

REVIEW – POST-MINED LAND REHABILITATION IN INDIA: CATALOGUING PLANTS SPECIES USED IN LAND REVEGETATION

A. Datar, P. Audet, and D. Mulligan

Centre for Mined Land Rehabilitation, Sustainable Minerals Institute
The University of Queensland, St. Lucia Campus, Brisbane, 4072 QLD, Australia

ABSTRACT

A comprehensive search of primary (journal) literature pertaining to post-mined land rehabilitation in India identified 57 studies from 1995 to 2011. From this collection, hierarchical classification criteria were used to systematically group like-studies from which 37 of those papers provided sufficient data to enable a robust qualitative assessment of the species used for revegetation in the post-mine environment. Using this information of plant species studied in the context of land rehabilitation, the putative environmental outcomes and impacts of these revegetation activities were analysed. Four species (Karanj, *Pongamia* sp.; Shisham, *Dalbergia* sp.; Shirish, *Albizia* sp.; and, Neem, *Azadirachta* sp.) emerged as having the highest frequency of reporting in the context of having an array of shared and relevant agro- and socio-economically relevant properties as well as being referenced with respect to environmental outcomes. Taking into consideration the notion that land rehabilitation success should be an amalgamation of numerous ecological factors, it is considered that these characteristics could be indicative of these four tree species being of the potentially greatest value to rehabilitating agro-ecosystem function within the context of Indian post-mined landscapes.

1.0 INTRODUCTION

India's mining sector represents an important contributor to the country's economic growth and technological development. In this regard, the country currently ranks 4th among leaders in the production of coal and lignite (6.8% of world production – US Dept Energy 2011; Ministry of Coal, National Gov't India 2011) as well as contributing significantly in the production of other mined commodities such as mineral fuels, metallic minerals, industrial materials, and metal alloys (see: Khullar 2006; Kuo 2005). Altogether, the combined value of these mined commodities is estimated to provide nearly 3% of India's annual gross domestic product (National Mineral Scenario, Ministry of Mines, Gov't India 2008a). Still, representing a similar scenario to that of other world producers within the mining sector (Hodge 1995), it can be argued that India's industrial growth is coupled with a significant environmental burden whereby ecosystem health and sustainability are detrimentally affected due to the inherently invasive characteristics and often pervasive impacts of mining toward both natural-undisturbed and managed agro-ecological landscapes. Accordingly, the Geological Survey of India (2007-08) has estimated an affected area of 1,394 sq km large-scale mapping, while approximately 2,760 million tonnes *per annum* of coal resources were extracted from various coalfield regions, namely within Andhra Pradesh, Madhya Pradesh and Orissa (Ministry of Mines, Gov't India 2008b). Upon closer examination of available Indian National and State policies on the development of mined resources (Ministry of Mines, National Gov't India, 2008a; Directorate of Geology & Mining, Gov't Tamil Nadu, India, 2010), a few notable amendments have been made emphasizing basic standards for environmentally sound exploration practices which incorporate assessments of risk and management criteria for potential land contamination and post-mining land-usages (data not shown). Based on these criteria and other analogous notions by Chattopadhyay (2006), such 'best environmental' considerations should involve multi-disciplinary approaches incorporating phytoremediation technologies, landscape development (e.g., ecohydrological management)

and revegetation schemes, and prevalent aftercare surveillance programs to assess the status and resilience of ecosystem function at various stages of post-mined land rehabilitation. This illustration seems to provide a well-defined and unambiguous perspective as to the assessment and potential implementation of post-industrial land rehabilitation in India; however, when compared to more well defined guidelines such as within the Australian context for post-mined land rehabilitation (Dept. Mines and Energy, Queensland Gov't, Australia, 1995), the reality of the Indian context imposes unique challenges due to the widespread distribution of mining activities across varied microclimates and the constraints of site-specific revegetation strategies based on local land-use requirements (e.g., ethnobotanical and/or agro-ecological usages). If circumstances prevailed wherein Indian National and State policies saw benefit from an appropriate revision or supplementation in relation to the latest peer-reviewed literature (among other sources), there is a unique opportunity to identify important aspects of rehabilitation based on current research.

1.1 Study Objectives

In light of the few available reviews in the field of Indian restoration ecology (Ghose 2004; Ghose and Kumar 2004; Pandey et al. 2009; Prasad 2007; Singh and Shukla 2008), a number of knowledge gaps have been identified regarding the broad-scale depiction of post-mined land rehabilitation in India. Among others, a few lingering research questions deserving of further consideration include:

Which plant species have been studied for the purpose of land revegetation? Which of these are considered most suitable for determining revegetation success and what characteristics make them more appropriate than others for this purpose? How are environmental and (or) physiological factors used to determine revegetation success? What is the significance of these factors toward ecosystem restoration?

With the purpose of addressing some of these apparent knowledge gaps and then building upon current notions of post-mined land rehabilitation within the Indian context, a comprehensive review of literature pertaining to post-mined land rehabilitation in India has been undertaken. From this review, an extensive list of plant species studied in the context of land rehabilitation has been compiled and analysed from the perspective of how revegetation activities have had an impact and contributed (or not) to an environmental outcome. This data compilation also used species reporting frequency to assess the species deemed most adapted (i.e., based on biological and socioeconomic suitability) to assess the species deemed most adapted (i.e., based on biological and socio-economic suitability) for the apparent challenges, rigors and requirements of the Indian post-mined landscape. Hence, it is considered that the species list presented here provides a relevant data supplement for existing rehabilitation guidelines as well as a functional database that is based on research, for potential implementation in future land revegetation projects.

2.0 REVIEW METHODOLOGY AND DATA DESCRIPTION

After a thorough review of scientific literature, a comprehensive selection of 57 studies (dating from 1995 to 2011) was compiled from available primary literature sources, each for having dealt with mining industry activities in India, and collectively focussing on a wide array of associated post-industrial land rehabilitation options. The repartition of mining activities investigated in the literature pool includes coal (35%), general and (or) generic mining (22%), limestone (8%), gypsum (7%), bauxite (7%), and a combination of seven other less prominently represented mineral resources (21%). From this literature pool, a hierarchical classification criteria was developed (Table 2) in order to systematically group like-studies according to their respective study types (e.g., literature reviews and syntheses, comparative experimental analyses, or case-study/field surveys), stated topics and specific objectives

(e.g., policy and management, species conservation, landscape/soil management, or vegetation responsiveness and productivity), and intended scope of impact (e.g., local, regional, national, or global). Of the 57 studies, 37 were deemed to provide a substantial data-pool for a robust qualitative assessment of species used for revegetation. For this reason, the data analysis focussed especially on these 37 studies and ecological relationships reported therein to avoid any inadvertent conjecture regarding the broader literature pool; still, it is acknowledged that a more in depth assessment of others topics identified from the literature review, yet not covered here, would be useful once sufficient meta-data are made available. Henceforth, a descriptive database of each reported plant species was generated including an identification of their respective taxonomy and growth forms, their context for study, and reported outcomes. In total, 245 different taxons consisting of 38 separate Orders and 69 Families (Table 3) having 12 distinct growth forms ranging from trees (42%), shrubs (5%), annual (2%) and perennial herbs (5%), herbaceous flowering plants (32%), succulents (0.5%), mosses (0.5%), grasses (9%) and sedges (2%), and vines (2%). With this database (not shown), the frequency of species reporting was determined as well as the diversity of bioindicators (e.g., plant physiological and productivity descriptors, soil nutrient composition, soil microbial diversity, plant species abundance and distribution, etc.) used to assess ecological responses in relation to revegetation.

Table 1. Hierarchical classification of the literature survey

Publication Type	Stated Study Objectives & Topics		References
	Primary	Secondary	
Lit. Reviews & Syntheses	Environmental Issues	Global Considerations	Hodges (1995)
		Regional Considerations	Ghose and Kumar (2004) Chattopadhyay (2006) Singh and Shukla (2008) Singh (2009)
	Revegetation Strategies	Site Assessment Criteria	Singh et al. (2002) Sheoran and Sheoran (2009)
		Soil Management	Khurana and Singh (2001) Ghose (2004)
	Soil Management	Site Assessment Criteria	Nikhil (2007) Ram and Masto (2010)
		Hydro Geology	Soni (1995) Pandey et al. (2005)
		Phytoremediation	Prasad (2007) Pandey et al. (2009)
Comparative Exp't Studies	Soil Management	Plant Physiology & Productivity	Rao and Tarafdar (1998) Sharma et al. (1998) Rao and Tak (2001) Ghose (2001) Rao and Tak (2002) Ganihar (2003) Singh et al. (2004) Singh and Singh (2006) Kshirsagar and Aery (2007) Khosla and Reddy (2008) Misra et al. (2009)

Table 1 (cont'd)

Publication Type	Stated Study Objectives & Topics		References
	Primary	Secondary	
Case Studies, Field Studies, & Site Surveys	Resource Management Policy Assessment	Local Level Sustainability	Sinha et al. (2007)
	Land-Use	Landscape Management	Roy (1997) Chauhan (2010)
	Revegetation Species Diversity	Plant Physiology & Productivity	Mohanty (1997) De and Mitra (2002) Hazariak et al. (2006) Hanief et al. (2007) Dowarah et al. (2009) Raizada and Juyal (2010)
		Landscape Management	Tarafdar and Rao (1997) Singh and Singh (1999) Singh et al. (1999) Chalya et al. (2000) Sharma et al. (2000) Raghu (2001) Dutta and Agrawal (2003) Sharma et al. (2004) Singh et al. (2006) Tripathi and Singh (2008) Juwarkar et al. (2009) Chauhan and Silori (2010) Chauhan and Ganguly (2011) Deo et al. (2011)
	Soil Development & Conservation	Plant Physiology & Productivity	Raman et al. (1993) Kundu and Ghose (1997) Mehrotra (1998) Dutta and Agrawal (2001) Sharma et al. (2001) Dutta and Agrawal (2002) Maiti (2007) Juwarkar and Jambhulkar (2008) Juwarkar et al. (2009) Singh and Soni (2010)

3.0 GENERAL TRENDS AND DISCUSSION

3.1 Identification of suitable revegetation species based on reporting frequency

In spite of the relatively modest peer-review literature pool available on the topic of post-mined land revegetation in India, there is still a remarkably extensive reporting of plant species ($n=245$ sp.) including vegetative growth forms and diverse bioindicators of ecological form and function. By consolidating these literature sources into a single dataset, the present study represents the first comprehensive list of plants (having a wide variety of growth forms and life history strategies) within the context of post-mined land rehabilitation in India. Although the list alone is not currently a sufficient indicator of rehabilitation development or success, its compilation has direct implications in terms of its use as a supplement for current land rehabilitation planning and implementation guidelines by providing a benchmark referencing source for future research. Likewise, the analysis of potential data-trends therein could provide further insight into the suitability of these species for the purpose of land rehabilitation based on the similarity and (or) frequency of environmental reporting (Fig.1). Here, approximately 45% of species were reported only once, while 65% of species were reported fewer than four times out of 37 studies resulting in a reporting frequency of less than 10% of the total literature pool. That being said, the remaining dataset (90%) indicates an occasional reporting frequency (15-25%) of 17 trees,

shrubs, and herbaceous plants, and an extensive reporting (30-50%) of four notable tree species. In other words, the current literature pool is dominated by the reporting of 21 plant species across a wide array of climatic, geologic, and ecological landscapes and environmental variability. Therefore, under the assumption that the reporting frequency is indicative of ecological relevance, such differences within the literature pool could suggest that:

- (1) A subset of species (i.e., occasionally and especially extensively reported) seems to be more suitable for land rehabilitation than others;
- (2) Their respective life history strategies (i.e., trees and shrubs versus other vegetative growth forms) could be more conducive to the colonization of Indian post-mined landscapes in relation to its inherent environmental challenges; and,
- (3) This subset of species could represent significant keystone indicators (i.e., predictors) of success within the current land rehabilitation framework taking into consideration the available pool of associated physiological and ecological data.

With this rationale, four species (Karanj, *Pongamia* sp.; Shisham, *Dalbergia* sp.; Shirish, *Albizia* sp.; and, Neem, *Azadirachta* sp.) have emerged as having the highest frequency of reporting in addition to an array of shared and relevant agro- and socioeconomically relevant properties along with notably similar environmental outcomes regarding their impact toward above- and belowground ecological factors (Table 3). These characteristics include that three (members of the Fabaceae) are promoters of nitrogen fixing interactions, while all four are relatively fast growers, well adapted to environmental conditions within more arid zones (i.e., intense heat, sunlight), and have root architectural adaptations for drought tolerance (Koul et al. 1990; Lowry et al. 1994; Scott et al. 2008; Tewari 1994). Furthermore, all four species similarly hold significant socioeconomic development applications toward landscape agro-ecology (i.e., shade intercropping, timber, fuel, and forage) and regional ethnobotanies (i.e., having pharmacopeia-ic relevance as antibiotics, pesticides, etc.). Correspondingly, when assessing the experimental context of their study (see Table 3: Reported outcomes of revegetation), all four species have often been found to increase soil microbial activity resulting in soil nutrient mineralization, increase belowground biodiversity due to rhizospheric interactions, increase nutrient cycling, and stabilization of the soil matrix. Altogether, these reported environmental outcomes have led to increased plant productivity and even species survivorship. Taking into consideration the notion that land rehabilitation success should be an amalgamation of numerous ecological factors, we consider (albeit tentatively, given the qualitative nature of the current data analyses) that these characteristics could be indicative of these four tree species being potentially significant keystone indicators of rehabilitating agro-ecosystem function within the context of Indian post-mined landscapes. More importantly, these plants already hold a significant socioeconomic status in Indian culture in terms of their inherent land-use values (e.g., shade intercropping, timber, fuel and forage, and pharmacopeia-ic relevance) thereby seemingly bridging the conceptual divide existing between the target environmental goals and socioeconomic goals; the latter of which are typically not always adequately or appropriately covered in land rehabilitation design or

intent. However, it is recognised that this perspective somewhat exceeds the analytical scope of the current dataset and that a more thorough investigation would be required to elaborate on the potential significance of these relationships.

Table 2. Abbreviated list of plant species studied in land revegetation

Order	Family	No. Diff. Genus	Order	Family	No. Diff. Genus
Alismatales	Araceae	1	Magnoliales	Annonaceae	1
Arecales	Arecaceae	1		Magnoliaceae	1
Arecales	Arecaceae	1	Malpighiales	Euphorbiaceae	6
Asparagales	Agavaceae	1		Phyllanthaceae	5
Asparagales	Ruscaceae	1		Salicaceae	2
Asparagales	Hypoxidaceae	1		Violaceae	1
Asterales	Asteraceae	11	Malvales	Dipterocarpaceae	2
Brassicales	Brassicaceae	1		Malvaceae	5
	Capparaceae	1	Myrtales	Combretaceae	4
	Salvadoraceae	2		Lythraceae	4
Caryophyllales	Amaranthaceae	3		Melastomataceae	1
Caryophyllales	Polygonaceae	1		Myrtaceae	9
	Tamaricaceae	1	Oxalidales	Oxalidaceae	1
Celastrales	Celastraceae	1	Pinales	Pinaceae	1
Commelinales	Commelinaceae	3	Poales	Cyperaceae	4
Cornales/Ericales	Boraginaceae	2		Poaceae	23
Cucurbitales	Cucurbitaceae	3	Polypodales	Pteridaceae	1
Ericales	Ebenaceae	1	Proteales	Proteaceae	1
	Myrsinaceae	1	Ranunculales	Berberidaceae	1
	Sapotaceae	2	Rosales	Cannabaceae	1
	Theaceae	1		Moraceae	5
Fabales	Fabaceae	64		Rhamnaceae	3
	Casuarinaceae	2		Rosaceae	2
Gentianales	Apocynaceae	3		Urticaceae	3
	Rubiaceae	6	Sapindales	Anacardiaceae	4
Gleicheniales	Gleicheniaceae	1		Meliaceae	5
Lamiales	Acantaceae	3		Rutaceae	2
	Bignoniaceae	1		Sapindaceae	2
	Lamiaceae	9		Simaroubaceae	1
	Acantaceae	1	Schizaeales	Lygodiaceae	1
	Scrophylariaceae	1	Solanales	Convolvulaceae	2
	Verbenaceae	1		Solanaceae	4
Laurales	Lauraceae	1	Urticales	Ulmaceae	1
Lycopodiales	Lycopodiaceae	1	Zingiberales	Musaceae	1
			Zygophyllales	Zygophyllaceae	1

N.B. The complete taxonomic list of plant species can be made available upon request

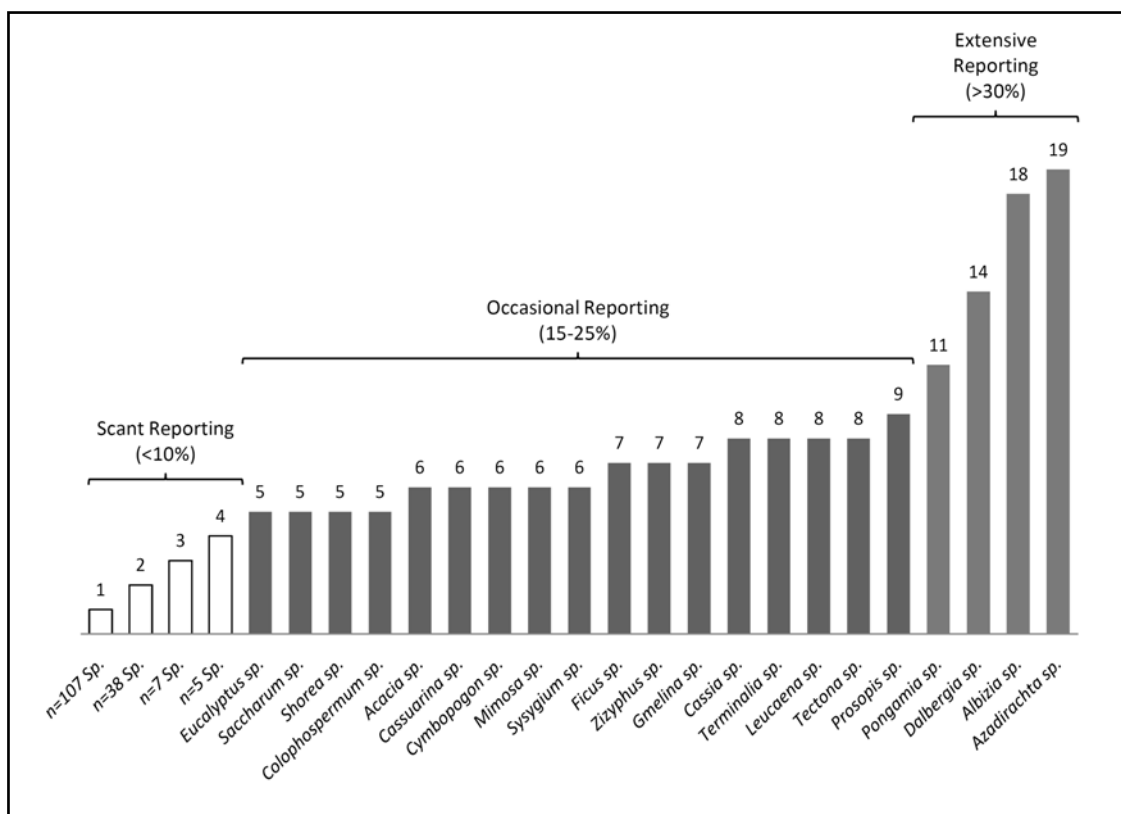


Figure 1. Taxon reporting frequency (n=245 reported sp.; N=37 studies).

Table 3. Highest reported species and their shared agro-ecological properties

Family	Genus	Common Names	Agro-Ecologically Relevant Properties*	Reported Revegetation Outcomes† [References]
Meliaceae	<i>Azadirachta</i>	"Neem" "Sacred Tree"	<ul style="list-style-type: none"> (Relatively) Fast Growth; Well-adapted to arid zones, adaptation to intense heat and sunlight; 	Increased soil microbial activity resulting in nutrient mineralization [Rao and Tak (2001); Sharma et al. (2001); Rao and Tak (2002); Singh et al. (2004); Maiti (2007); Juwarkar et al. (2008); Tripathi and Singh (2008); Juwarkar et al. (2010)]
Fabaceae	<i>Dalbergia</i>	"Indian Rosewood" "Shisham"	<ul style="list-style-type: none"> Root architectural adaptations for drought tolerance; Economic development applications (timber cropping, landscaping); 	Increased belowground biodiversity and (or) symbiotic mutualisms (e.g., mycorrhizal and bacterial associations) [Raman et al. (1993); Mehrotra (1998); Rao and Tak (2001)]
	<i>Albizia</i>	"Lebeck Tree" "Shirish"	<ul style="list-style-type: none"> Ethnobotanical usages (e.g., anthelmintic, antifungal, antidiabetic, antibacterial, antiviral, contraceptive and sedative). 	Increased productivity and (or) site survivorship [Sharma et al. (1998); Chaulya et al. (2000); De and Mitra (2002); Singh and Singh (2006); Hanief et al. (2007); Juwarkar et al. (2008); Chauhan and Silori (2010)]
	<i>Pongamia</i>	"Indian Beech" "Karanj"	<ul style="list-style-type: none"> Promoter of nitrogen fixing interactions‡; 	Increased nutrient deposition and soil carbon stock due to litter fall and (or) rhizospheric mineralization [Singh et al. (1999); Singh et al. (2004); Singh et al. (2006); Juwarkar et al. (2010); De and Mitra (2002)] Increased soil moisture retention and soil matrix stabilization [Sharma et al. (2001); Sharma et al. (2004); Maiti (2007); Juwarkar et al. (2010)]

*Based on: Koul et al. (1990); Scott et al. (2008); Tewari (1994); Lowry et al. (1994)

†In combination with other re-established species; ‡Characteristic of the Fabaceae only.

3.2 Potential implications for future policy development

Being mindful of the limitations of using literature review strategies for guiding land rehabilitation policy, it is considered that the comprehensive list of vegetation provided here and subsequent identification of potential bioindicators of agro- and socio-economic development within the Indian context should provide useful data supplements toward the implementation of current rehabilitation guidelines. In fact, given the sometimes provisional status of land rehabilitation at the National and State policy levels among growing economies, assessments of the most current primary literature sources should represent a step-forward for identifying suitable research benchmarks by consolidating entire reference sources within a single, comparative framework. As such, the hierarchical review methodologies described above could represent substantial tools for evaluating similar data-pools to derive relevant opportunities for discovery and identify potential ecological challenges based on current research.

4.0 REFERENCES

- Chattopadhyay S (2006) Sustainable regeneration of derelict mine sites. *Journal of the Institute of Town Planners - India* **3**, 42-48.
- Chauhan SS (2010) Mining, development and environmental: a case study of Bijolia mining area in Rajasthan, India. *Journal of Human Ecology* **31**, 65-72.
- Chauhan SS and Ganguly A (2011) Standardizing rehabilitation protocol using vegetation cover for bauxite waste (red mud) in eastern India. *Ecological Engineering* **37**, 504-510.
- Chauhan SS and Silori CS (2010) Rehabilitation of red mud bauxite wasteland in India (Belgaum, Karnataka). *Ecological Restoration* **28**, 12-14.
- Chaulya SK, Singh RS, Chakraborty MK and Tewary BK (2000) Bioreclamation of coal mine overburden dumps in India. *Land Contamination and Reclamation* **8**, 189-199.
- De S and Mitra AK (2002) Reclamation of mining-generated wastelands at Alkusha-Gopalpur abandoned open cast project, Raniganj Coalfield, eastern India. *Environmental Geology* **43**, 39-47.
- Deo B, Nahak G and Sahu RK (2011) Studies on the uptake of heavy metals by selected plant species growing on coal mine spoils in sub-tropical regions of India. *Journal of American Science* **7**, 26-34.
- Department of Mines and Energy (1995) Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland. State Government of Queensland, Australia.
- Directorate of Geology & Mining (2010) State Mineral Policy of Tamil Nadu, India. State Government of Tamil Nadu, India.
- Dowarah J, Deka Boruah HP, Gogoi J, Pathak N, Saikia N and Handique AK (2009) Eco-restoration of a high sulphur coal mine overburden dumping site in northeast India: a case study. *Journal of Earth System Science* **118**, 597-608.
- Dutta RK and Agrawal M (2001) Litter fall, litter decomposition and nutrient release in five exotic plant species planted on coal mine spoils. *Pedobiologia* **45**, 298-312.

Dutta RK and Agrawal M (2002) Effect of tree plantations on the soil characteristics and microbial activity of coal mine spoil land. *Tropical Ecology* **43**, 315-324.

Dutta RK and Agrawal M (2003) Restoration of open cast coal mine spoil by planting exotic tree species: a case study in dry tropical region. *Ecological Engineering* **21**, 143-151.

Ganihar SR (2003) Nutrient mineralization and leaf litter preference by the earth worm *Pontoscolex corethrurus* on iron ore mine wastes. *Restoration Ecology* **11**, 475-482.

Ghose MK (2001) Management of topsoil for geo-environmental reclamation of coal mining areas. *Environmental Geology* **40**, 1405-1410.

Ghose MK (2004) Restoration and revegetation strategies for degraded mine land for sustainable mine closure. *Land Contamination and Reclamation* **12**, 363-378.

Ghose MK and Kumar A (2004) Mineral industries and their environmental aspects in Indian context. *Indian Journal of Engineering and Materials Sciences* **11**, 433-437.

Hanief SM, Thakur SD and Gupta B (2007) Vegetal profile of natural plant succession and artificially revegetated limestone mines of Himachal Pradesh, India. *Journal of Tropical Forestry* **23**, 128-135.

Hazarika P, Talukdar NC and Singh YP (2006) Natural colonization of plant species on coal mine spoils at Tikak Colliery, Assam. *Tropical Ecology* **47**, 37-46.

Hodges CA (1995) Mineral resources, environmental issues, and land use. *Science* **268**, 1305-1311.

Juwarkar AA and Jambhulkar HP (2008) Phytoremediation of coal mine spoil dump through integrated biotechnological approach. *Bioresource Technology* **99**, 4732-4741.

Juwarkar AA, Mehrotraa KL, Nair R, Wanjari T, Singh SK and Chakrabarti T (2010) Carbon sequestration in reclaimed manganese mine land at Gumgaon, India. *Environmental Monitoring and Assessment* **160**, 457-464.

Juwarkar AA, Yadav SK, Thawale PR, Kumar P, Singh SK and Chakrabarti (2009) Developmental strategies for sustainable ecosystem on mine spoil dumps: a case study. *Environmental Monitoring and Assessment* **157**, 471-481.

Khosla B and Reddy MS (2008) Response of ectomycorrhizal fungi on the growth and mineral nutrition of Eucalyptus seedlings in bauxite mined soil. *American-Eurasian Journal of Agriculture and Environmental Science* **3**, 123-126.

Khullar DR (2006) (Ed) Mineral Resources. In 'India: A Comprehensive Geography' (Ed Khullar DR) pp. 630–659. (Kalyani Publishers: New Delhi, India).

Khurana E and Singh JS (2001) Ecology of seed and seedling growth for conservation and restoration of tropical dry forest: a review. *Environmental Conservation* **28**, 39-52.

Koul O, Isman MB, and Ketkar CM (1990) Properties and uses of neem, *Azadirachta indica*. *Canadian Journal of Botany* **68**, 1-11.

Kshirsagar S and Aery NC (2007) Phytostabilization of mine waste: Growth and physiological responses of *Vigna unguiculata* (L.) Walp. *Journal of Environmental Biology* **28**, 651-654.

Kundu NK, Ghose MK (1997) Shelf life of stock-piled topsoil of an opencast coal mine. *Environmental Conservation* **24**, 24-30.

Kuo C (2005) The Mineral Industry of India. In '2005 Minerals Yearbook'. United States Geological Survey.

Lowry JB, Prinsen H, and Burrows DM (1994) *Albizia lebbeck*: a promising forage tree for semiarid regions. In 'Forage Tree Legumes in Tropical Agriculture'. (Ed Gutteridge RC and Shelton HM) pp 75-83. (CAB International: Wallingford, Oxon, UK).

Maiti SK (2007) Bioreclamation of coalmine overburden dumps with special emphasis on micronutrients and heavy metals accumulation in tree species. *Environmental Monitoring and Assessment* **125**, 111-122.

Mehrotra VS (1998) Arbuscular mycorrhizal association of plants colonizing coal mine spoil in India. *Journal of Agricultural Science* **130**, 125-133.

Ministry of Coal, National Government of India. Estimates of coal production [Online]. <http://www.coal.nic.in/>

Ministry of Mines, National Government of India 2011. National mineral scenario [Online]. <http://mines.nic.in/>

Ministry of Mines (2008a) National Mineral Policy of India. National Government of India.

Ministry of Mines (2008b) Indian minerals industry and national economy. In 'National Minerals Yearbook'. Indian Bureau of Mines, Ministry of Mines, National Government of India..

Misra V, Tiwari A, Shukla B and Seth CS (2009) Effects of soil amendments on the bioavailability of heavy metals from zinc mine tailing. *Environmental Monitoring and Assessment* **155**, 467-475.

Mohanty R (1997) the study of the restoration process in Panchapatmali mines, India. *Engineering Geology and the Environment* **3**, 2471-2475.

Nikhil K (2007) Soil quality standards (SQS) for bio-reclamation of coal overburden dumps: ISO-14000 requirements. *Journal of Industrial Pollution Control* **23**, 19-23.

Pandey DN, Chaubey AC, Gupta AK and Vardhan H (2005) Mine spoil restoration: a strategy combining rainwater harvesting and adaptation to random recurrence of droughts in Rajasthan. *International Forestry Review* **7**, 241-249.

Pandey, VC, Abhilash PC and Singh N (2009) The Indian perspective of utilizing fly ash in phytoremediation, phytomanagement and biomass production. *Journal of Environmental Management* **90**, 2943-2958.

Prasad MNV (2007) Phytoremediation in India. In 'Phytoremediation: Methods and Reviews'. (Ed N Willey) pp.435-454 (Springer: Berlin).

Raghu V (2001) Accumulation of elements in plants and soils in and around Mangampeta and Vemula barite mining areas, Cuddapah District, Andhra Pradesh, India. *Environmental Geology* **40**, 1265-1277.

Raizada A and Juyal GP (2010) Tree species diversity, species regeneration and biological productivity of seeded *Acacia catechu* Willd. in rehabilitated limestone mines in the north west Indian Himalayas. *Land Degradation and Development*, doi:10.1002/ldr.1067

Ram LA and Masto RE (2010) An appraisal of the potential use of fly ash for reclaiming coal mine spoil. *Journal of Environmental Management* **91**, 603-617.

Raman N, Nagarajan N, Gopinathan S and Sambandan K (1993) Mycorrhizal status of plant species colonizing a magnesite mine spoil in India. *Biology and Fertility of Soils* **16**, 76-78.

Rao AV and Tak R (2001) Influence of mycorrhizal fungi on the growth of different tree species and their nutrient uptake in gypsum mine spoil in India. *Applied Soil Ecology* **17**, 279-284.

Rao AV and Tak R (2002) Growth of different tree species and their nutrient uptake in limestone mine spoil as influenced by arbuscular mycorrhizal (AM)-fungi in Indian arid zone. *Journal of Arid Environments* **51**, 113-119.

Rao AV and Tarafdar JC (1998) Selection of plant species for rehabilitation of gypsum mine spoil in arid zone. *Journal of Arid Environments* **39**, 559-567.

Roy S (1997) On environmental rehabilitation of Lambhidhar limestone Mine, Mussoorie, Uttar Pradesh. *Indian Minerals* **51**, 179-184.

Scott PT, Pregelj L, Chen N, Hadler JS, Djordjevic MA and Gresshoff PM (2008) *Pongamia pinnata*: an untapped resource for the biofuels industry of the future. *Bioenergy Research* **1**, 2-11.

Sharma KD, Kumar P, Gough LP and Sanfilippo JR (2004) Rehabilitation of a lignite mine-disturbed area in the Indian desert. *Land Degradation and Development* **15**, 163-176.

Sharma KD, Kumar S and Gough LP (2000) Rehabilitation of lands mined for limestone in the Indian desert. *Land Degradation and Development* **11**, 563-574.

Sharma KD, Kumar S and Gough LP (2001) Rehabilitation of gypsum-mined lands in the Indian Desert. *Arid Land Research and Management* **15**, 61-76.

Sharma SD, Soni P and Chandra V (1998) Amelioration of the overburden of iron ore mine for tree establishment. *Annals of Forestry* **3**, 239-244.

Sheoran V and Sheoran AS (2009) Reclamation of abandoned mine land. *Journal of Mining and Metallurgy* **45**, 13-32.

Singh AN, Raghubanshi AS and Singh (2004) Comparative performance and restoration potential of two *Albizia* species planted on mine spoil in a dry tropical region, India. *Ecological Engineering* **22**, 123-140.

Singh AN, Raghubanshi AS and Singh JS (2002) Plantations as a tool for mine spoil restoration. *Current Science* **82**, 1436-1441.

Singh AN and Singh JS (1999) Biomass, net primary production and impact of bamboo plantation on soil redevelopment in a dry tropical region. *Forest Ecology and Management* **119**, 195-207.

Singh AN and Singh JS (2006) Experiments on ecological restoration of coal mine spoil using native trees in a dry tropical environment, India: a synthesis. *New Forests* **31**, 25-39.

Singh AN, Zeng DH and Chen FS (2006) Effect of young woody plantations on carbon and nutrient accretion rates in a redeveloping soil on coal mine spoil in a dry tropical environmental, India. *Land Degradation and Development* **17**, 13-21.

Singh G (2009) Environmental issues with best management practices of responsible mining. In '20th National Convention of Mining Engineers' pp. 1-15. Neyveli, India. 30 January - 1 February 2009.

Singh G and Shukla AK (2008) Environmental issues with best practice examples of responsible mining in India. In '21st World Mining Congress and Expo' pp. 255-265. Krakow, Poland. 7-12 September 2008.

Singh KP, Singh PK and Tripathi SK (1999) Litterfall, litter decomposition and nutrient release patterns in four native tree species raised on coal mine spoil at Singrauli, India. *Biology and Fertility of Soils* **29**, 371-378.

Singh L and Soni P (2010) Binding capacity and root penetration of seven species selected for revegetation of uranium tailings at Jaduga in Jharkhand, India. *Current Science* **99**, 507-513.

Sinha S, Bhattacharya RN and Banerjee R (2007) Surface iron ore mining in eastern India and local level sustainability. *Resources Policy* **32**, 57-68.

Soni P (1995) Biorestitution of surface mined lands. *Van Vigyan* **33**, 40-52.

Tarafdar JC and Rao AV (1997) Mycorrhizal colonization and nutrient concentration of naturally grown plants on gypsum mine spoils in India. *Agriculture, Ecosystems and Environment* **61**, 13-18.

Tewari DN (1994) (Ed) 'A monograph on *Dalbergia sissoo* Roxb.' (Ed Tewari DN) (International Book Distributors: Dehradun, India).

Tripathi N and Singh RS (2008) Ecological restoration of mined-out areas of dry tropical environment, India. *Environmental Monitoring and Assessment* **146**, 325-337.

United States Department of Energy (2011) Estimates of coal reserves [Online]. <http://www.eia.gov/cneaf/coal/reserves/reserves.html>