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Gender inclusivity in artisanal and small-scale tanzanite mining in Mererani Demarcated Area, Tanzania, Africa: A future perspective

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Abstract

This study examines the impact of Tanzania's 2017 regulatory and institutional reforms on artisanal and small-scale mining (ASM) operations, with a focus on women's participation in the tanzanite production value chain. Using a longitudinal research design and descriptive analysis of secondary data from the resident mine office, the study highlights significant growth in ASM activities in the Mererani area. In 2023, the ASM operators and other actors in the study area totalled 45,385 people, with men comprising 35,095 (77.33%) and women comprising 10,290 (22.67%). This indicates a substantial increase from the 4,210 people (3,231 (76.7%) men, and 979 (23.3%) women) recorded in 2018. Notably, the number of women holding mining licenses grew from 10 to 100, while female mine workers increased from 100 to 600 during the same period. Despite these advancements, men continue to dominate license-holding, although the gender gap has narrowed, indicating progress toward gender inclusion. The study also reveals a gradual expansion in tanzanite trading, with a rising number of license holders between 2018 and 2023. To further enhance women's involvement, the paper advocates for a multifaceted approach, including targeted financial and technical support, establishment of cooperative unions, capacity building in value addition, and the creation of a more conducive operational environment. These measures are crucial for promoting equitable and inclusive economic growth in the Mererani area. The findings underscore the importance of sustained efforts to support ASM operations and promote gender equality in Tanzania's tanzanite mining sub-sector, which remains a vital contributor to the national economy.

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1. Introduction

The extractive industries, including the mining sector, have long been recognized as male-dominated spheres with significant gender imbalances. However, governments and international institutions in the Global South have periodically attempted to introduce regulatory measures and policies aimed at advancing gender inclusivity across these industries (Lahiri-Dutt 2018). At the global level, the adoption of the Sustainable Development Goals (SDGs) in 2015 by the United Nations has provided further impetus for such efforts. Specifically, SDG 5 on Gender Equality calls for achieving gender equality and empowering all women and girls, including in the context of economic activities such as artisanal and small-scale mining (ASM) (Denoncourt 2022; United Nations 2015).

The ASM serves as a crucial source of livelihood and represents one of the primary non-agricultural rural activities in the Global South (Maconachie and Conteh 2021; Hilson 2016). It ranges from informal to formal and can be disorganized or well-organized mining activities carried out using basic tools and equipment, often by individuals, families, or small cooperatives with minimal or no mechanization, and limited capital investment (Hilson 2002; Veiga and Hinton 2002; IGF 2017). Hilson (2002) further elaborates that ASM is typically characterized by its labour-intensive nature, low levels of mechanization, and reliance on basic tools and techniques for the extraction and processing of mineral resources (Veiga et al. 2015; Hilson and Maconachie 2017). These mining operations are often informal, operating outside the regulatory framework, and driven by individuals or small groups seeking to supplement their livelihoods (Hilson 2002; Veiga and Hinton 2002). The ASM industry is noted for having a negative impact on the socio-economic position and progress of women due to various environmental, health, safety, and economic concerns (Arthur-Holmes and Abrefa Busia 2021; Geenen et al. 2022; Yakovleva et al. 2022). According to the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF 2017), ASM can be distinguished from large-scale commercial mining by its decentralized and scattered nature, as well as its low levels of capital investment and technological sophistication. ASM activities are typically undertaken by marginalized populations, often in remote or economically depressed regions, and play a crucial role in providing income and employment opportunities for these communities (Veiga and Hinton 2002; IGF 2017). However, the literature on women miners highlights positive economic and labour impacts, emphasizing that ASM employment provides women with an escape from poverty (e.g., Labonne 1996; Yakovleva, 2007; Arthur-Holmes and Abrefa Busia 2021). Studies indicate that women can earn up to three times higher wages by working in the mining industry compared to other forms of rural employment (Arthur-Holmes and Abrefa Busia 2021). However, women consistently receive lower wages than men for performing the same tasks in the mining sector (Buss et al. 2019; Laing and Moonsammy 2021). Beyond providing a source of livelihood, this employment in the mining sector has a multiplier effect within these communities, as women often reinvest their earnings in children's education, farming improvements, food security, and entrepreneurial activities (Yakovleva 2007; Weldegiorgis et al. 2018; Hilson et al. 2018; Orleans-Boham et al. 2020; Arthur-Holmes and Abrefa Busia 2022).

The number of individuals participating in ASM is challenging to pinpoint due to the sector's informal and dynamic nature (World Bank 2019). However, various studies have estimated that around 40 million people in the Global South are actively involved in ASM, with an additional 150 million relying on it indirectly for their livelihoods (IGF 2018; Hilson et al. 2018). A most recent study has reported that an estimated 130-270 million people worldwide rely on ASM operations for income generation, whereas, in rural sub-Saharan Africa, the number is around 60 million (Girard et al. 2022). In Tanzania, the ASM sector has shown continuous growth, with the number of artisanal and small-scale miners increasing from 150,000 in 1987 to 680,385 by 2011, of whom 27.6% were women (MEM 2012). Other estimates suggest even higher figures, ranging from 600,000 to 1.5 million people involved in ASM across the country (Marwa and Warioba 2015).

In recent years, there has been increased focus on women's participation in artisanal mining, particularly in relation to social, cultural, economic, and policy-related aspects. In 2018, the World Bank conducted a study in the diamond mining areas of western Central African Republic (CAR), which revealed that while the employment and income benefits from ASM activities mostly accrue to men, the associated risks – including health, social, environmental, and economic – tend to disproportionately impact women and their families (World Bank 2018). Further, the roles typically undertaken by women in ASM operations, such as stone crushing, washing, panning, and transporting gravel, are often more physically demanding compared to some of the tasks dominated by men, who are more likely to serve as mine owners, managers, and sellers (Macintyre 2006; Hinton 2016; IGF 2018; Reichel 2020). This highlights the gendered nature of participation and the uneven distribution of both the benefits and the burdens within the artisanal and small-scale mining sector. Gender inclusivity in the context of ASM can be defined as the active engagement and empowerment of women and other underrepresented groups throughout the various stages of the mining value chain (Eftimie et al. 2012; Lahiri-Dutt 2018). According to Eftimie et al. (2012), gender inclusivity in ASM involves ensuring that women have equal access to and control over resources, benefits, decision-making processes, and leadership opportunities within the ASM sector. This includes addressing the social, cultural, and economic barriers that have traditionally limited women's participation and agency in ASM activities (Lahiri-Dutt 2018). Lahiri-Dutt (2018) further emphasizes that gender inclusivity in ASM requires recognizing and valuing women's roles, knowledge, and contributions, and proactively integrating gender perspectives into policies, programs, and institutional frameworks governing the sector. This approach aims to foster a more equitable and sustainable development of the ASM industry, with benefits and opportunities distributed more evenly among women and men. Within the ASM sector, women often face significant barriers and disadvantages despite their crucial roles (Bashwira et al. 2014; Rutherford and Buss 2019).

The Tanzanian government's past regulatory management of the mining industry, including the Tanzanite mining operation, is marked by the enactment of the 1998 Mining Act, the 2009 Mining Policy, and the 2010 Mining Act, which promoted foreign investment. Subsequently, these efforts led to conflicts between ASM and large-scale miners due

to insufficient regulation, limited enforcement capacity, and socio-economic pressures driving informal trade, necessitating further governance reforms to secure the tanzanite supply chain (Schroeder 2010; Helliesen 2012). Particularly, the 2009 Mineral Policy of Tanzania includes a section (section 6.2) on promoting women's participation and prohibiting child labour in mining activities. This policy highlights the government's commitments through the following objective "*to encourage and promote women participation in mining activities and strengthen enforcement of laws and regulations against child labour in mining activities*" and its statements: (i) promoting women's participation in mining activities; (ii) ensuring that all programmes related to mining, including education and training opportunities, are based on gender equality and equity; and (iii) collaborating with stakeholders to strengthen monitoring and enforcement of laws and regulations on child labour in mining activities (URT 2009).

Furthermore, in 2017, the Tanzanian government instituted a series of legal and institutional reforms within the mining sector, including the tanzanite subsector. These reforms, including the enactment of new laws, such as: Natural Wealth and Resources (Permanent Sovereignty) Act, the Natural Wealth and Resources (Revenue and Re-Negotiation of Unconscionable Terms) Act, and the Written Laws (Miscellaneous Amendments) Act, aimed to enhance state control, increase revenue, and promote local content by mandating state ownership of at least 16% in mining operations and enabling contract renegotiations (Jacob and Pedersen 2018; Poncian 2019). The formalization and support of the ASM sector are critical development strategies with the potential to enhance rural livelihoods, reduce poverty, and promote sustainable and equitable mineral extraction in Tanzania (Schoneveld et al. 2018; Huggins et al. 2024). However, formalization processes in Tanzania, carry significant risks, particularly for women, who often face exclusion due to limited access to licenses, capital, and technical skills, as well as socio-cultural barriers that restrict their participation in formalized roles (Huggins et al. 2024; Huggins and Kinyondo 2024). For instance, formalization prioritized licensed operators, marginalizing women engaged in informal ancillary activities like food vending or material transport, which are vital to ASM economies but often undervalued (Huggins et al. 2024). In Mererani, the Government of Tanzania's 2019 Mining (Mirerani Controlled Area) Regulations introduced a walled trading area with formal contract requirements to curb smuggling and enhance traceability, but these measures inadvertently excluded many women miners due to financial and administrative barriers, compounded by initial security practices like strip-searching that disproportionately affected them (URT 2019; Huggins and Kinyondo 2024). To address ASM-specific challenges, the government increased consultations with ASM organizations, fostering greater stakeholder inclusion to counter past criticisms of top-down policies, and invested in training centers and regional mineral demonstration and trading hubs for gold ASM, to improve skills, reduce smuggling, and enhance market access (Schoneveld et al. 2018; Jacob and Pedersen 2018). This reform process culminated in the introduction of new regulations, specifically the Mining (Mererani Controlled Area) Regulations of 2019, which were tailored to establish and govern the Mererani demarcated area. This notable regulatory reform was intended to curb the rampant smuggling of tanzanite by introducing a trading market within the wall, while also increasing government revenue generation from the trade of this precious gemstone. The smuggling of tanzanite out of Tanzania, particularly to Kenya, has been a persistent challenge in the Mererani mining sector, driven by the gemstone's high value and global demand. The 2001 Wall Street Journal article alleged that tanzanite was being used to fund terrorist activities, highlighting extensive smuggling networks that undermined Tanzania's economy and tarnished the gem's reputation (Schroeder 2010). These illicit activities were facilitated by the porous border with Kenya and weak regulatory oversight, with tanzanite often mis- or under-declared or traded informally to evade taxes (Helliesen 2012; Donahue 2018). To address this, the Tanzanian government's 2019 Mining (Mirerani Controlled Area) Regulations established a walled area with a single-entry point for all individuals holding valid access cards, military and other security oversight, and a tanzanite trading market within a controlled environment to preserve its locality, rarity, value, authenticity, and enhance traceability and curb smuggling (URT 2019; Huggins and Kinyondo 2019). Other support services within the wall include the tanzanite market, financial institutions, and relevant government agencies. This regulatory framework was designed to enhance the traceability and transparency of the tanzanite supply chain. Despite several initiatives and interventions by the government, women still face economic and socio-cultural barriers that restrict their effective involvement in mining activities and, hence, receive minimal benefits. These barriers include critical inaccessibility of capital and finances for mining operations from mainstream financial facilities, lack of appropriate managerial and technical skills, machinery and technology, and lack of access to geological information on the availability of gems (Schoneveld et al. 2018; Huggins and Kinyondo 2019; Huggins and Kinyondo 2024). These challenges highlight the need for gender-inclusive formalization strategies, such as accessible licensing, targeted financing, and training programs, to ensure women benefit equitably from Mererani's tanzanite ASM value chain (Schroeder 2010; Huggins and Kinyondo 2019).

The significance of ASM extends beyond just employment, as the revenues generated from these activities play a crucial role in supporting households' essential expenses, such as school fees, medical costs, and support to subsistence agriculture, providing a pathway for wealth creation (Verbrugge 2016; Hilson et al. 2018). Consequently, the formalization and support of the ASM sector have been identified as key development challenges, with the potential to boost rural livelihoods, reduce poverty, and promote more sustainable and equitable mineral extraction (Hilson 2013; Perks 2016). Despite the mining legal and institutional reforms in 2017 and capacity-building initiatives such as the Sustainable Management of Mineral Resources Project, ASM is still struggling and is not inclusive in terms of gender (URT 2018). Hilson and McQuilken (2014) and Hilson et al. (2017) reported several initiatives aimed at improving ASM operations in Sub-Saharan Africa, but the sub-sector has not produced the intended outcomes.

In the context of tanzanite production in Tanzania, a rare and valuable gemstone found only in the country, specifically in the Mererani area of Simanjiro District, the Mererani area is within the western limb of the Lelatema Antiform (Wilson et al. 2009; Harris et al. 2014) and is the only known deposit of gem-quality tanzanite in the world (Malisa 1998; 2003). The

Lelatema Antiform belongs to the fault-bounded granulite-gneiss complexes of the Pan-African Mozambique Belt in Tanzania (Muhongo and Lenoir 1994). The tanzanite mining site is divided into five blocks: Tanzanite One undertakes larger mining in Block C; medium-scale mining is undertaken by Kilimanjaro Mining in Block A, and Tanzanite Africa in Block D-extension. The neighbouring Blocks B and D are mined by artisanal and small-scale miners. The tanzanite ASM activities have historically been dominated by men, with women often relegated to peripheral roles or excluded altogether. Addressing gender inclusivity in the tanzanite production value chain, therefore, is an important consideration to ensure that women are equally represented, empowered, and able to benefit from the various activities and processes involved in the chain. In the context of this study, the tanzanite production value chain encompasses the following major activities: mining (extraction and sorting); trading and brokerage (local tanzanite traders and brokers, tanzanite trading centers and stations); beneficiation and value addition (cutting, polishing, and jewelry making); ancillary economic activities (food and catering businesses, hawking and vending, transportation services, equipment rental and maintenance, and other small-scale enterprises supporting the ASM operations); and supportive services (mining equipment and tool suppliers, financial services (e.g., micro-lending, mobile money), technical assistance and training providers, and health and safety services).

This study aims to explore the gender gaps in the tanzanite ASM production value chain and propose strategies to enhance their participation and targeted empowerment. Reliable, sex-differentiated information on participation and trends in the tanzanite ASM sector is crucial for informing policies, programs, and investments aimed at promoting gender equity and women's empowerment. These evidence-based findings will enable effective decision-making processes to address gender inclusion in the production value chain.

2. Geological overview

2.1. Regional Geological Setting

The wealth of Tanzanian gemstones, including tanzanite, is controlled by the presence of various rock types formed over geological time. The tanzanite host rocks are Neoproterozoic in age (Malisa 2003) and form part of the Neoproterozoic Mozambique Mobile/Metamorphic Belt (NMMB) or Pan-African Mozambique Belt of East Africa (Stern 1994; Giuliani et al. 2014; Thomas et al. 2014; Leger et al. 2015). This belt extends southwards from the Arabian-Nubian Shield into southern Ethiopia, Kenya and Somalia through Tanzania to Malawi and Mozambique, including Madagascar and the Antarctica continent (Kröner and Stern 2005). This belt evolved from two distinct events: the Mozambique cycle (1100 to 850 Ma) and the Pan-African cycle (800 to 550 Ma), resulting in the formation of high-grade granulites, gneisses, and migmatitic lithologies due to deformation and metamorphism. These events resulted in the formation of high-grade granulites, gneisses and migmatitic lithologies due to deformation and metamorphism (Kröner et al. 2005; Thomas et al. 2013). Geologically, particularly in Tanzania, this belt is commonly dominated by granulite and amphibolite metamorphic facies rock units comprising quartz-feldspar-garnet-sillimanite-graphite schists, quartzites, marbles, and calc-gneisses, which were formed during the Neoproterozoic Pan - African event (Kröner et al. 2005).

2.2. Tanzanite Geological Setting

The Mererani graphite-tanzanite deposit is situated in northeast Tanzania, approximately 65 km southeast of the city of Arusha (Cairncross 2020). The geological setting of the tanzanite is reported by many researchers, such as Keller (1992); Dirlam et al. (1992); Stern et al. (1994); Malisa (2003) and Giuliani et al. (2014). Giuliani et al. (2014) present a more contemporary explanation of tanzanite's (and tsavorite's) geological setting, with a focus on the NMMB. This geological province is home to the most valuable gem and graphite deposits, respectively, in East Africa (Dissanayake and Chandrajith 2016). Tsavorite is mined nearby at Lemshuku, 35 km west-southwest of Mererani, and Namalulu, 80 km south of Mererani (Feneyrol et al. 2012). This part of the Mozambique Belt has been termed as the 'Gemstone Belt of East Africa' by Malisa and Muhongo (1990). Garnet (tsavorite, spessartine, and rhodolite), ruby, sapphire, zoisite (tanzanite), kyanite, diopside and numerous other minerals (Malisa 1987; Bocchio et al. 2012; Feneyrol et al. 2013) are mined in large, medium and small-scale operations. Tanzanite is associated with several other minerals found at Mererani including graphite, diopside, pyrite, quartz, grossular (tsavorite), dolomite, and calcite (Jaszczak and Trinchillo 2013). Apart from its unique colour, tanzanite may contain solid, liquid, and/or vapour inclusions. Liquid hydrogen sulfide has been reported by Taylor et al. (2013), and this releases a fetid, sulfurous odour when the crystals are broken (Rankin et al. 2014). Mineral inclusions found in tanzanite include graphite, actinolite, calcite, diopside, gypsum, ilmenite, quartz, rutile, titanite, and xenotime (Dunn 1975; Malisa et al. 1986; Olivier 2006; Taylor et al. 2013; Rankin et al. 2014). Structurally, tanzanite is hosted in "a structurally complex region consisting of granulite facies meta-carbonate and meta-silicate rocks overprinted by amphibolite to greenschist facies retrogression" (Harris et al. 2014). Harris et al. (2014) reported that the graphitic gneiss that hosts the gemstones was formed by metamorphism of black shales based on carbon and oxygen isotope analyses of tanzanite (including tremolite, tsavorite, diopside, and kyanite) from Mererani Hills and surrounding areas (Figure 1). Similarly, Malisa (2003); Giuliani et al. (2011; 2014) and Feneyrol et al. (2017), have the same conclusion. Further, the study by Francis (2017) summarized the geological occurrence, associated minerals, and crystal forms of tanzanite.

3. Materials and Methods

3.1. Data Collection

This study employed a longitudinal research design with quantitative approach to comprehensively assess the impact of the 2017 legal and institutional reforms on the participation of women and men in the ASM tanzanite mining operations in the Mererani demarcated area. The secondary data from the Resident Mine Office (RMO) covering the period from 2018 to 2023 were utilized to analyze gender dynamics in Mererani's tanzanite ASM value chain, specifically focusing on participation trends post-2019 Mining (Mirerani Controlled

Area) Regulations, which established a walled area with a single-access point. Pre-2018 data were excluded due to inconsistent reporting, as the area's porous nature prior to the regulations allowed miners and operators to access the site without oversight or restrictions. This lack of regulation made it difficult to accurately track and document participation, resulting in a significant gap in reliable data for understanding the dynamics of the mining community. The present RMO's data capture and report accurate ASM operators in the Mererani area. The study focused on the ASM operations in blocks B and D to establish the number of people involved and the nature of their activities and roles played in the Tanzanite production value chain. During this study's period in 2023, the Mererani ASM demarcated area had a total of 45,385 people (Men: 35,095; Women: 10,290) working in ASM's various operations in the Tanzanite production value chain.

3.2.Data Analysis

This study employed a robust analytical approach to examine the longitudinal trends in the gender dynamics of the Mererani artisanal and small-scale tanzanite mining operations. The secondary source data were descriptively analyzed to identify trends of persons involved in Mererani tanzanite ASM operations, by their gender distribution, between 2018 and 2023. Through descriptive statistics, this study disaggregated figures for men and women involved in the ASM activities. This provides a baseline understanding of the gender distribution within the sector after reforms. Further, the analysis focused on the involvement of men and women in several aspects of the tanzanite production value chain, such as mining license holders, mine workers, investors, tanzanite traders, and ancillary economic services by quantifying the percentage changes in the number and proportion of female and male in all activities. The findings are provided in graphs and tables to show the patterns and changes in gender composition and involvement in the Mererani tanzanite ASM industry over the last six years.

4. Results

4.1. ASM population distribution in Mererani Demarcated Area

The Mererani ASM demarcated area had a total of 45,385 people (Men: 35,095 (77.33%); Women: 10,290 (22.67%)) in 2023, while in 2018 there were only a total of 4210 people (Men: 3231 (76.7%); Women: 979 (23.3%)) (Figure 2). Further analysis indicates that there is a noticeable fluctuation percentagewise between Men and Women in each year as follows, in 2018 (Men: 76.75% and Women: 23.25%), 2019 (Men: 64.31% and Women: 35.69%), 2020 (Men: 73.06% and Women: 26.94%), 2021 (Men: 69.52% and Women: 30.48%), 2022 (Men: 70.10% and Women: 29.90%) and 2023 (Men: 90.68% and Women: 9.32%). These people played a key role in the Tanzanite production value chain. It is evident that the reforms in the legal and institutional frameworks and the introduction of the tanzanite market in the demarcated area have stimulated and attracted many people, both women and men, to engage in Tanzanite mining operations and ancillary economic services, hence, responding to employment challenges and improving their livelihood.

These data indicate that both genders are engaged in direct tanzanite production value chain (i.e., mining licence holders, mine workers, investors, large holders of tanzanite trading licences, holders of brokers licences, holders of stations for selling and buying tanzanite); and executing ancillary economic services (i.e., clothes and mixed items shops, food businesses – Mama and Baba Lishe, pharmacy, motorcyclists – boda boda and Hawkers – Machinga).

4.2. Tanzanite Mining Licence Owners and Mine Workers

The graph of Figure 3 depicts the continuous gender inequality in the Tanzanite mining sub-sector in Mererani, Tanzania. The number of participants has drastically increased from 1,810 (11.26%) in 2018 to 14,260 (88.74%) in 2023. Examining the participation of women and men, there is a notable increase in the number of women joining the Tanzanite mining operations. In 2018, there were 1700 men and 110 women, whereas in 2023, the numbers increased to 12,130 men and 2,136 women. Figure 3 shows steady growth in ASM participants in the last six (6) years, still, there is a disparity between male and female involvement in the sub-sector in terms of license ownership and employment opportunities.

4.3. Tanzanite Trading

The results indicate that women's participation in the production value chain is remarkably increasing in all three main activities, the trading, brokers and selling and buying stations operations. The number of licenses issued to each gender indicates that still, men are leading in the production value chain (Figure 4). The results show a considerable decrease in women holding licenses to operate stations for selling and buying Tanzanite in 2023, whereas, for men the number increased drastically in the same period.

4.4. Ancillary Economic Services

The mining operation needs several ancillary economic services, and it has a tendency to attract other economic activities around the mine sites. The economic activities, however small they may look but have a great contribution to the household's well-being. Women have engaged in activities such as hawkers (30 in 2018; 150 in 2023), followed by food business (63 in 2018; 120 in 2023), and cloth shops and mixed items shops account for a small number of women. Generally, in all activities show the number of women has grown steadily in all activities (Figure 5).

4.5. Mine Investors and Value Addition

In recent years, the tanzanite ASM production value chain in the Mererani demarcated area has envisaged a significant increase of people involved in the mine investments (mine investors). The number has risen from 2 women in 2018 to 70 women in 2023 (Table 1), whereas men rose from 20 to 110 in the same period. These are the people with finances but don't hold mining licenses. The growth in the number of women in that category indicates that women have the financial capabilities to invest in mining operations. However, they have not engaged in tanzanite value-addition activities.

In this activity, there is still a low number of participants, even men, this may be due to a lack of technological capabilities, capital and required skills.

4.6. Modernization of the Tanzanite ASM production value chain

The 2017 mining reforms and the 2019 Mining (Mirerani Controlled Area) Regulations transformed Mererani's tanzanite ASM value chain by establishing a walled trading area with a single-entry point and security oversight to curb smuggling and enhance traceability, leading to a significant increase in ASM participation from 4,210 to 45,385 between 2018 and 2023. However, women's participation fluctuated (23.3% to 9.32%), reflecting socio-cultural and economic barriers, particularly in Mererani's hard rock mining, which relies on explosives and mechanized tools like jackhammers, demanding physical strength and technical skills that often exclude women due to limited training access (Schroeder 2010; Huggins et al. 2024). While the trading market aimed to create a formal and structured environment for ASM operators, it faced significant criticisms: the requirement for formal contracts to enter the walled area excluded many artisanal miners, especially women, who lack financial and administrative resources for licensing (Huggins and Kinyondo 2024; Huggins et al. 2024). Initial reports of police strip-searching women to prevent smuggling further deterred female participation, underscoring the gendered impact of security measures (Huggins and Kinyondo 2024). To address these challenges, this study proposes modernizing the ASM value chain by providing accessible geological data from the Geological Survey of Tanzania to improve mining efficiency, developing gender-inclusive financing models to facilitate women's access to licenses, and adopting blockchain-based platforms to ensure transparent trading and reduce smuggling, building on lessons from past regulatory efforts (Schroeder 2010; Huggins and Kinyondo 2019). These interventions aim to enhance women's access to high-value roles and boost local economic benefits, though persistent enforcement challenges, such as limited local capacity and centralized governance, must be addressed to ensure success (Huggins and Kinyondo 2019, 2024). It is with those in mind that this study proposes a production value chain flow chart as opposed to the traditional one (Mining-Cutting and Polishing-Manufacturing-Retail) (Collet et al. 2013) (Figure 6).

5. Discussion

This paper examined the roles played by men and women in the Mererani demarcated area, revealing significant insights into gender dynamics within the tanzanite production value chain. The results show that, despite reforms in the mining sector, participation has grown from 4,210 individuals in 2018 to 45,385 in 2023, largely influenced by the 2019 Mining (Mirerani Controlled Area) Regulations, which introduced formalized operations through a security wall. However, a persistent gendered division of labour remains, primarily due to the organizational structure of ASM activities, as noted in various studies (e.g., Buss et al. 2017; Koomson 2019; Buss et al. 2019; Rutherford and Chemane-Chilemba 2020).

Men dominate high-value roles, such as digging, which account for 77.33% of these positions, driven by the physical demands of hard-rock mining, including the use of explosives and mechanization. In contrast, women's overall share in the workforce has declined from 23.3% in 2018 to just 9.32% in 2023, despite a tenfold increase in the number of women holding licenses (from 10 to 100). This suggests that the benefits of formalization have disproportionately favoured men, granting them greater underground access (Schroeder 2010; Huggins et al. 2024). The decline in women's participation, juxtaposed with their growth in ancillary roles – such as food selling and ore crushing – raises important questions about the effectiveness of reforms in addressing cultural barriers. These barriers include prevailing taboos that label women as unclean for engaging in underground work, compounded by the lack of pre-2018 data, which limits our understanding of historical gender dynamics in Mererani area (Hinton et al. 2003; Verbrugge 2017). While there is a slight increase in women engaging in direct mining activities (from 100 to 600 workers), the structure of ASM, which often requires physique and technical skills more readily accessible to men, reinforces their confinement to lower-paid secondary roles. This trend is consistent with global studies on ASM (Buss et al. 2017; Koomson 2019). The sixfold rise in female workers indicates potential for bridging the gender gap; however, the decrease in their overall share highlights unintended consequences of the securitization measures, such as restricted mobility due to the wall's single-entry point, which disproportionately affects women involved in ancillary activities (Huggins and Kinyondo 2024). Comparing Mererani to the national ASM average, where women represent 27.60% (Mutagwaba et al. 2018), underscores the need for targeted interventions to enhance women's participation in the tanzanite production value chain. The current reliance on Resident Mine Office (RMO) data post-2018 also constrains the longitudinal analysis, potentially underrepresenting informal participation before the establishment of the wall.

To effectively close the gender gap, initiatives focused on attracting more women to the tanzanite value chain are essential. Women, who often engage in labour-intensive roles such as gem sorting, stone crushing, and transporting materials, could greatly benefit from targeted training in advanced technologies like computer-aided design (CAD) and automated grading systems powered by artificial intelligence (Chow and Reyes-Aldasoro 2022). These technologies could alleviate physical demands and enhance precision in tasks traditionally performed by women, enabling their transition into higher-value roles such as gemstone cutting and quality assessment. Furthermore, the implementation of blockchain-based traceability platforms (Cartier et al. 2018) could empower women traders and brokers by ensuring transparent market access and fair compensation, thereby reducing exploitation within the supply chain. By equipping women with the necessary skills through accessible training programs, barriers related to limited technical knowledge and market exclusion can be effectively addressed (Eftimie et al. 2012; Lahiri-Dutt 2018). This approach aligns with the goals of Tanzania's 2009 Mineral Policy, which advocates for gender equity in mining. The government's mining policy also promotes the value addition of tanzanite within the country, presenting an opportunity for women to enhance their livelihoods. Research by Collet et al. (2013) indicates that local gem cutting retains revenue within country, as this stage in the value chain yields the highest income. Nevertheless, successful value addition necessitates a skilled workforce

proficient in jewelry design, manufacturing, business management, and modern technologies (Wannarumon 2011; Collet et al. 2013; Hsu et al. 2014).

Another critical intervention involves the establishment and strengthening of women-led cooperatives within the tanzanite ASM sector. Some cooperatives and associations are playing various roles in mineral and gemstones including tanzanite such as policy advocacy (Tanzania Mineral Dealer's Association – TAMIDA, Tanzania Women Miners Association – TAWOMA, Tanzanite Women Miners Development Union – TWMDU), self-help financial activities (Manyara Women Mining Network) and dispute resolution (Manyara Region Mining Association – MAREMA) (Denoncourt 2022; Huggins et al. 2024). Addressing the financial challenges faced by women miners, such as the need for modern tools and equipment, is vital for their engagement in mining operations (Spiegel 2012). Furthermore, the targeted training in advanced technologies can facilitate women's transition into higher-value roles, while blockchain traceability can improve fair compensation for women traders. Women-led cooperatives can help overcome financial barriers and combat cultural taboos, thereby enhancing women's representation and empowerment in the tanzanite value chain. The potential for value addition, in line with the government's export goals, underscores the importance of skill development in jewelry design and manufacturing, although current low female technical capacity remains a significant challenge (Collet et al. 2013).

6. Conclusion

This study's findings present a complex and nuanced picture of gender dynamics in the artisanal and small-scale mining (ASM) of tanzanite in the Mererani demarcated area. While the participation of men has steadily increased, the engagement of women has fluctuated, with their overall share declining from 23.3% in 2018 to just 9.32% in 2023. This trend is particularly concerning, given that the number of women holding mining licenses and other formal roles has grown slowly, compared to men, even as they expand their involvement in ancillary economic activities. To address these challenges and unlock the full potential of the tanzanite ASM sector, a multifaceted approach is required. Policymakers and stakeholders must prioritize gender-centred reforms, strengthening regulatory frameworks and support mechanisms to enhance women's participation and empowerment. Capacity-building initiatives, improved access to finance, and the integration of emerging technologies can further catalyse the advancement of women in the tanzanite production value chain. By leveraging the value addition potential of tanzanite through innovative technologies, the local communities in Mererani can benefit from increased employment opportunities, improved mining practices, and fairer trade. This, in turn, will contribute to more sustainable and equitable community development, as well as broader socioeconomic growth and gender equity in Tanzania.

6.1. Recommendations

Future research should investigate gendered barriers faced by women in navigating the tanzanite ASM ecosystem, exploring innovative solutions that foster inclusive and impactful reforms. This study proposes a few recommendations, including advanced gemstone cutting, polishing, enhancement, identification, sorting, grading, and traceability technologies, that can significantly improve women's participation in the tanzanite ASM value chain in Mererani, Tanzania. These technologies are grouped in the following areas:

a)-Application of advanced gemstone cutting and polishing techniques such as:

i. -Lasers are used to precisely cut and polish gemstones, resulting in improved symmetry, proportions, and overall appearance (Breeding et al. 2010; McClure et al. 2010).

ii.-Computer-aided design (CAD) and computer-aided manufacturing (CAM) technologies allow the creation of highly complex and customized gemstone cuts, leading to improved brilliance and fire (Wannarumon 2011; Awotwe 2016; Prabhu 2020; Sun 2023; Mancebo 2023).

b)-Application of gemstone enhancement and treatment techniques such as:

i. -High-pressure, high-temperature (HPHT) and irradiation and heat treatment techniques enhance the colour of various gemstones to increase their value (Schmetzer 2010; Song et al. 2016; Phichaikamjornwut et al. 2019; Karampelas et al. 2020).

c)-Improvement of gemstone identification, sorting and grading can be done through techniques such as:

i. -Advanced spectroscopy techniques like Raman spectroscopy, UV-Vis-NIR spectroscopy, and X-ray diffraction are used to accurately identify and characterize gemstones (Gaft et al. 2015).

ii.-Application of automated gemstone grading systems, especially artificial intelligence (AI)-powered systems, grade gemstones' cut, colour, clarity, and carat weight with high precision, while reducing human bias and errors (Chow and Reyes-Aldasoro 2022).

d)-Gemstone traceability, origin and fair trading can be done through:

i. -Blockchain-based platforms/technology is well-developed to trace the movement, ensuring transparency (fair trading) and authenticity of gemstones in the supply chain (Cartier et al. 2018; Min 2019).

ii.-Analyzing the isotopic composition of gemstones such as tanzanite to determine their geographical origin (Giuliani et al. 2000), which is important for ensuring ethical sourcing, fair trading and in some cases preventing the trade of conflict gemstones.

However, Tanzanite brokers, dealers and traders are recommended to acquire the required skills and training that will enable them to understand the negative side of the technologies especially the ones that produce synthetic and laboratory-grown gemstones. For example, the:

i. -chemical vapour deposition (CVD) and high-pressure, high-temperature (HPHT) techniques produce gem-quality diamonds and other synthetic gemstones which are almost indistinguishable from natural stones (Song et al. 2016).

ii.-gemstone growth optimization technique to produce larger, higher-quality synthetic gemstones with improved optical and physical properties (Tripathi and Barua 2019).

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Declaration of competing interest

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Authorship credits

Author	A	B	C	D	E	F
MMM						

A - Study design/ Conceptualization **B** - Investigation/ Data acquisition
C - Data Interpretation/ Validation **D** - Writing
E - Review/Editing **F** - Supervision/Project administration

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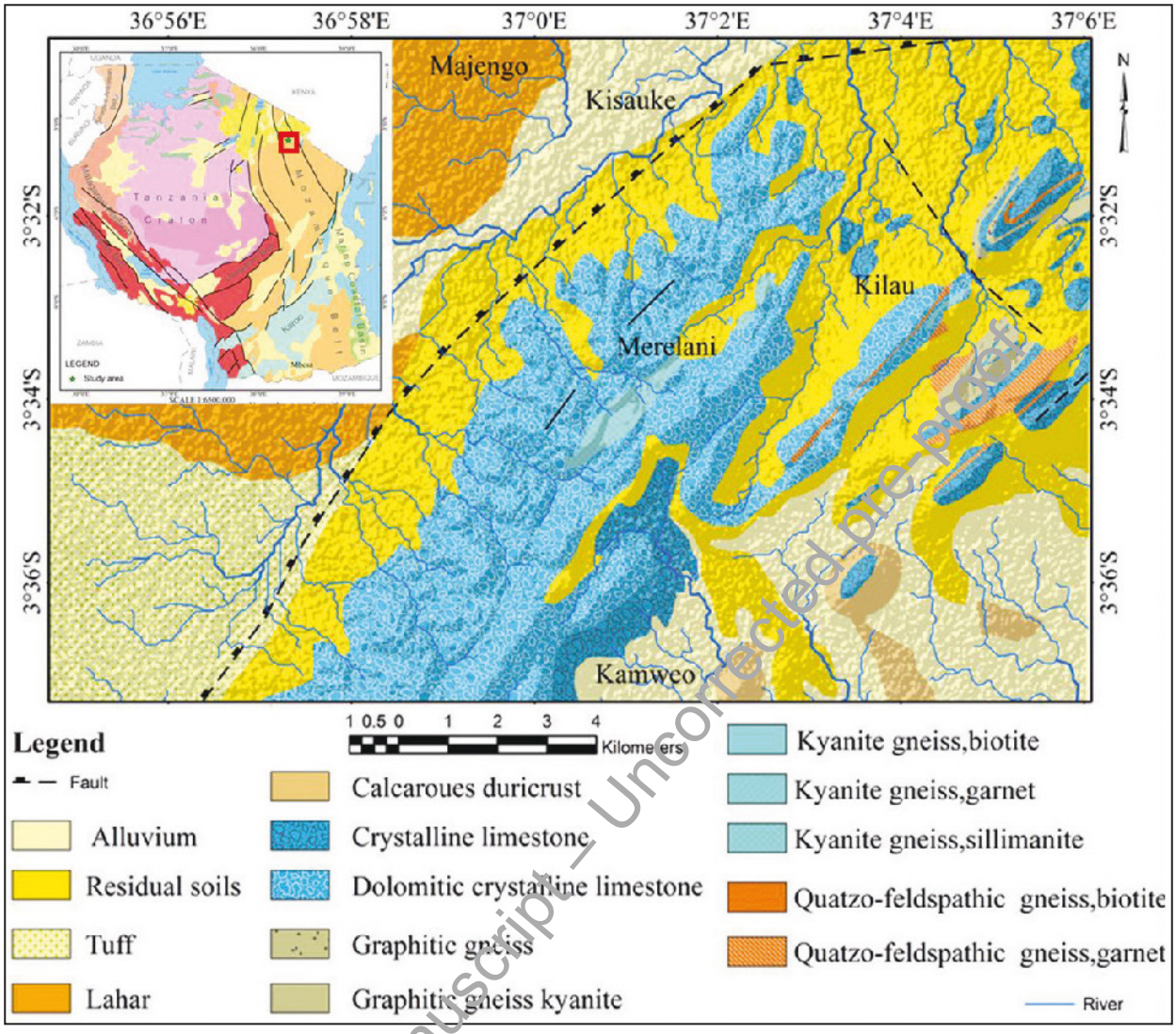

FIGURE 1. Geological map indicating the lithological units around the Mererani area, inserted is a geological map of Tanzania indicating the location of Merarani (red-coloured box).

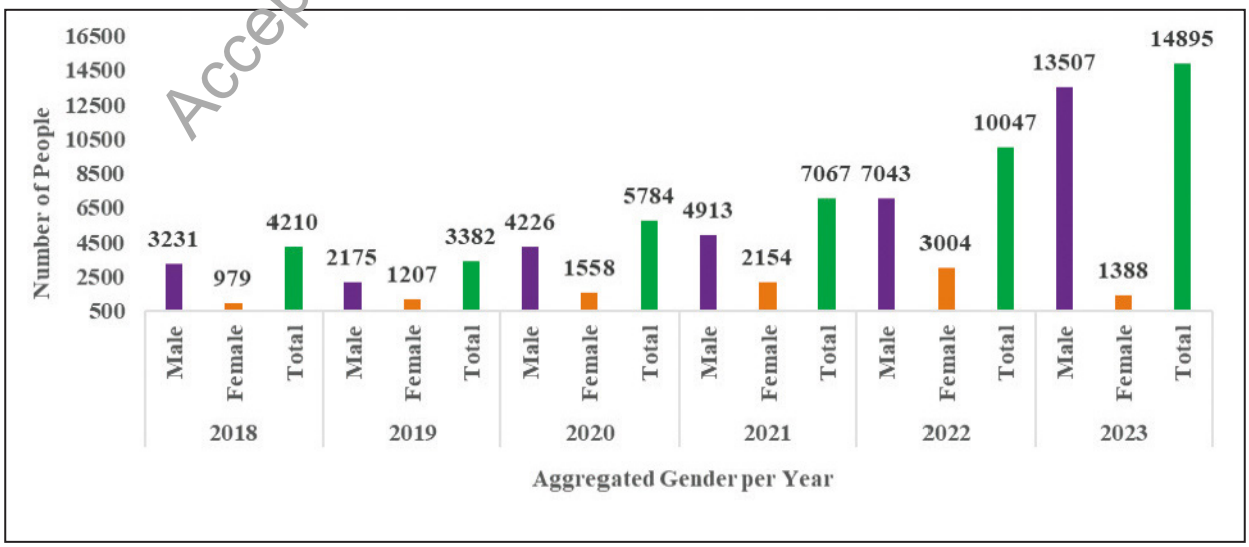

FIGURE 2. The distribution of people and their aggregated gender for the years 2018 to 2023.

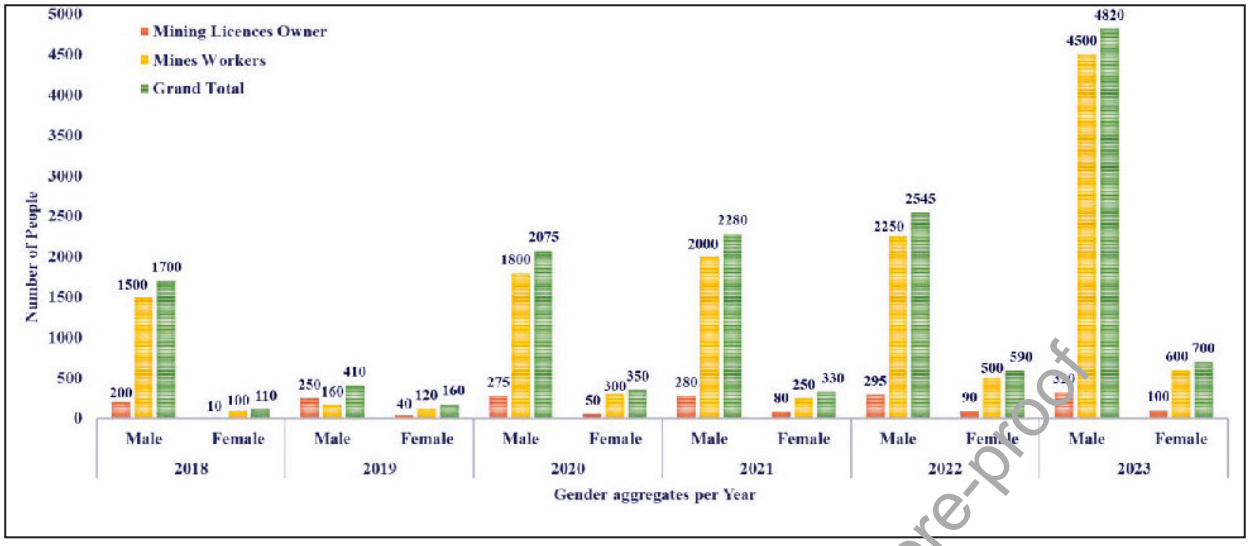

FIGURE 3. Number of people participating in the direct mining operations

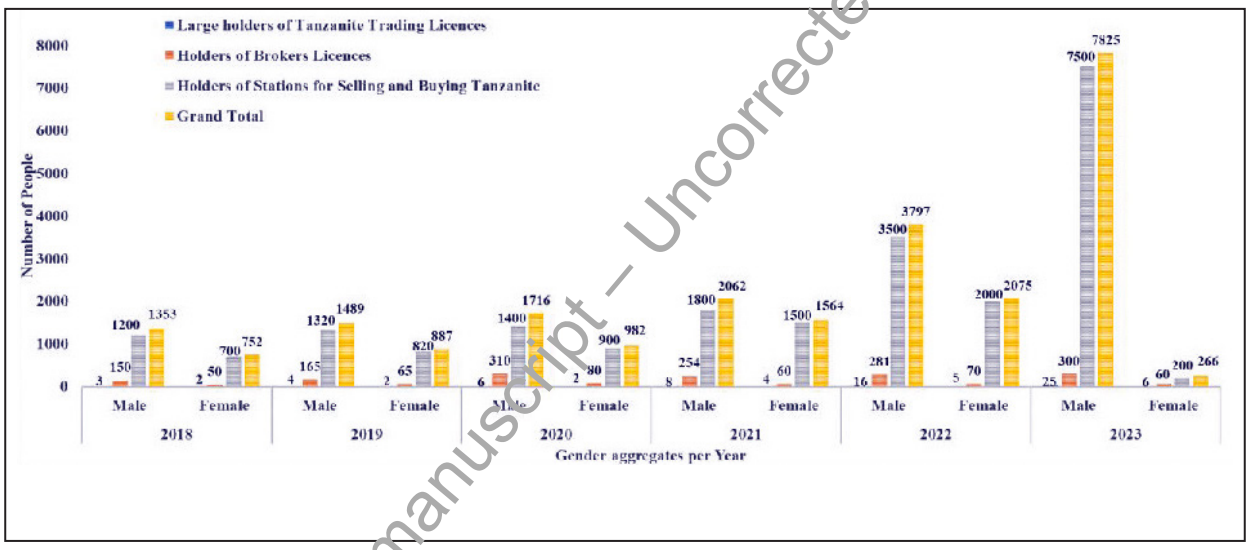

FIGURE 4. The graph illustrates the number of men and women holding licenses to operate the stations for selling and buying tanzanite in the Mererani demarcated area.

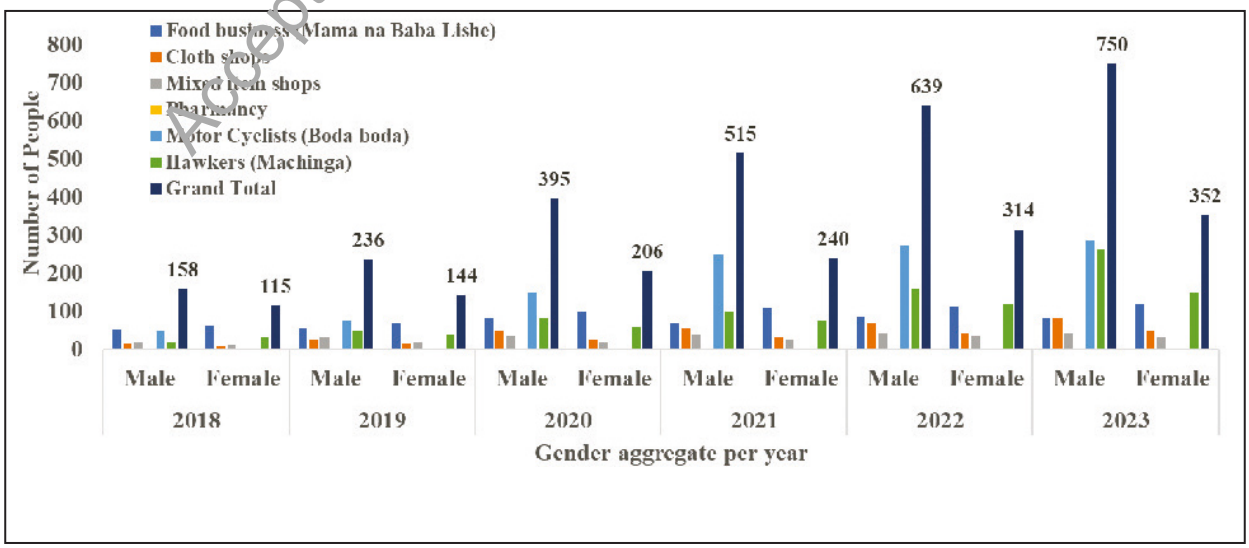

FIGURE 5. The distribution of people engaged in ancillary economic activities within the Mererani,disaggregated by gender for the years 2018 to 2023.

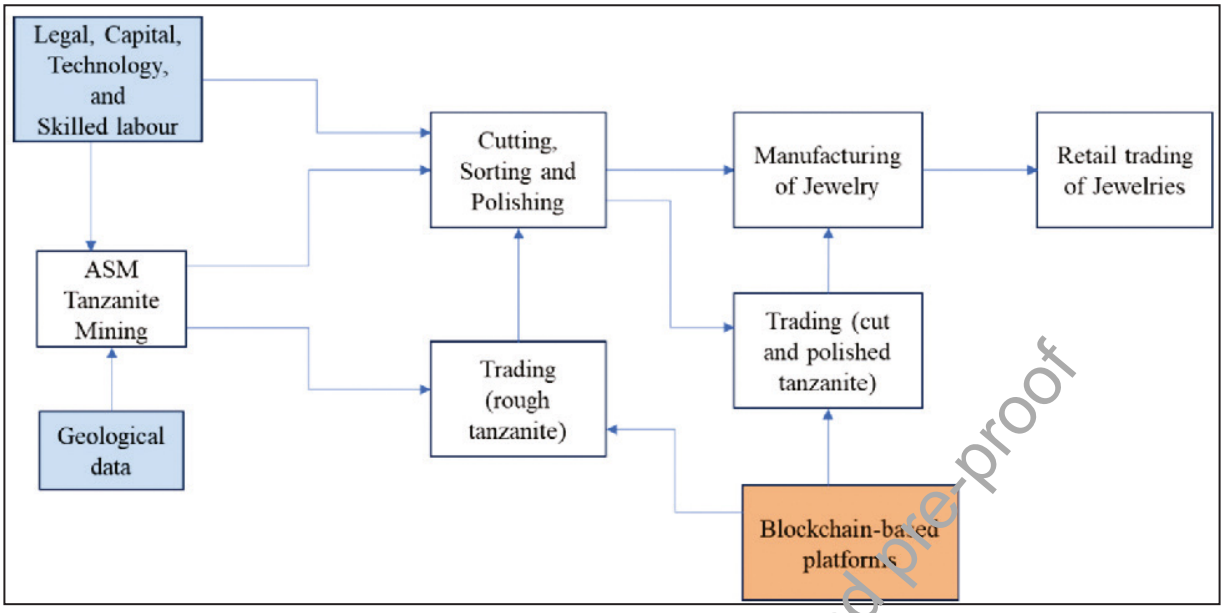

FIGURE 6. Proposed tanzanite production value chain flow chart (Author's own construction).

TABLE 1: The distribution of people in other production value chain activities in the Mererani demarcated area.

Economic Activities	Year	2018		2019		2020		2021		2022		2023	
	Gender	M	F	M	F	M	F	M	F	M	F	M	F
Mine investors		20	2	40	16	40	20	55	20	60	25	110	70
Holders of value-addition licences		0	0	0	0	0	0	1	0	2	0	2	0

M: male, F: female