RECLAMATION REVISITED: MINAS GERAIS, BRAZIL[1]

by

Terrence J. Toy[2]
and
James Jackson Griffith

Abstract. The last systematic evaluation of surface-mine reclamation in Brazil was completed in 1986. Since that time, there have been significant changes in reclamation laws and reclamation practices. The purpose of this investigation was to examine the evolution of reclamation during the past 13 years based upon mine visits and interviews with reclamation personnel at the mines, with environmental consulting companies, and with the regulatory authority. Overall, reclamation quality has improved substantially since 1986. Nearly all mines work to reclaim the lands that they disturb. Environmental analyses and reclamation planning is much more thorough than in the past. At most mines, geotechnical studies have largely eliminated the occurrence of mass-movements. Hillslope-gradient reduction and terracing provide stable platforms for reclamation. Revegetation is a two- or three-stage process, rather than the nearly exclusive use of rapid-growing, introduced, vegetation species as in the past. Nevertheless, there is a wide range in reclamation quality, from excellent on a world-class scale, to minimal, apparently intended to temporarily appease the regulatory authorities. Reclamation quality will continue to improve as laws, regulations, and their enforcement become simplified but more stringent, post-reclamation land use receives more attention, and reclamation specialists gain experience.

Additional Key Words: Reclamation, Surface mines, Brazil, Minas Gerais.

Introduction

Mining has long been a major industry in Brazil. The mining sector, processing sector, and mineral exports accounted for 2%, 26%, and 27% respectively of Brazil's gross domestic product in 1995. Brazil is a world leader in the production of iron ore, gold, bauxite, tin, and manganese. Within Brazil, most mining is found in the State of Minas Gerais (General Mining), located in the southeastern part of the country. Brazil and Minas Gerais possess large mineral reserves that will provide the base for mining operations well into the future.

Reclamation of mine lands is a relatively new concept in Minas Gerais, despite a 300-year mining history. Prior to 1986, mining and environmental laws usually were unsuccessful in mandating effective mine-land reclamation. In 1986, mines were required to be licensed and to submit an environmental assessment as part of the licensing process. In 1988, the new Brazilian Constitution specifically required that all mines reclaim the lands that they degrade. In 1989, mines were required to prepare detailed reclamation plans. In 1997, penalties were specified for violations of reclamation laws and regulations, including fines up to US$5,000,000 (when enacted in 1997) plus confiscation of equipment and mineral products. The legal requirements for reclamation changed dramatically between 1986 and 1997.

A comprehensive examination of mine-reclamation practices in Brazil was completed by Barth and Brazilian associates in 1987, and reported at the 1988 national meeting of the American Society for Surface Mining and Reclamation (Barth et al., 1988). Although reclamation at some mines was excellent, more than 50% of the mines did not engage in any

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[2]Terrence J. Toy is professor of Geography and Geology, University of Denver, Denver, CO 80208.

James Jackson Griffith is professor of Forestry Engineering, Federal University of Viçosa, Minas Gerais, Brazil.

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form of reclamation. It was reported in this study that usually there was little concern for long-term, post-mining land use, hillslope stability, soil erosion and compaction, post-reclamation site management, and research quality. Reclamation suffered due to incomplete soil analyses, salvage, re-distribution and amendment, together with poor site preparation, reliance on introduced plant species, and poor seeding techniques. The purpose of the present research was a reassessment of current reclamation practices in Minas Gerais following enactment of the aforementioned legislation.

Research Methodology

The evolution of reclamation practices in Minas Gerais was examined through a comparison of the findings in the Barth et al. (1988) report with information gathered during mine visits and interviews in Autumn, 1999. The general structure of the Barth et al. (1988) report was retained to facilitate the comparison. Some of the mine participants and the co-author were involved in both investigations. The Barth et al. (1988) report was based exclusively on eight mine visits and interviews with mine personnel. The present study included seven mine visits and mine personnel interviews, as well as interviews with three environmental consultants and three regulatory-agency personnel in order to obtain various perspectives concerning the quality of reclamation in Minas Gerais. The mines included in the present study extract three different mineral resources and included small-, medium-, and large-size operations.

The persons interviewed averaged more than 10 years of reclamation experience. One individual was responsible for reclamation at several mines. Each person interviewed was promised confidentiality and so the mines, consulting companies, and regulatory agencies are not identified in this report. Indeed, the participants in the interviews often provided quite candid commentary regarding the reclamation successes and failures, incentives, and obstacles.

Reclamation: Past and Present

A comparison of past and present reclamation practices in Minas Gerais, Brazil is summarized in Table 1. In some cases, there was little change in the conditions documented by Barth et al. (1988). In other cases, there have been significant improvements in reclamation quality.

Minimal Changes

Reclamation planning still tends to emphasize short–term, aesthetic and visual goals, rather than long-term, post-reclamation land use. Dense vegetation covers often mask landforms that are not conducive to many types of land use. Land is regarded as a plentiful resource in Brazil, so productive land use after mining frequently is not considered an important issue. Regulatory authorities intend to change this perspective, through the mining license renewal process. One model for reclamation with long-term objectives is provided by Toy et al. (in preparation).

By North American and European standards, topsoil analyses and salvage are woefully inadequate. There is widespread opinion that most of the Minas Gerais soils are shallow, often rocky, and of poor quality due to intensive weathering and leaching; hence, salvage and re-spreading is not worth the investment. Indeed, the reclamation specialists at many mines have learned to revegetate with little or no topsoil. Today, reclamation laws require the use of topsoil in reclamation, so more mines undertake soil analyses and salvage than in the past. The value of topsoil for revegetation within the Brazilian environmental setting seems to warrant additional consideration.

Erosion control continues to be a important goal at nearly all mines. Steps are taken to divert "runon" from disturbed lands and to repair rills and gullies after reclamation. Downstream water quality is very important because downstream towns and villages commonly depend on stream-flow for their water supply and sediment loads tax the capabilities of rudimentary, in-home, water-treatment facilities. Rapid revegetation is regarded as the key to erosion control.

The timely revegetation of reclaimed surfaces is especially important in the climatic regime of Minas Gerais, with an extended rainy season of high-intensity precipitation. Revegetation serves the aesthetic, visual, and erosion-control goals of reclamation. Revegetation in the past usually made use of fast-growing, introduced, plant species, such as "grease grass" (*Melinis minutiflora*). Species selection is limited by seed-availability while seed companies provide only the species that are in demand. Seed is "hand-broadcast," sometimes resulting in uneven distribution and barren areas. Steep hillslope gradients often preclude the use of seeding equipment, except on level terrace surfaces. Hydroseeding no longer is used extensively at most mines but reserved

Table1. Comparison of Reclamation Practices: Past and Present.

Minimal Change Between 1986-1999	Significant Change Between 1986-1999
1. Planning emphasis on short-term goals	1. Nearly all mines reclaim disturbed lands
2. Incomplete topsoil analysis and salvage	2. Improved standards and expectations
3. Concern for erosion control	3. Comprehensive site analyses and planning
4. Concern for rapid revegetation	4. Nearly all mine have geotechnical studies
5. Variable post-reclamation site maintenance	5. Several mines reconstruct topography
6. Tailings ponds and lakes in valleys	6. Revegetation in 2 or 3 stages
7. Variable research quality	7. Mulching of severe areas
	8. Discontinued 2 destructive practices

for difficult or inaccessible areas. Most mining companies operate nurseries to provide the tree and shrub seedlings for reclamation.

Post-reclamation site maintenance is variable in quality. Water management, erosion and sediment problems usually are high-priority maintenance issues. Weed, ant, fire, and grazing control usually are lower-priority maintenance issues, although they may quickly degrade vegetation covers resulting in accelerated erosion. Some reclamation specialists suggest that vegetation must compete under prevailing environmental conditions without episodic intervention, analogous to the "hands-off" post-reclamation bonding period for coal mines in the United States.

Runoff, sediment, ore-washing residues, and ore-processing tailings are directed into and fill stream valleys forming large ponds and lakes. Drainage and reclamation of these sites is scheduled at eventual mine closure. From engineering and economic perspectives this is the logical place for these waste products. From a geomorphic perspective, stream valleys are "high energy" locations in the landscape, characterized by runoff and tributary-stream convergence, and subject to high rates of fluvial processes from time to time (Toy and Hadley, 1987). Deposition in the valley also creates a perturbation in the longitudinal profile of the stream course and, over time, fluvial processes tend to remove such irregularities in gradient, transporting the sediment downstream.

Barth et al. (1988) reported variable research quality at most mines. It is important to understand that there are two types of reclamation research. The first type of research is intended to contribute to the scientific reclamation literature and must adhere to sound scientific protocols. The second type of research is intended to improve the quality or reduce the cost of reclamation at a specific mine and may take short-cuts in the scientific method. Most mines conduct both types of research, the first type in conjunction with university professors or students and the second type by the reclamation specialists themselves at the mine.

Significant Changes

Nearly all mines now attempt to reclaim the lands that they disturb, most with good to excellent results. The largest mines tend to produce the best reclamation because they have available the necessary expertise and financial resources for the job. Small mines tend to produce the least successful reclamation due to expertise and financial resource limitations. Sometimes they turn to university professors and students for assistance but still can provide little material support. The moderate-size operations can produce high-quality reclamation using innovative techniques, such as lawn and garden clippings for revegetation, as shown in Figure 1. Regulatory authorities monitor reclamation activities and quality from time to time.

Reclamation standards and expectations have improved considerably during the past decade as required by law. Environmental assessments, comprehensive environmental reports, and reclamation plans are necessary to obtain and maintain a mining license. Now, license renewal applications must include mine-closure plans indicating the post-reclamation land use. Mining and reclamation plans are subject to review by regulatory agencies and approved by a special state board. In the past, most of these plans were conceptual rather than practical. This is changing; the mines are expected to perform as indicated in their plans. Regulatory authorities are emphasizing reclamation quality and non-governmental organizations (NGOs), as well as other local stakeholders, continue to pressure state and national government agencies to improve environmental protection.

Figure 1. Two-year old reclamation using lawn and garden clippings.

At nearly every mine, there is evidence of past mass-movements - landslides and slumps. Nearly all mines commission geotechnical studies to minimize such occurrences today. Hillslope-gradient reduction and terracing during reclamation increase the mass-stability of the landscape and facilitate erosion control. There was evidence of recent mass-movements at only one of the mines visited.

Topographic reconstruction is a critical initial step in the reclamation process whereby grading and shaping operations integrate hillslopes and stream channels into the surrounding, undisturbed, landscape (Toy, 1998). The new landforms are the platforms upon which subsequent reclamation practices take place. Typically, hillslope gradients are reduced and terraced where necessary, as shown in Figure 2. Stream-channel gradients are reduced and merge into regional drainages. Topographic reconstruction at three of the mines visited is excellent equal to, if not superior to, topographic reconstruction observed at most mines in the United States. The reclamation specialists at these mines to not consider full topographic reconstruction to be excessively expensive due to the savings realized in water and erosion control, revegetation, and site maintenance. Topographic reconstruction is considered a good investment at these mines.

At several mines, revegetation is a two- or three-stage process using both native and introduced plant species. As described by Griffith et al. (1996), this process commences with rapid establishment of vegetation to protect the surface from erosive forces and progresses to a self-sustaining vegetation cover in accordance with selected land-use objectives. The regulatory authority encourages revegetation with native species although this commonly requires "hand-collection" of seed from nearby, undisturbed, areas. All mines include legumes in the seed mix. Mulches commonly are spread on steep or hot, north-facing, hillslopes. Mulches are held in place with netting, stakes, or bamboo frames. Clippings and prunings from gardens and parks are used effectively for revegetation and provide seed sources, nutrient supplies, and serve as mulch.

Barth et al. (1988) recommended discontinuation of two destructive practices: (1) the purchase of topsoil from nearby farms and (2) needless disturbance of land by heavy-equipment operators. The purchase of topsoil degrades the farmland and is not necessary when on-site topsoil is salvaged. Topsoil is no longer purchased by the mines. Areas to be mined are delineated for equipment operators and disturbance of land beyond these boundaries is prohibited as specified in agreements with subcontractors.

Figure 2. Terraced reclamation hillslope.

Conclusions

Since 1986, mine-land reclamation in Minas Gerais, Brazil has improved substantially due to changes in laws and regulations, corporate attitudes, and implementation of reclamation practices. Barth et al. (1988) found that only about one-half of the mines visited attempted any form of reclamation of the lands that they disturbed. Today, reclamation is required by the national constitution, all mining requires licenses, the licensing process requires detailed environmental analyses, and reclamation plans require review by the regulatory authority with approval by a state board. The legal structures are in place to mandate effective reclamation.

In many cases, corporate attitudes seem to have changed from the perception of reclamation as an expensive and unnecessary task, charged to a small under-staffed and under-funded office at each mine, to a perception of environmental protection and reclamation as an important part of mining operations and the responsibility of all mine personnel. Even allowing for some exaggeration, attitudes toward reclamation have improved during the past 13 years. Because land is plentiful in Brazil and reclamation costs cut into thin profit margins, there will always be those who contest the need for reclamation.

The reclamation personnel at the mines have gained valuable experience through trial-and-error as well as specific experimentation. Many hold university degrees with coursework in disciplines related to reclamation, such as forestry and soil science. Over the years, they have adopted and adapted reclamation practices that produce the best results within their environmental setting. Available expertise need not limit reclamation quality in Minas Gerais.

Although the recipe and ingredients exists for high-quality reclamation, on the ground, the quality of reclamation ranges from excellent on a world-class scale to minimal, token efforts, apparently intended to appease regulatory authorities for a while. Regular inspections by trained personnel, backed by more stringent and uniform enforcement of reclamation laws, are necessary to reduce the range in reclamation quality among the mines.

We believe that reclamation has improved substantially in Minas Gerais since 1986 and will continue to improve. The evolution of mine-land reclamation in Brazil tends to parallel the evolution of reclamation in other parts of the world. A more detailed discussion of this investigation is forthcoming in the International Journal of Surface Mining,

Reclamation, and Environment (Toy and Griffith, 2001).

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