, and mineral extraction in Papua New Guinea. J. Roy. Anthropol. Inst. 14 (1), 21–37. https://doi.org/10.1111/j.1467-9655.2007.00476.x.

Hamago, J., 2022. The Ambiguities of Mine Closure: Making Sense of the Residual Landscape at Tolukuma, Papua New Guinea. University of Queensland, unpublished PhD.

Hayes, G., 1996. Estimates of Mortality of Papua New Guinea Based on the 1990 Census and the 1991 Demographic and Health Survey. Port Moresby, United Nations Fund for Population Activities.

Hilson, G., 2019. Why is there a large-scale mining 'bias' in sub-Saharan Africa? Land Use Pol. 81, pp852–861.

Hilson, G., Sauerwein, T., Owen, J., 2020. Large and artisanal scale mine development: the case for autonomous co-existence. World Dev. 130, 104919 https://doi.org/10.1016/j.worlddev.2020.104919.

Hoenigman, D., 2015. The Talk Goes Many Ways. Australian National University, Unpublished PhD.

Howes, S., Mako, A.A., Swan, A., Walton, G., Webster, T., Wiltshire, C., 2012. A Lost Decade? Service Delivery and Reforms in Papua New Guinea 2002-2012. Australian National University, Development Policy Centre.

IISD, 2019. Mining Project Rehabilitation and Closure Guidelines: Papua New Guinea. https://www.iisd.org/system/files/publications/mining-rehabilitation-closure-guide-papua-new-guinea.pdf.

Kemp, D., Owen, J.R., 2015. A Third Party Review of the Barrick/Porgera Joint Venture Off-Lease Resettlement Pilot: Operating Context and Opinion on Suitability. The University of Queensland.

Kemp, D., Owen, J.R., 2019. Characterising the interface between large and small-scale mining. Extr. Ind. Soc. 6 (4), 1091–1100. https://doi.org/10.1016/j.exis.2019.07.002.

Lasslett, K., 2014. State Crime on the Margins of Empire: Rio Tinto, the War on Bougainville, and Resistance to Mining. Pluto Press.

Lole, H., 2005. The Trend in Artisanal and Small-Scale Mining Development in Papua New Guinea. Paper Presented at the Community and State Interests in Small Scale Mining. Sharing Experiences from the Asia-Pacific Region, Manila: Philippines. http://artisanalmining.org/Repository/01/The_CASM_Files/CASM_Meetings_National/2005_Philippines/PSDN_paper_lole.pdf.

Lynas, D., 2018. A good business or risky business: health, safety, and quality of life for women small-scale miners in PNG. In: Lahiri-Dutt, K. (Ed.), Between the Plough and the Pick: Informal, Artisanal and Small-Scale Mining in the Contemporary World. ANU Press, Canberra, pp. 151–170.

McGlynn, P.J., Renzaho, A.M.N., Pham, M.D., Toole, M., Fisher, J., Luchters, S., 2018. Critical examination of evidence for the nutritional status of children in Papua New Guinea—a systematic review. Asia Pac. J. Clin. Nutr. 27 (1), 1–18. https://doi.org/10.6133/apjcn.042017.02.

Moran, M., Curth Bibb, J. (Eds.), 2020. Too Close to Ignore. Australia's Borderland with PNG and Indonesia. Melbourne University Press.

Mudd, G.M., Roche, C., Northey, S.A., Jowitt, S.M., Gamato, G., 2020. Mining in Papua New Guinea: a complex story of trends, impacts and governance. Sci. Total Environ. 741, 140375 https://doi.org/10.1016/j.scitotenv.2020.140375.

Nash, J., 1979. We Eat the Mines and the Mines Eat Us: Dependency and Exploitation in Bolivian Tin Mines. Columbia University Press.

NSO, 2019. Papua New Guinea Demographic and Health Survey 2016-18. Port Moresby, 13. National Statistical Office.Tolukuma mine liquidated. https://postcourier.com.pg/tolukuma-mine-liquidated/.

Oxfam Community Aid Abroad, 2004. *Mining Ombudsman Case Report.* Tolukuma Gold Mine, Melbourne.

UNDP, 2010. Human Development Report 2010. The Real Wealth of Nations: Pathways to Human Development. United Nations Development Programme.

UNDP, 2020. Global Multidimensional Poverty Index 2020. Charting Pathways Out of Multidimensional Poverty. United Nations Development Programme.

UNDP, 2021. Samoa Amongst Pacific Nations Preparing for Multidimensional Poverty Index. Media release.

UNDP, 2022. Global Multidimensional Poverty Index 2022. Briefing Note for Countries on the 2022 Multidimensional Poverty Index: Papua New Guinea. United Nations Development Programme.

Whiting, N., 2020. Landslide Buries 15 People, Including Three Children, from PNG Gold Mine Camp. ABC News. https://www.abc.net.au/news/2020-12-30/up-to-15-suspected-dead-in-papua-new-guinea-landslide/13022136.

World Health Organization, 2017. Mercury and Health. https://www.who.int/news-room/fact-sheets/detail/mercury-and-health.