Sustainability science for mine-spoil restoration

Generation of mine waste threatens the economic, ecological and social sustainability of our country. This is one of the visible consequences of imperilled nature–society interactions. Various forms of mining – regardless of whether acknowledged or omitted from studies on land use change, ecological degradation and biodiversity loss – have a role in ecological problems in India. Unsustainable mining, in conjunction with other threats to ecosystems, exacerbates the local environmental degradation, livelihood insecurity and global climate change[1].

In an insightful review, Singh and colleagues[2] propose plantations as a tool for mine-spoil restoration. Plantations are useful for enhancing the productivity of degraded landscape under a variety of circumstances; nevertheless, they are inadequate mine-spoil restoration tools in isolation. I would argue that to restore mine overburden, a broader vision that incorporates holistic science and policy is called for. Indeed, we shall have to draw on sustainability science[3,4] to address the imperilled nature–society interactions as well as to construct a self-sustaining functional ecosystem capable of supporting biodiversity, performing ecosystem functioning and providing ecosystem services to society.

Numerous studies note the evidence of climate change and its implication for terrestrial and oceanic ecosystems in India. In addition to amelioration of local environment, a holistic restoration approach can also address the challenges of global climate change by sequestering large amount of atmospheric carbon dioxide and qualify for the carbon credit earning under the Kyoto Protocol[5–7].

I wish to suggest that holistic strategy for restoration of mine-spoil must essentially include the following: (i) Policy measures and incentive mechanism to store fertile top-soil layer for use in post-mining restoration operation, (ii) protection to adjacent refugia, remnant vegetation and ancient trees, (iii) attracting seed dispersers, (iv) rainwater harvesting, (v) assisted soil remediation through addition of pond-bed silt and sediment as well as earthworm, (vi) assistance to available persistent rootstock, if any, (vii) direct seeding, (viii) vegetative cutting, and (ix) plantations, such as proposed by Singh *et al.*[2], as a last option if need be, should be resorted to only in sequential combination with strategies suggested here.

Design and enforcement of mining and restoration policy must accept the role of incentives to retrieve and store topsoil before starting the mining operations. Market mechanisms such as recovering the full cost related to: (i) pre-mining vegetation and soil removal, (ii) protection to adjacent vegetation and trees as seed source, (iii) post-mining restoration of overburden, (iv) treatment to adjacent farmlands and streams affected by mining operations, and, (v) cost of the preventive measures to mine-induced groundwater pollution, are essential measures that will provide robust incentives to mine owners for minimizing the damage to the environment. Without such a policy in place, the problem will persist.

Throughout the mining operations, protection to adjacent vegetation that is likely to serve as seed source in the vicinity is required. Catalysing natural regeneration of native forest species originating from remnant forests and ancient trees in the vicinity is a useful method in combination with direct seeding and increases likelihood of restoration success. Remnant vegetation also supports a variety of fauna that help in seed dispersal in adjacent areas. Such a primary succession in post-mining landscapes has been found to be useful.

Rainwater harvesting[8] is a crucial step for ecological restoration of mine-spoils[9]. For example, rehabilitation success to revegetate mine-spoils in arid regions in India was achieved using a combination of rainwater harvesting, soil amendments and plant establishment methods using trees, shrubs and grasses. Such an approach is also socially useful to enhance productivity and availability of products to people[9].

Addition of organic wastes has been found to increase N fertility at a surface coal mine reclamation site, which ultimately stimulated microbial activity and improved the chemical and physical properties of the reclaimed soil[10]. Silt of the traditional rainwater harvesting systems, called ponds and tanks, is the most effective indigenous soil amendment practice in India. Pond silt is not only mineral-rich, but also a seed bank for a variety of grasses, herbs, shrubs and trees.

Restoration of a variety of wastelands, including mine overburden by direct seeding, planting of large vegetative cuttings, and wherever possible, assistance to persistent root-stock has provided effective results in Rajasthan[1]. Although persistent rootstock recovery will not be a chief strategy as spoil heaps may be too high to overcome, nevertheless, peripheral dump areas have been reclaimed by assistance to root-stock through a combination of rainwater harvesting.

Direct seeding of native species has proved a most useful and cost-effective restoration method[1,11]. Seed mixture for direct seeding must be carefully selected based on physical and chemical properties of mine-spoil as well as ecological, economic and social criteria. An useful approach is to include framework species across taxa, herbs, shrubs and trees, early and late successional species, as well as a select few keystone species to accelerate the restoration of a functional ecosystem. Direct sowing also provides a large base for choice of species. Since it is not necessary to raise the seedling in the nursery, a large number of species can be tried out, compared to planting. Production of seedlings in the forest nursery requires large inputs in terms of time and money. This can be avoided by opting for direct sowing. Direct sowing is also advantageous as it is comparatively easier to maintain the species mix than in a plantation. It can be combined with planting, natural regeneration or both. Direct sowing helps in enhancing biodiversity per unit area. Direct sowing requires a simple technique for rainwater harvesting in combination with minimal soil work. Thus, ecologically sound multi-tier vegetation can be effectively developed[11].

In conclusion, I would reiterate that we would also need to draw on the cultural resources such as local knowledge and skills to help address the challenge of mine-spoil restoration. A broader vision alone can address the productivity enhancement of wastelands such as mine-spoil, and can contribute to overall approach for ecological, economic and social sustainability in India. A holistic science and policy suggested here is a step in that direction.

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Promoting science in India

This is with reference to the three letters by Animesh Chaturvedi, Pushp Deep Pandey and Mohan Karuppayil respectively (*Curr. Sci.*, 2002, **83**, 103–107). These letters are thought-provoking, emphasizing the steps to be taken to improve science education in India. As a first step, it should be made mandatory that only students who have cleared the national level exams like UGC/CSIR, NET, SLET and GATE will be allowed to join the Ph D programme. This filters off those candidates who join Ph D just to engage themselves in some activity. Candidates admitted both at the national institutes and universities should be provided with a good fellowship and accommodation. Psychological test, as suggested by Chaturvedi (p. 103) combined with a strict eligibility as suggested above will definitely present the best candidates for scientific research. The opportunities and channels for a scientific career shall be made clear to the students at the postgraduation level itself.

For the last many years universities are reeling under a financial crunch to carry out scientific research and hence they introduced self-financing courses. Are the universities improving the syllabi, teaching and research with the money they generate? Or is it being used for the general university expenditure? The salaries of the faculty and the basic expenditure of the departments are borne by UGC. Then, where does this money go? It should be made mandatory that the money generated by introducing self-financing courses be made available only to that particular department which generates the money, to improve its facilities. If there is no improvement in the quality of education imparted for the paying students, then there will be no takers in the long run. Let universities be the centres for teaching excellence. Research in the universities must be confined to faculty who can generate their own money through grants. Those who cannot get grants can at least take up full-time teaching instead of running away from both teaching and research and blaming the university for non-availability of funds. In most of the universities, faculty are given a contingency grant every year to run a lab, which is generally not sufficient. Hence, orientation courses for young faculty about the possible sources of funds should be conducted periodically. To avoid all this, I would like to make a suggestion, which may not please everyone – make universities as centres for high-quality teaching and national laboratories as centres for research. Neither of them will do both teaching and research at the same point of time.

Universities nowadays recognize private institutions for postgraduation courses in science. This should be discouraged. The quality and basic values should be preserved. A candidate who joins the university after clearing the entrance exam is given the same degree as a candidate who studies in a private institution. This is not fair. Let universities alone confer the postgraduate degrees and thus preserve their value. We need postgraduates of quality and not in quantity.

Another aspect is the lack of appreciation of importance of research in the general public. For them, scientific research is just another job; they do not know what researchers do. Efforts should be made to popularize the fact that research is the basis for all inventions and even necessities, as in medicine.

Urgent steps are to be initiated to stimulate the young minds to opt for science as a career, to see a definite role for India in world science.

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