GARIMPO CANAAN - A SUCCESSFUL CASE OF RECLAMATION OF AN ARTISANAL GOLD MINE IN THE AMAZON

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ABSTRACT

Deforestation in the Brazilian Amazon region was increased in the 1970’s. The total amount of forest already cut to the date is over 700,000 km² or over 18% of the original forest. Mining activities in the Amazon also escalated after 1970, with thousands of artisanal miners extracting gold and removing portions of forest and soil along the riverbanks and streams, causing deforestation and releasing sediments and mercury into the water bodies.

In the last three decades, hundreds of thousands of pits were opened in the process of colluvial gold exploitation and most of these pits have never been refilled. Following a common trend, miners migrate to new areas without reclaiming the mines spreading the environmental impact all over the Amazon. About 300 to 600 new open pits formed by hydraulic monitor mining are opened annually in the Tapajós region, the world’s largest artisanal gold mining area.

In the Tapajos River basin, an example of good artisanal gold mining practice was identified. The owner of the “Garimpo” Canaan has introduced outstanding environmental practices which have made the area a reference in reclamation of open pits in the region. In this site, most old pits have been backfilled with the tailings from new excavations. In some refilled pits the vegetation is recomposing naturally and others have been reforested. After 6 years of plantation some areas showed trees with average diameter of 15 cm, height of 10 m and volume of 23 m³/ha. This example represents not only an environmental achievement but also a long-term alternative of economic diversification for miners in the area, as the surface gold deposits have been depleting in a fast pace.

Keywords: reclamation, artisanal gold mining, mercury contamination, deforestation, rehabilitation of degraded areas, environmental impacts, Global Mercury Project

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INTRODUCTION

Current Scenario and Trends of Deforestation in the Brazilian Amazon

Deforestation in the Brazilian Amazon region has escalated since late 1960s, in particular after a government policy towards developing farms in the region, which included fiscal incentives for farmers. This motivated numerous agricultural and livestock projects, causing disorderly clear cuts throughout the forest. According to Fearnside (2005), the accumulated deforestation in the Brazilian Amazon forest until 2003 totalled an area of 648,500 km² (17% of 3,800,000 km² of the original forest). The Brazilian Institute for Space Research (INPE, 2007) concluded that the deforestation rate has decreased from 23,800 km²/a in 2003 (0.65% of the forest) to 11,224 km²/a in 2007 (0.27% of the forest). Some government officials recognize their limitation to control deforestation. The establishment of cultivated pastures has been identified as one of the main causes of deforestation (Margulis, 2003).

Mining activities in the Brazilian Amazon were initiated in the 1970s, when thousand of informal artisanal miners, using rudimentary processes to extract gold from secondary and primary ores, invaded farms and properties owned by mining companies. Artisanal mining activities have removed portions of forest along the riverbanks, and although it is smaller in extent than farming, this has caused more intense soil disturbance. Enormous pits have been opened along the rivers to extract gold from elluvial and colluvial gold ores. Millions of tonnes of material are annually processed by hydraulic monitors and tailings are dumped into the water bodies.

The Artisanal Small Scale Gold Mining Sector (ASM) in the Brazilian Amazon

Artisanal small scale gold mining (ASM) is the largest anthropogenic source of mercury release to the environment. About 1000 tonnes of Hg/a are used and released by ASM worldwide (Swain et al., 2007). According to UNIDO - United Nations Industrial Development Organization (2006), about 30 million people are directly involved in the ASM worldwide and about 200,000 miners are located in the Amazon (Veiga and Baker, 2004) where artisanal mines are known as “garimpos” and miners as “garimpeiros”.

In 2006, Brazil produced 40 tonnes of gold, and around 5.2 tonnes was officially produced by “garimpeiros” (DNPM, 2006). As most “garimpeiros” operate informally, the official production amount is underestimated. According to SEMMA - Mining and Environment Secretary of Itaituba (2006), the real gold production can be as higher as twice the official production, and this institution estimates that around 3 tonnes of gold is annually produced in the Tapajos River Basin in the Amazon region. The rudimentary techniques used by “garimpeiros” result in one to three parts of mercury lost to each part of gold produced. In addition, 1 to 2 tonnes of sediments per gram of gold produced are dumped into the local water streams, as no procedure for tailing containment is used. Hundreds of thousands of pits were opened in the colluvial gold exploitation in the last three decades and most of these pits have never been refilled (Veiga and Hinton, 2002).
Site location: Tapajos River Basin – Itaituba – Brazil

This study focuses on the Tapajos region in Brazil, known as one of the largest artisanal gold mining areas (100 km²) in the world. By the 1980s, the construction of the gravel “Transgarimpeira” road created many villages and consequently intensified the process of degradation and deforestation (Silva, 2001). From 1991 to 2000, the “garimpos” in the Tapajós region have produced 64 tonnes of gold (Veiga et al., 2002). According to Veiga and Hinton (2002), the artisanal mining cycle is well known: discovery, migration, and relative economic prosperity followed by resource depletion, outmigration and economic destitution. There is no precise estimate about the number of abandoned mines in the entire Amazon region, but only in the Tapajos region it has been estimated that between 300 and 600 open pits with dimension above 10,000m³ have been opened and abandoned annually (Sousa and Veiga, 2007a).

Veiga and Hinton (2002) listed the following as main causes for the abandonment of artisanal gold mines:

- Depletion of surface ore: most “garimpeiros”, with the current level of technology, are not able to mine hard rock deposits with complex geology. As surface deposits are depleted, miners migrate to other areas.
- ASM has never been addressed properly by all levels of government and the existing regulatory framework has not been effective. The Brazilian Government limited the locations where artisanal miners can work in Brazil creating “Garimpo” Reserves. Miners must obtain a special permit from the official regulatory organ (DNPM – National Department of Mineral Production) presenting an elaborate environmental impact assessment. As the process and requirements are beyond the reality of miners, they remain illegal, and consequently do not have access to credit and incentive, including proper training and environmental awareness.
- Disorganization and transience is a basic characteristic of artisanal mining. In general miners work either independently or in small groups. The concept of associations and cooperatives has not been widely successful and miners are very suspicious of initiatives in this regard.

In summary, there is a combination of elements causing the abandonment of artisanal mines, including depletion of ore bodies, lack of proper technology, lack of formal support from governments, poor law enforcement, poor environmental awareness and the inability of the miners to organize themselves in associations. This forms a scenario for rapid prosperity followed by abandonment of areas.

REHABILITATION OF EXPLOITED MINES

In the Amazon, programs addressing prevention of environmental degradation are rare, and the few successful examples did not have the necessary scale or funds to cope with the dimension of the problem. Artisanal mining has been in the area for at least 30 years and no significant work on reclamation has been done since then, hence the environmental impacts are enormous. Three main impacts, in particular, deserve special consideration: siltation, mercury contamination and deforestation.
Deforestation in the “garimpo” areas usually aims at providing the miners with lumber to build their camps and other facilities. Mining villages were formed in this way and completely built with locally extracted wood, without any legal support and control (Mathis, 2003).

Preliminary survey in the Tapajós region indicates that miners release between 3,000,000 and 6,000,000 tonnes/a of tailings into the rivers (Sousa and Veiga, 2007a). Twenty open pits evaluated randomly in the Crepori River (tributary of the Tapajós River) region showed volumes of sediments varying from 10,000 m³ to 50,000 m³. Usually miners start a new pit when the depth reaches 10 m. Most of these pits are not reclaimed and the miners’ preferred destination for tailing disposal is the local streams.

The area disturbed directly by excavation of pits by hydraulic monitors in the Tapajós region is estimated to be at least 12,000 ha and the rate of reclamation is insignificant (Sousa and Veiga, 2007a). The extension of the environmental destruction is not the most relevant fact in this particular case, but the distribution of the pits, since these operations are located in very sensitive areas along the rivers. Any complex and costly reclamation method will not be effective in a region with severe scarcity of basic infrastructure, low level of education and high logistic costs. Therefore, the ideal procedures to rehabilitate degraded areas in artisanal mining are not necessarily the ones with high technical level, but the ones with the highest chances of successful implementation. Simplicity is thus mandatory.

The success of a reclamation program depends on the understanding of the relationship between the living and non-living components of the soil. The ultimate objective of a reclamation program is to create suitable conditions for the development of a self-sustaining ecosystem (Stracker and Welham, 2006). However this depends on the environmental and socio-economic context of the area.

One of the challenges to be considered in a reclamation program in the ASM, is the characteristic of the soils. Soils provide the medium for plant growth, water flow control and serve as shields to retain migration of hazardous compounds (Stracker and Welham, 2006). Most of the tropical soils where ASM work are rich in clay minerals and hydrous ferric oxides. These lateritic soils are poor in nutrients and this stresses the need for organic soil salvation in a reclamation program in ASM regions. Elements, like nitrogen, are largely available in organic matter and their absence may compromise significantly plants development. Recapping open pits increases substantially the chances of a successful revegetation program however, soil handling and earth movement is one of the most expensive parts of the reclamation process. In ASM, removing and saving surface layer of soil for reclamation purpose is a challenging and expensive task for the miners.

The large majority of the roots seeking nutrients are located on the soil surface (first 30 cm). The natural seeds and vegetative propagules in the area are also located in the litter layer. If a simple capping with organic soil is applied, coloniztion by seeds of local plants can occur naturally, when environmental factors like moisture and temperature are favorable. Besides the chemical properties of soils, the physical characteristics also need to be favorable for vegetation development.
Garimpo Canaan - A Successful Case of Reclamation in the Amazon

Artisanal miners work under many adverse conditions in remote areas, and any process of environmental rehabilitation of degraded areas has the chance of being successful only if it is perceived to bring any economic benefit to miners. Moreover, the procedures must be practical and inexpensive enough to encourage miners to comply. As stressed by Ribeiro (2006), the Brazilian environmental legislation in the Amazon is very strict. Nevertheless, a preliminary survey in the Tapajós area showed that 99.3% of miners do not wait to obtain an environmental license to operate (Sousa and Veiga, 2007a). Cases of rehabilitation of ASM sites have happened due to volunteer initiatives rather than to law enforcement.

In a mine site in the Tapajos River Basin, known as Garimpo Canaan, an artisanal miner named Mr. Paulo Carneiro is considered a role model. His 10,000 ha property has been used in the UNIDO (United Nations Industrial Development Organization) Global Mercury Project as an example of high standards of reclamation of mined areas (Sousa and Veiga, 2007b). The Garimpo Canaan employs basically the most common technique in the region to recover gold. The colluvial gold ore is dismantled by hydraulic monitors and pumped to carpeted sluice boxes to concentrate gold. The concentrate is recovered every eight hours and it is amalgamated with mercury in designated plastic-lined pools, away from water streams. A large amount of sediments is generated. In terms of gold recovery, there is not much difference between the usual practices in the region and the practices of Garimpo Canaan. The main differences lie on the environmental practices applied by Mr Carneiro.

In Garimpo Canaan, most old pits have been filled with the tailings from new pits. In some filled pits the vegetation is being regenerated naturally. Other sites have been reforested with species such as African Mahogany (*Khaya ivorensis*), Neem (*Azadirachta indica*), Teak (*Tectona grandis*), Brazil Nut Tree (*Bertholletia excelsa*), Crabwood (*Carapa guianensis*), Açaí Palm (*Euterpe oleracea*), Amazonian Mahogany (*Swietenia macrophylla King*) and Eucaliptus (*Eucalyptus spp*). This is a unique case identified in the Tapajos region. Gold mining has been conducted in Garimpo Canaan for more than 20 years, but reclamation/revegetation started about 7 years ago. An inventory was conducted in the Canaan area, and the diameters and heights of the trees were measured aiming to estimate the survival rate, the growth and yield of these plantations.

The main rationale for the reclamation program established in the Canaan has been:

- Reduction of river siltation
- Mitigation of the effects of deforestation by recomposing the landscape
- Diversification of the local economy, as surface gold deposits are being depleted quickly, the mine owners (who are also farm owners) have to diversify their activities to assure sustainability
- Reforestation not only represents an environmental step, but also an alternative livelihood for miners in long-term. According to Verissimo et al. (2002), one m$^3$ of Amazonian Mahogany (*Swietenia macrophylla King*) reached a price of US$ 800 in 1994 in the State of Pará, Brazil. Although currently there is no road in Garimpo Canaan to transport these trees to the consuming centers, this is a long-term investment, as the harvesting age is expected to be 25 years.
The idea of sustainable mining has been largely discussed in the region, and the authorities tend to agree that artisanal gold mining is not a sustainable activity as the mineral deposit is finite and most mines are open pits. However, everyone agrees that the economy of the region can be replaced by other economic activities based on renewable resources. Reforestation with valuable trees is undoubtedly one of these sustainable activities and has to be encouraged and promoted among miners.

According to Mr. Carneiro’s expectations, in 25 years, one hectare of his plantation, with 556 Mahogany trees/ha, may reach the gross value of US$ 3,200/annum. With examples like this it is easier to convince miners that reforestation is not only an environmental activity, but a highly profitable business as well.

According to McClain et al. (2001), the choice of species for reclamation in the Amazon should be based on the nutrient efficiency and growth rates. In Canaan, the species were selected based on technical and economic aspects in consultation with EMBRAPA (Brazilian Institute of Agricultural Research). The seeds were purchased from EMBRAPA or collected locally when available. The substrate for the preparation of seedlings was composed of 1/3 of cattle manure, 1/3 of decomposed wood and 1/3 of organic soil. Each seedling was accommodated in a plastic bag ranging from 0.5 to 1kg of substrate. The seedlings were watered regularly and the main pests were controlled based on visual monitoring. The most common pests are: ants (*Atta capigurara*), termites (*Isoptera*), caterpillar (*Hypsipyla grandella*) and fungus. They have been controlled with industrial insecticide (Deltametrine) and natural insecticide (such as an infusion of Neem leaves - *Azadirachta indica*). The seedlings were produced in a simple nursery with 50% shadow, covered by palm leaves, and the weeds were removed manually.

In Canaan, the step of refilling open pits has been the most important activity in the reclamation process. The sluice boxes were positioned in such a way that the tailing slurry drained directly into an old pit. A triple barrier made of palm leaves was positioned after the sluice box, inside the pit. This improvised filter retained the tailings in 3 stages and water, containing only very fine particles not retained by the barriers, returned to the river. These barriers moved when the palm leaves were clogged with sediments. All processes were manual. In some pits, the process of reclamation was considered finished as soon as the pit was refilled. Without a cap of organic matter the natural revegetation takes a long time, as the lateritic sediment is very poor in nutrients. Natural revegetation process happened in many years.

Soil salvation was conducted in few cases. When new pits were opened, the soil (about 30 cm of depth) was saved in a separate location, in order to be reused for reclamation. This was performed by using hydraulic monitors and a fence of palm tree leaves to retain the removed soil. The saved soil was manually transported and poured on top of the filled pit. This soil was rich in organic matter, seeds and nutrients, and in just a matter of months the pits were covered with vegetation. When natural revegetation finds suitable condition to develop, its early stages of succession are usually dominated by grasses (*Poaceae*), sedges (*Cyperaceae*), and herbaceous dicots (Skole et al., 1999).

In areas where the pits were reforested, the plantation limits went beyond the pit borders. The seedlings were planted in 50x50x50 cm holes, filled with 1/3 of ovine or cattle manure, 1/3 of decomposed wood and 1/3 of organic soil. The spacing between trees ranged from 18 to 35 m/plant. After plantation, several
interventions were necessary to ensure the plantation’s phyto-sanitation and growth. These included manual and chemical weeding (use of herbicides) to eliminate competition, use of insecticide to control mainly ants, and use of fertilizers to assure proper growing and yield. These interventions varied case by case, depending not only on technical recommendations but also on the investment capacity of the Canaan owner. Overall, the main procedures included:

- For fertilization, it was used 120 g/hole of fertilizer NPK 10-28-20 during the plantation and repetition every year for the first 4 years. Mr. Carneiro, also used the fertilizer ARAD and NPK 04-30-10 to replace NPK 10-28-20, when this latter was not available. In some cases, manure was also used, but the dose was not controlled.
- Silviculture treatments started from the preparation of seedlings, with pulverization of Neem oil to combat fungus, insects and bacteria. The insecticide Deltametrine was occasionally employed against ants (*Atta capiguara*), termites (*Isoptera*) and caterpillar (*Hypsipyla grandella*), however the Neem oil, locally produced, was the main treatment used against pests and diseases.
- The control of weeds was manual according to visual monitoring of competition. Miners were the main labour force to maintain the plantations.

The growth and yield of these plantations were inventoried through sampling. In each sample, the following characteristics of the trees were measured: diameter at breast height (DBH) (at 1.3m from ground), the total height, and characteristics such as bifurcation, mortality and diseases. In the Blocks 1A, 1B, 1C and 1D, ten plot samples ranging from 20 to 40 trees each (area ranging from 738.5 to 1,303.8 m²) were selected in the area. The volume of the trees was calculated by using the volume of cylinder and an average shape factor of 0.5. The reforested areas used in this case study are shown in Table 1.

According to Verissimo et al. (2002), the natural density of Mahogany in the Brazilian Amazon forest ranges from 0.3 to 2.1 trees/ha. The plantation in Canaan produced 285 to 555 trees/ha, which is equivalent to the amount of Mahogany found in 1000 ha of natural forest. In addition, for each Mahogany tree harvested in the natural environment, about 31 other trees with diameter above 10 cm are cut in order to obtain the Mahogany. This gives an idea of the environmental impact of extracting Mahogany in a natural environment, and the importance of plantations. The main results of the inventory are presented in Tables 2 and 3.
Overall the trees growth is compatible to other existing plantations in the Amazon, as reported by Guimarães et al. (2004) and Browder et al. (1996). Trees (African Mahogany) in Block 1A showed an average diameter of 15.16 cm and average height of 9.59 m, at the age of 5.8 years. It is expected that at the harvesting age (25 years) the trees will reach a commercial diameter of 40 cm. Another inventory in five years is suggested to confirm the growth trend. The obtained average survival rate above 81.05% is reasonable for native species and it is comparable with 80% mentioned by Guimarães et al. (2004) for similar projects with Mahogany in the Amazon. The reason of some mortality was not established, however, most of tree deaths have occurred in the first year that likely indicates seedlings poor adaptation to the field conditions. The survival rate of Teak is very high, 97.91%. Basal area of African Mahogany is
4.61m²/ha and volume is 23.19m³/ha. The standard deviation of ±2.88m³/ha and coefficient of variation (C.V.) of 12.41% obtained in Block 1A, indicate that the samples are relatively homogeneous in terms of volume distribution. The low sampling error (8.10%) indicates that the sampling size was adequate for the purpose of this inventory and validates the sampling method for volume as a function of diameter, height and shape of the tree.

In Block 1B, the Neem tree brings an additional advantage, since not only its wood has value but also the leaves and seeds, that can be used to extract oil which is a powerful repellent for malaria mosquitoes. The gross revenue with this Neem plantation can potentially reach US$ 2,000/ha.annum based on calculations from Bittencourt (2006).

CONCLUSION

Refilling open pits is a crucial step in the rehabilitation of degraded artisanal gold mines in the Tapajos region. In Garimpo Canaan, the use of triple barriers made of palm tree leaves has been an efficient way to retain tailings. The loss of material (not retained by the barriers) varies according to the particles size, the slurry flow and the quality of the barrier. Even partially refilled pits represent a progress when compared with the usual abandonment of mined areas. In areas refilled and not recapped with organic soil, natural vegetation has a slow growth rate. Saving the original surface organic soil for recapping pits is expensive for mine owners as this requires intensive manual labour. Organic soil has been used as an efficient substrate for seedlings. Reforestation has been tested in the reclamation process in the Garimpo Canaan. This is an attractive economic opportunity that may ensure economic sustainability to the farmers. The plantations in Canaan are still young for commercial purpose (6 years old), as harvesting is expected after 25 years, but an inventory has indicated consistent growth rates. The current growth rate of 4 m³/ha.annum of Mahogany and Teak is comparable to other plantations mentioned in the literature, which may represent future gross revenue of US$3,200/ha.annum. Neem trees are presently an important source of leaves and seeds for the production of oil frequently used in Canaan as natural insecticide and fungicide. Rehabilitation of degraded areas must be promoted among artisanal miners and Garimpo Canaan is an excellent reference to be followed.

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Fig. 1 – Sequence of refilling an open pit using palm tree barriers to retain tailings and reclamation of the area using Mahogany (6 years old)