

**QUARRY RECLAMATION IN MÉRIDA, YUCATÁN, MÉXICO:
A REVIEW ON ACHIEVEMENTS AND CURRENT LIMITATIONS**

**[REGENERACIÓN DE CANTERAS EN MÉRIDA, YUCATÁN, MÉXICO:
UNA REVISIÓN SOBRE SUS POSIBILIDADES Y LIMITANTES]**

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SUMMARY

In Merida, Yucatan, Mexico, quarry exploitation is one of the mining activities which most impacts the environment, eliminating vegetation as well as soil. This activity requires restoration measures after exploitation. Nevertheless, few companies are implementing reclamation projects. Motives are diverse and range from legal to economic. The Materiales Anillo Periferico Company (MAPSA) has established and successfully managed several types of agroforestry systems on exploited land. At present they are evaluating native tree species which can grow under quarry conditions. The goal is to establish multi-species systems which satisfy owners' needs and at the same time provide conservation. Restoring sites to this original condition is impossible. After exploitation, no vegetation is left, and the remaining substrate is only a layer of the bed-rock on the ground water table. However, it is possible to stimulate investment in productive quarry use. Among the factors which make difficult the propagation of experiences generated in MAPSA are high investment costs of regeneration, clandestine mining, and lack of enforcement. It is necessary to identify mechanisms which link economic, ecological and social aspects. At the same time it is necessary to establish links among productive, business, and scientific sectors, and publicize the results in order to stimulate reclamation of quarry sites.

Key words: agroforestry systems, quarry exploitation, regulations.

RESUMEN

En Mérida, Yucatán, México la explotación de canteras es una de las actividades mineras que más impacta al ambiente pues elimina tanto la vegetación como el suelo. Esta actividad requiere de la aplicación de medidas de mitigación después de la explotación. Sin embargo, son pocas las empresas con áreas ya explotadas que están llevando a cabo algún proyecto de regeneración. Los motivos son diversos y van desde los legales hasta los económicos. La empresa Materiales Anillo Periférico (MAPSA) ha establecido y manejado con éxito diversos tipos de sistemas agroforestales. Actualmente, se están evaluando nuevas especies arbóreas nativas que puedan desarrollarse bajo las condiciones de cantera. La meta es establecer sistemas agroforestales que satisfagan necesidades de los propietarios y al mismo tiempo realizar prácticas de conservación. Alcanzar la restauración histórica del sitio es imposible. Después de la explotación no hay vegetación y el sustrato que queda es sólo una fracción de la roca madre. Pero sí es posible estimular la inversión en el uso productivo de las canteras. Entre las limitantes que dificultan la propagación de las experiencias generadas en MAPSA están los altos costos de inversión en la regeneración, el clandestinaje, la poca claridad en las leyes y sus reglamentos. Es urgente identificar mecanismos que vinculen los aspectos económico, ecológico y social. Se requiere establecer vínculos entre los sectores productivo, empresarial y científico, y difundir los resultados generados para estimular la regeneración de los sitios de cantera

Palabras clave: sistemas agroforestales, explotación de canteras, reglamentación.

INTRODUCTION

Where open quarry mining takes place (i.e. the exploitation of rock layers to obtain materials for construction industry use), generally the soil is

denuded, the landscape is altered, and the ecosystem is destroyed. Inappropriate management of mining activities may provoke severe impacts on neighboring sites. This is due to discharge of contaminants, sediments, chemicals or metals (Gardner 2001). Many

exploited mines are abandoned and their sites are left highly disturbed, with little or no recovery. These sites are then often used as public dumps. As a consequence, they are a source of bad odors, contaminated soils, leachates containing pathogens or toxins that contaminate groundwater, and promote proliferation of bothersome fauna (mosquitoes, rats, etc.) (Meyer *et al.*, 1999).

Mining near cities is an undesirable economic activity, even though it plays an important role in the development and maintenance of living standards (Gardner 2001). Nevertheless, cases exist of activities which promote mine reclamation processes in different parts of the world (Jim 2001, Gardner 2001, Griffith and Toy 2001, Sarrailh and Ayrault 2001, Clemente *et al.*, 2004). Efforts range from applying decontamination treatments to the site to “creating” new soil layers (Holmes and Richardson 1999).

One of the most important mining activities in Yucatan, Mexico is limestone quarry exploitation. Limestone is obtained from quarries to be used in construction materials (gravel, lime, cement). The visual impact produced by the resulting landscape alteration is great, due to drastic modification of relief and vegetation (Clemente *et al.*, 2004). It is common to find large abandoned holes which accumulate garbage near tourist or urban developments and highways, and few measures are employed to restore exploited quarries.

The use of limestone in the construction industry in Yucatán dates from prehistoric times. In his writings, De Landa (1556) informs: “*Yucatan is a land of the least soil which I have seen... There are few parts in which a new City could be dug without reaching a large rock slab.*” The ancient Mayas took advantage of this rare quality. Morley (1987) reports that the Mayan pyramids are made of a cementing material which is very easy to work with. This material is limestone which, upon being burnt, produces lime. It is mixed with gravel to provide support to buildings. Populations still exist who produce lime in the same manner as did the ancient Mayas. During colonial times (1522-1821), the Mayas were forced to raise new population centers and construct roads. For these purposes they used materials obtained from limestone (Meyer *et al.*, 1999).

Currently, various Federal and State government plans are considering the development of new roads and infrastructure throughout the state. This is promoting new quarry exploitation. The government itself exploits rock material near its construction sites.

An Environmental Protection Law exists for the state of Yucatan which regulates quarry exploitation and regeneration activities. Nevertheless, little has been

achieved in this respect. The Yucatan State Government Secretary of Ecology (SECOL) is charged with providing follow-up on quarry regeneration actions. In 2003, this institution estimated there were 19 companies of varying size dedicated to quarry exploitation in the state (G. Valladares 2004, SECOL, Yucatán, personal communication). Principal companies include: CEMEX, Apasco, Predeco, Procom, Mitza, Cementos Maya, MAPSA, and the state government itself.

It is necessary to identify regeneration options for active and inactive areas in order to reverse impact. One alternative, which does not require great effort, is allowing natural succession processes to take effect. However this takes decades. Another option is to productively regenerate these areas, establishing “designer ecosystems” which give rise to future forests, as MacMahon (1998) proposes. A site may be restored for a particular function or to conserve certain species. This may, for instance, include restoring the forest architecture without restoring all its species. For example, in Quintana Roo, Mexico, the architecture of the acahual (secondary vegetation growth after shifting cultivation) promotes a rapid fire cycle, and at the same time diminishes the diversity of species. A return to mature forest structure using a designer approach may both break the fire cycle and promote biodiversity. This implies manipulating altered systems, not only leaving them to natural succession processes (Allen *et al.*, 2003). Another option is constructing diverse agroecosystems that are both productive and mimic to a certain extent the forest architecture.

The purpose of this paper is to review the literature on quarries reclamation and to discuss the limitations and possibilities for limestone mine reclamation in the outskirts of the city of Merida, Yucatan. We present a successful reclamation experience based on agroforestry systems, and analyze some current limitations and needs for extending it throughout the region. As part of this review we provide our own tree growth and survival data from the agroforestry plots most recently established by MAPSA.

METHODS

Anillo Periferico Materials S.A. (MAPSA) is a Yucatan company which has been dedicated to quarry exploitation for 27 years. Quarry exploitation implies extracting all rock material, until arriving to a meter or less of the ground water level (Figure 1). At the end of the process, only a carbonate rock lacking organic material and biological activity remains (Sims 1990). For almost three decades, the company has exploited 65 hectares. Of these, 30 hectares are being recovered by establishing and managing agroforestry systems.



Figure 1. Exploited MAPSA quarry. Soil mounds which were separated before exploitation may be observed. In the lower part, rising of the ground water table may be observed (Photo by: Montañez 2000).

In 1990, MAPSA started rehabilitating its quarries. It planted 12 Has with a tree-grass mixture of *Leucaena leucocephala* (huaxín) and *Cynodon nlemfuensis* (Star grass). Success with this trial motivated the owners to plant two more Has. With a mixture of legume trees as forage for cattle (*L. leucocephala*, *Gliricidia sepium*, *Guazuma ulmifolia* and *Albizia lebbek*) at a global density of 1,250 plants ha⁻¹. Survival, growth and adaptation of these trees was evaluated by Castillo and Cervera, 1998. Since 1995 the Faculty of Veterinary Medicine and Animal Science of the Universidad Autónoma of Yucatan has been collaborating with MAPSA on this project. The goals are (1) reestablishment of plant cover, (2) efficient productive use of light, soil and space, and (3) short, medium, and long term income generation (Armendáriz 1998, Castillo and Cervera 1998).

In January 2000, three more Has. were prepared for planting agroforestry systems. The first step of this recovery strategy was to separate the first 20 cm of soil at the moment of opening a new rock extraction area. Regeneration was initiated by applying a 1-m thick gravel fill at the bottom of the exploited quarry, above which the stored top soil was placed. The depth of the aquifer (1.5 m below the new ground level) should be sufficient to avoid flooding during the rainy season. Mahogany (*Swietenia macrophylla*) and ramon (*Brosimum alicastrum*) plantations were established in order to evaluate their survival in quarry conditions. Mahogany was planted in a 4 x 4 m arrangement, as a monoculture and associated with tamarindo (*Tamarindus indica*), or with tamarindo and achiote (*Bixa orellana*). Ramon was planted in a 4 x 4 m arrangement, also as a monoculture and associated

with huaxín (*L. leucocephala*) or with huaxín and pixoy (*G. ulmifolia*).

Planting was done manually in August 2000. Nine months after planting, *Leucaena* and *Guazuma* foliage was completely pruned up to one meter in height. Pruning continued every 90 days between September 2001 and June 2002 in order to avoid light competition. From November 2000 to April 2001 (the dry season), the mahogany and ramon plants were watered three times weekly. All plots were weeded every 30 days.

Data on the trees was collected every three months from September 2000 to June 2002. Survival percentages of each species were recorded. Total height was measured with a metric pole. For mahogany, diameter at breast height (DBH) was measured.

RESULTS

By the second year after transplanting, the survival of all tree species established in 2000 was higher than 90%. Tree growth was also successful. Mahogany trees had an outstanding growth: in two years, they reached 5 m heights and a DBH of 5 cm (Table 1, Figure 2). Soil fertility and soil depth as well as the proximity of the water table to plant roots can explain these results. Other plots established previously by MAPSA in a contiguous quarry show qualitatively similar results.

The hurricane Isidore in 2002 demonstrated that this system can be resistant when local climate conditions are extreme. With the high precipitation conditions

caused by Isidore, the site remained flooded for five months. Water rose to two meters above ground, and 60% of trees planted in 1994 and in 2000 were lost (Figure 3). Mahogany, tamarind and pixoy plants survived these conditions. Polycultures which combine tree species with different physiology can reduce the risk of total loss when natural disaster strikes.

Table 1. Growth of the species after two years.

Specie	Common name	Height in year 2002 (m)
<i>Swietenia macrophylla</i>	mahogany	5
<i>Brosimum alicastrum</i>	ramón	3
<i>Bixa orellana</i>	achiote	2
<i>Tamarindus indica</i>	tamarindo	2.5
<i>Leucaena leucocephala</i>	huaxín	pruning
<i>Guazuma ulmifolia</i>	pixoy	pruning

Review of other studies carried out in quarries managed by MAPSA

The survival rates of species planted in 1994 was greater than 90%. Forage production and quality was evaluated for some species (Armendáriz, 1998). One conclusion of these studies was that given the quarry's soil conditions and micro-environment, it is possible to develop agroforestry systems. This allows for the

regeneration of these areas, while generating income at the same time.

Another study conducted in MAPSA was an analysis of basic costs of the rock extraction process, and of the regeneration process through a silvopastoral system (SPS). The goal was to identify possibilities of internalizing the costs of the regeneration process (Coba, 1998). This study estimated that extracting material from one hectare of quarry costs 123,682.71 dollars and the gross profit generated (before taxes) was 94,000.11 dollars.

If we consider that reclamation must be carried out by law, that costs represent only 16% of gross profits, then companies should not object to carrying out regeneration. High profits can be obtained from quarry exploitation, so investing in agroforestry systems for regeneration and productive purposes should not be resisted by companies.

In 2001, Llamas (2004) evaluated forage yield and quality of *L. leucocephala*, *G. ulmifolia*, *A. lebeck* and *G. sepium*, 6 years after planting. The most productive species were *G. sepium* and *G. ulmifolia* with 2,193 and 1,467 kg DM ha⁻¹ year⁻¹, respectively. *A. lebeck* did not perform well under quarry conditions and is not recommended.



Figure 2. Multispecies agroforestry system where the main crop is *Swietenia macrophylla*. Sanitary pruning are realized to control the shoot borer (*Hypsiphylia* sp.) (Photo by: Montañez 2002).



Figure 3. Multispecies agroforestry system established in the MAPSA quarry, which was flooded for five months after Hurricane Isidore in 2002. The aquifer rose more than 1 m (Photo by Montañez 2002).

MAPSA is a successful example of limestone mine regeneration. This is demonstrated by the fact that after 14 years, the owners continue to be interested in creating and innovating reclamation practices with agroforestry systems. In 2002, the SECOL administration officially recognized MAPSA for their successful recovery actions.

By linking businesses and universities, management strategies and activities are being identified for accelerating the recovery process. This link has benefited both parties. Universities have the opportunity to expand research in relevant fields, and the business continues to obtain new concessions, while obtaining further income from agroforestry products.

Limitations and possibilities of quarries reclamation

In the state of Yucatan, several uses for abandoned quarries have been proposed. Recreational parks have been created, and some companies have tried to carry out aquaculture and deer raising. These options have not been very successful. In contrast, only one company (MAPSA) has regenerated a large area, through the establishment of agroforestry systems.

Upon regenerating quarries, one should consider additional evaluation criteria, besides ecological factors. Among these are economic, historical, cultural, social, moral, and aesthetic criteria (Higgs 1997, Swart *et al.*, 2001, Winterhalder *et al.*, 2004).

Other essential factors are political will and government capacity to coordinate the interests of those parties involved in regeneration.

Several causes explain the small numbers of results obtained in quarry reclamation in Yucatan (Table 2). We identify legal, economic, and ecological limitations. Quarry exploitation regulation in the Yucatan is relatively recent, unclear, and inefficient. This allows for negligence on the side of companies. Fifteen years ago, no law existed compelling companies to carry out regeneration projects. Currently, the Environmental Protection Law of Yucatan (1999) states that “in order to exploit and extract minerals not reserved to the Federation, an Environmental Impact Statement is required”. This statement should contain a description of possible environmental consequences due to the activity. Also, it should express measures to prevent and mitigate exploitation, considering protection and restoration of soil, flora, and fauna.

Although the law requires a reclamation program in these areas, upon ceasing exploitation, it is common for quarries to be totally abandoned. Often, required exploitation permits are not sought, and clandestine mining is realized. Because of this, the current SECOL administration demands that research groups provide a current list of those quarry areas already exploited and under exploitation, as well as management recommendations (G. Valladares 2004, SECOL, Yucatán, personal communication).

Table 2. Factors to consider upon realizing quarry regeneration projects in Merida, Yucatan, Mexico.

	Limitations	Possibilities
Legal	<ul style="list-style-type: none"> • Unclear laws • Lack of follow-up on mitigation activities • Lack of current information on regeneration activities 	<ul style="list-style-type: none"> • Actualize laws and enforce them • Training of personnel in charge of follow-up • Renovating information on active and passive quarries
Economic	<ul style="list-style-type: none"> • High investment costs • Few profits • Negligence 	<ul style="list-style-type: none"> • Determine who should pay • Establish productive conservation systems • Motivate investment
Ecological	<ul style="list-style-type: none"> • Scarce, infertile soil • Long term recuperation • Lack of studies recommending management practices 	<ul style="list-style-type: none"> • Site conditioning • Studies identifying native species which activate and facilitate ecological succession • Support for research projects • Publicizing information generated

SECOL identifies several difficulties with applying state environmental regulations in controlling quarry exploitation (G. Valladares 2004, SECOL, Yucatán, personal communication). First, few economic resources are available for vigilance. Secondly, legal administrative procedures favor the offender. Thirdly, when a business owner is negligent, environmental costs of investment are rarely internalized. Finally, the change in governmental administrations every six years does not facilitate program continuity, as it takes time to train new personnel.

An important economic limitation is the high investment cost of regeneration. Business owners try to satisfy their own interests and refuse to invest in activities which do not generate income. This currently leads to financial responsibility falling on taxpayers (Hobbs and Norton 1996; Holl and Howarth 2000). For this reason, it is important to establish productive systems such as AFS, through which economic and ecological benefits may be obtained.

One of the main ecological limitations is that little soil remains after exploitation. Other limitations include the closeness of the aquifer, the risk of flooding, and the difficulty in finding local species adapted to these conditions which may also generate income. Scientific research is necessary in order to identify useful and adequate species and intercropping schemes, optimal planting densities, and sound productive management practices.

Possibilities

Quarry regeneration in the Yucatan has possibilities of success if some of the aforementioned problems can be solved. It is necessary to identify who should pay for regeneration of exploited quarries. Is it the

government, which is financed by citizens' tax money? Is it the business, which benefits from the resource exploitation? Or is it the consumer, who demands the product to satisfy certain needs?

In the legal aspect, it is important to consider, as part of authorizing documents, those obligations and specific regeneration tasks for which the business would be responsible. This would help the authority to verify compliance on the site.

Quarry restoration only for conservation purposes implies high investment costs, and few are willing to assume them. Rather, successful restoration requires carrying out regeneration practices using viable productive systems, like agroforestry systems which mimic to a certain extent those natural communities which have been displaced. This approach results to be more attractive for business owners.

It is necessary to identify species mixtures which could be established under extreme site degradation conditions. These should generate clear benefits, and short term investment recovery. The challenge is, and has been, to improve project management and to select appropriate and compatible plant species in order to increase the benefit/cost ratio.

Finally, it is important to establish robust alliances among universities, research centers, companies and social organizations, through which long term research projects can be developed. It is also necessary to publicize these studies and their recommendations. Only then will it be possible to make progress in regenerating exploited quarry areas and recover a small part of the harmony in which the ancient Mayas lived with their environment.

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