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Restoration of Areas Mined for Iron-Ore

Forestry & Biodiversity Area

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What of thee I dig out

Let that quickly grow over

Let me not hit thy vitals

Or thy heart

Atharva Veda 1000 BC

Mining and land degradation

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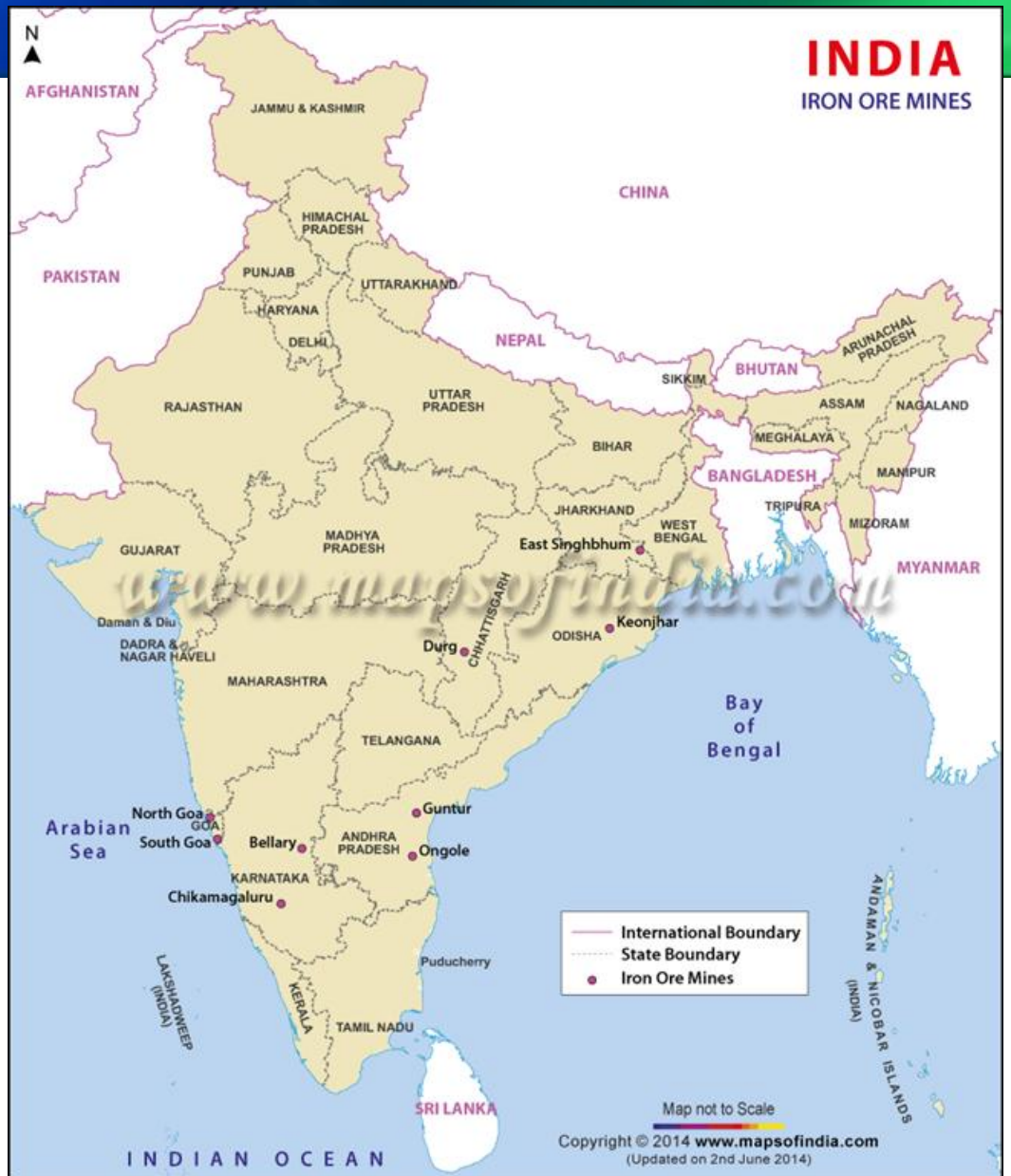
- Mining contributes to land degradation accounting for an area of 0.26mha in the country or 0.08% of the geographical area (ICAR, 2010)
- Land degradation if land restoration practices not taken
- E.g. in Goa, Iron ore dump material flows into fertile agricultural lands, streams/nallahs & working mine pits (Alvares, 2002).
- For each tonne of iron-2-3 tonnes of reject
- 30 million tonnes of rejects generated annually (ore to oreburden ratio ranges from 1 : 2.5 to 3 tonnes)

Location of Iron-ore Mines



Some statistics…

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- Production (2014-15)- 128909 th. Tonnes
- Export- 7491 th. Tonnes
- Import- 12093 th. Tonnes
- The production of iron ore increased from 5 million tonnes in 1953 to 152 million tonnes in 2013-14.
- Mining lease granted /executed- as of 2014- 664
- Total area (2014)- 86000 hectare
- Hematite & magnetite: Most important iron ores in India.

-59% of higher grade hematite ore deposits, found in the Eastern Sector.

-92% of magnetite ore deposits in the Southern Sector (Karnataka)

- Sources: http://ibm.nic.in/writereaddata/files/03282016115329IMIG%202013-14.pdf
- https://www.emis.com/sites/default/files/EMIS%20Insight%20-%20India%20Mining%20Sector%20Report.pdf
- http://ibm.nic.in/writereaddata/files/03282016115329IMIG%202013-14.pdf

Afforestation in mined areas

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Total Mines covered	Area covered	Trees Planted	Trees survived	Survival %
105	67 hectare	306613	202913	66.2

http://www.ibm.nic.in/writereaddata/files/03282016115329IMIG%202013-14.pdf

Restoration of iron-ore mined areas- the challenge…

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- Mine rejects- disturbed ecosystems
- Poor physically, chemically, biologically and nutritionally
- Hence poor media for plant growth.
- Acidity, poor water holding capacity major impediments to revegetating the mine dumps.
- Soil amendments, mulching and topsoil replacement result in favourable conditions for plant growth.
- Selection of plant species with suitable ecological traits to speed up regeneration

A case study from Goa

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- Development of a method for the rehabilitation of abandoned mine dumps.
- Identification of suitable amendments, plant species for initiating the process of ecological succession.
- M/s. Dempo Mining Co. old dumpsite at Dhabadaba mining operations, Bicholim Taluka, North Goa-20 ha
- Mine rejects-low grade lumpy ore, aluminous and siliceous powdery ores, screen fines, quartzites, phylites.laterites clays, poor grade iron ore
- Limonitic/magniferous clays and a mixture of above constituents

Quality of dump material

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- 5 ha area of dump as trial plot

S. No.	Test	Results	Protocol
1	pH	6.2	Mechanical
2	Electric conductivity (EC) mS/cm	1.3	Mechanical
3	Water holding capacity (%)	40	Mechanical
4	Organic matter (% by mass)	0.6	IS : 2720 part-22
5	Nitrogen, N (% by mass)	0.01	Jackson (1967)
6	Phosphorus, P (% by mass)	0.11	Gravimetry
7	Potassium, K (% by mass)	0.22	AAS, Varian (1989)
8	Iron, Fe (% by mass)	46.1	AAS, Varian (1989)
9	Aluminum, Al (% by mass)	4.7	AAS, Varian (1989)
10	Manganese, Mn (% by mass)	1.4	AAS, Varian (1989)
11	Exchangeable Hydrogen ions (meq/100 gm)	1.1	Jackson (1967)
12	Bulk density (gm/cc)	1.77	Mechanical

10 samples collected randomly
Acidic, low nutritional content

3 models of rehabilitation trials

Table 1 Models of rehabilitation

Name of area	*Model name*	*Area* (in hectares)
Stone-pitched area	A	2.5
Bench-terraced area	B	1.5
Soil-eroded area or gunny crates area	C	1.0
Total		5.0

Of 20 ha area=2/3rd stone pitched with laterite stones to prevent downward movement of sediment.

1/3rd of area consisting of barren slopes

Table 2 Model-wise pits and soil–water conservation measures

Name of intervention	Model A	Model B	Model C	Total
Site preparation				
Bench terracing (number)	—	5	4	9
Bunding (hectares)	—	0.6	0.4	1
Soil and water conservation				
Pit digging 45 × 45 × 45 m size (number)	2350	1625	1025	5000
Seed pits 2 × 2 × 10 m size (number/hectares)	—	1500/0.6	1000/0.4	2500/1.0
Gully plugging (number)				
Minor size	—	9	50	59
Major size	—	—	8	8
Total	—	9	58	67
Gunny bag toe-wall (number)	—	—	4	4
Gunny bag crates (3 × 6 × 6 m size) (number)	—	—	70	70
Water harvesting or percolation ponds (number)	1	2	—	3

Stone pitched area: Slope 30-40 degree
Bench terraced areas:
Low slopes-15-30 further reduced to 10
Gunny bag crates: Planted with *Agave americana* behind crates to stabilise soil
Gunny bag crates-staggered, alternate, spacing of 12m X 12 m

Table 3 Ratio of amendments applied for dumps/soil treatment

Name of amendment	Size of pits: 0.45 × 0.45 × 0.45 metres	2 × 2 × 0.10 metres	Others (back of gunny bag crates)
Cow dung	6 (kg per pit)	14 (kg per pit)	2 (kg per crate)
Gypsum	8 (kg per pit)	18 (kg per pit)	5 (kg per crate)
Mycorrhiza	20 kg for the entire rehabilitation area in ratio of 1 : 2 : 3 (that is, mycorrhiza + cow dung + water)		

Species used in each model

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- Model A: 2350 plants. Species are *Anacardium occidental* (grafted and seedling), *Garcina indica*, *Phyllanthus emblica*, *Dendrocalamus strictus*, *Alstonia scholaris*, *Acacia auriculiformis*, *Acacia mangium* and *Casurina equisitifolia*
- Model B: 1625 plants. Species are *Anacardium occidental* (grafted), *Garcina indica, Phyllanthus emblica.* Six shrubs also planted. *Panicum maximum*, Pennisetum pedicellatum, *Dodonea viscosa*, Chrysopogon zizanioides*, Stylosanthes guianensis, Panicum antidotale*
- Model C: 1025 plants. Species are *A. occidental* (grafted & seedling), *Dendrocalamus strictus*, *G. indica* and *A. auriculiformis.* In addition, 1000 plants of *Agave* are planted and 4 kg of *P. pedicellatum* are used along the slopes

Changes in the properties of soil

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S. No.	Test	Results before treatment (March 2003)	Results after treatment (1st quarter), Sept 2003
1	pH	6.2	7.5
2	Electric conductivity (EC) mS/cm	1.3	915
3	Water holding capacity (%)	40	30.21
4	Organic matter (% by mass)	0.6	0.6
5	Nitrogen, N (% by mass)	0.01	0.33
6	Phosphorus, P (% by mass)	0.11	0.135
7	Potassium, K (% by mass)	0.22	0.01
8	Iron, Fe (% by mass)	46.1	41.55
9	Aluminum, Al (% by mass)	4.7	3.05
10	Manganese, Mn (% by mass)	1.4	0.1
11	Exchangeable Hydrogen ions (meq/100 gm)	1.1	0.1
12	Bulk density (gm/cc)	1.77	1.48

- **Contents of phosphate and nitrates increased**
- **Percent iron content reduced**
- **Enhancement of nutrients**

Plant growth

- Trees growth enhanced in terraced area and gunny bag crates compared with stone-pitched areas
- Grasses reduce downflow of dump material
- Low mortality rate (10%)

Soil and water conservation

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- Several soil and water conservation measures
- Inward bench terracing-most beneficial in reducing the slope of dumps and arresting siltation and retaining soil moisture
- Contour bunds and rain water harvesting to retain moisture
- Placement of gunny bag crates in a staggered manner along slopes helps in soil stabilisation. Gunny bag crates placed with GI wire in high slope area -40-50^0
- Construction of loose boulder checks using laterite stones along gullies and on upper reaches of gully plugging have further helped control erosion

Cost efficacy of each model

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- Stone pitched area: <Rs 50,000 per ha (excluding stone pitching)
- Inward bench terracing: Rs 115,000/ha
- Gunny bag crates: Rs 130,000 per ha but most effective for steep slopes

Timeline for restoration activities

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- October-December: Soil and water conservation work
- January-February: Advance soil working
- April-May: Good time for mixing and filling pits
- End of May-planting
- September: Hoeing and mulching

Recommendations

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- Inward bench terracing for slopes,35^0; gunny bag crates for more than 35^0. Gully plugging where cracks oc cur along slopes
- Stone pitching recommended where water sources are impacted due to heavy erosion. But expensive-not large scale proposition
- Toe walls help check soil erosion
- Earth working and addition of amendments must be completed by March and then left to weather.
- Gypsum and organic manure improve the physico-chemical condition of the soil
- Use of mycorhizae helps vegetation in stressed conditions
- Silvi-pastoral model of plantation recommended

Caveats for mine restoration…

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- Future public health and safety are not compromised
- Environmental resources are not subject to physical and chemical deterioration
- Post-mining use of the site is beneficial and sustainable in the long term
- Adverse socio-economic impacts are minimised
- Opportunity is taken to maximise socioeconomic benefits

Source: http://www.teriuniversity.ac.in/mct/pdf/new/forestry/MCT%202014%20(1).pdf

Thank you!