SUSTAINABLE MANAGEMENT AND OPTIMIZATION OF MINING WASTES: AN INTEGRATED MULTIDISCIPLINARY APPROACH

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Our economy needs to collect raw materials (RMs) from mining activities and this produces an impressive amount of mining wastes and a number of environmental problems associated with the disposal of them. Nowadays, the advances of the innovative technologies and markets make mining waste sources of valuable minerals/elements, but, in order to exploit them, it is necessary to know accurate information and to develop smart strategies of management and planning. In this framework, we tested an integrated multidisciplinary approach for sustainable management and optimization of mining wastes (**Fig.1**). We sampled iron (Fe) and manganese (Mn) wastes produced in Joda West Mine (State of Odisha-India) (**Fig. 2**).

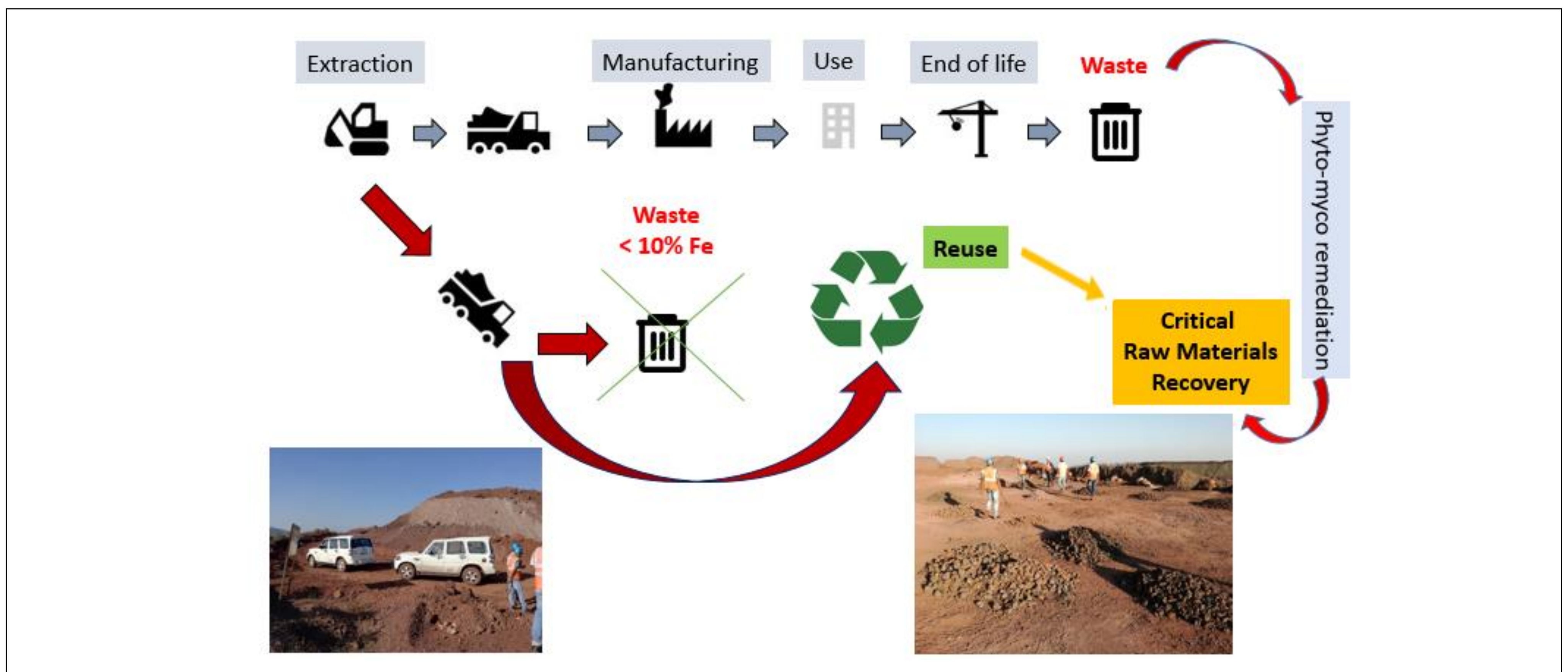

Fig. 1. A scheme of the proposed multidisciplinary strategy for classification and reuse of iron and manganese mining wastes.

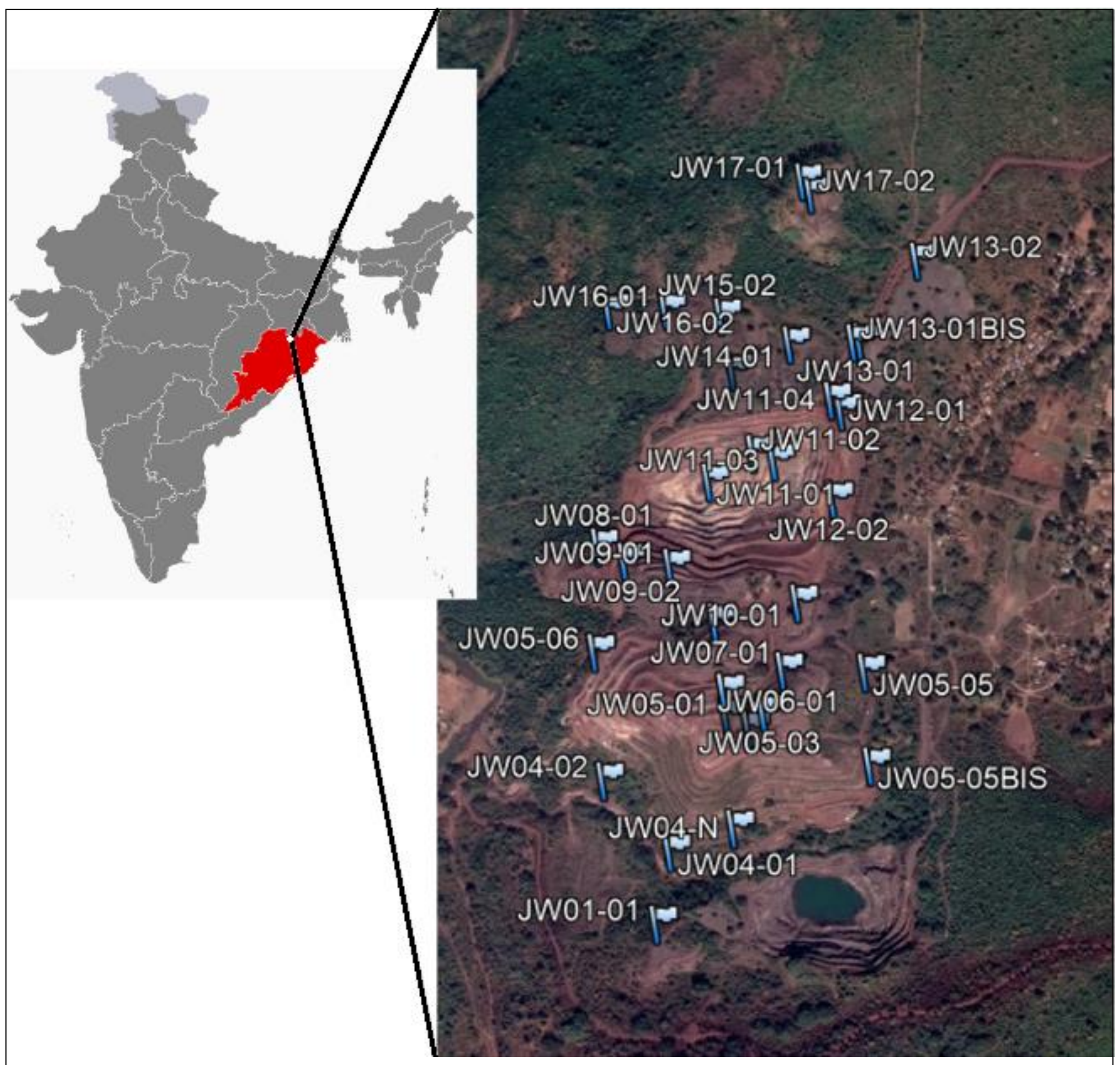

Fig. 2. Location of the study area and *in situ* sampling campaign.

X-Ray Powder Diffraction, X-Ray Fluorescence and spectral signatures analysis were used in order to characterize the mining waste samples. Mineralogical, chemical (**Table 1**) and spectral data were used as input to classify Sentinel-2A image. The characterized mining waste map (**Fig. 3**) identifies waste deposit areas with different percentage of Fe and Mn and represents a suitable tool for further optimizing strategies of mining waste management [1,2]. The four classes have been overlaid on Sentinel-2A image in true color (Red: band 4; Green: band 3; Blue: band 2; spatial resolution: 10 m) location map.

Table 1. Characterization of most representative mining waste samples

Sample Code	Fe (%)	Al (%)	Mn (%)	Hematite (%)	Goethite (%)	Muscovite (%)	Kaolinite (%)	Pyrolusite (%)
JW1201	39.1	3.6	15.6	36.9	2.4	n.d.	22.2	n.d.
JW1301bis b	16.9	1.3	46.9	19.8	6	19.8	18.1	10.8
JW1302	28.5	2	29.1	10.8	6.7	26.1	16.8	6.3
JW0504	9.8	13.8	1.8	4.4	4.2	20.3	52.5	n.d.
JW1301bis a	49.5	3.2	1.8	23.4	25.4	20.1	15.3	n.d.

The potentialities of phyto-mycoremediation of classified mining wastes (Classes 1 - 4) for heavy metals uptake and bioaccumulation were evaluated, in the perspective of their subsequent recovery from biomass through hydrometallurgical methods. The phyto-mycoremediation system consisted of sunflowers (*Helianthus annuus L.*) [3] colonized by an arbuscular mycorrhizal (AM) fungal strain (GA5 *Rhizophagus intraradices*) [4].

No significant differences were observed in leaves development and length of aerial parts of *Helianthus annuus* grown on contaminated and blank soil, suggesting that presence of high contamination levels did not hinder the growth of sunflower plants. Typical AM fungal structures were observed in sunflower roots with abundant vesicles and hyphae (**Fig. 4A**), while root colonization was not observed in not mycorrhized plants (**Fig. 4B**), as expected.

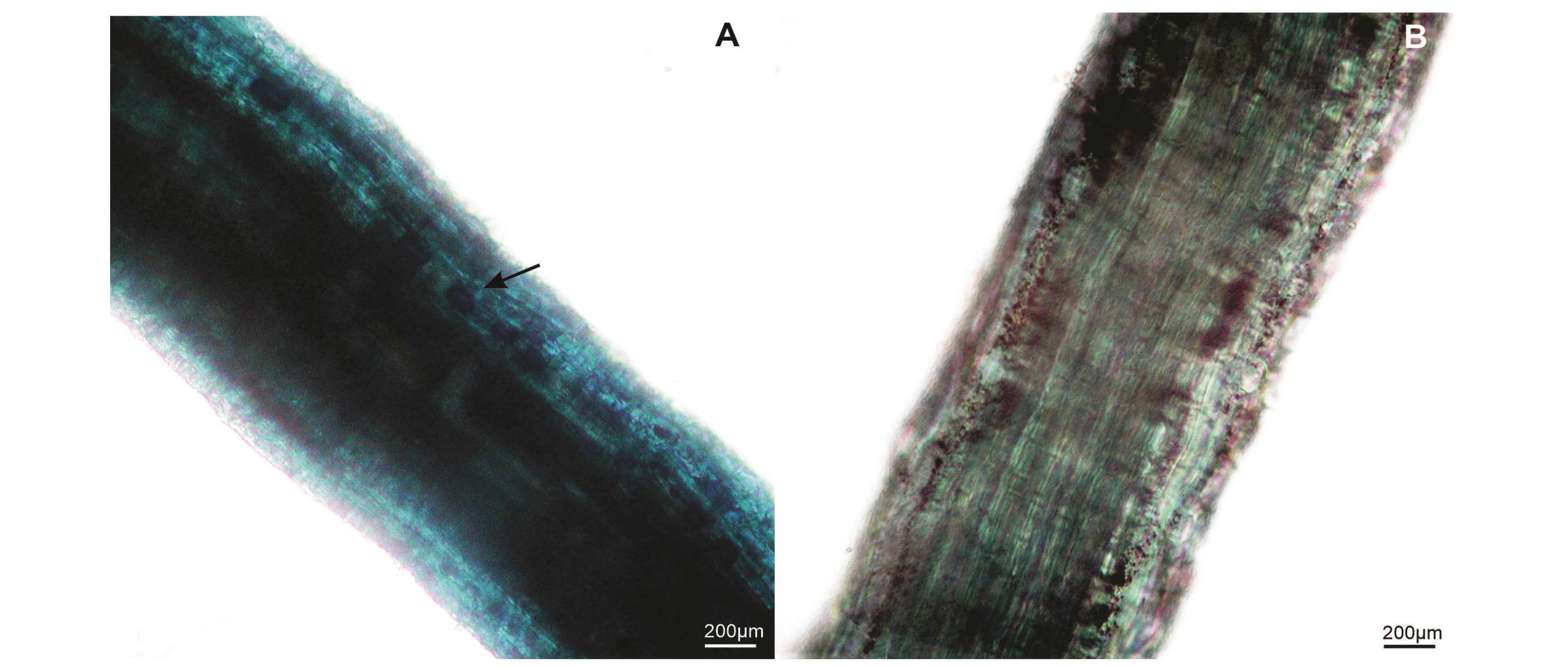

Fig. 4. (A) Root colonization of sunflower plant by the arbuscular mycorrhizal (AM) fungus *Rhizophagus intraradices* GA5 strain after 133 days. Detail of sunflower roots with intraradical hyphae, arbuscules and vesicles developed by the AM fungus are indicated by the arrow. (B) Uncolonized root of sunflower plant in control treatment.

Results indicated that the system was suitable for the uptake of several elements.

Bioconcentration factors in shoots (BC_S) followed the order P(5.35)>S>Sr>K>Ca> Ga> Rb> Zn(0.9)> Cu>As>Ni>Cr>Mn (0.01)>Ti=Fe (0.00).

Bioconcentration factors in roots (BC_R) followed the order S (15.01)> K> P> Ga> Ca (0.94)> Zn> Sr> Ni> As> Cu> Cr> Ti> Rb> Fe (0.10)>Mn (0.08).

Translocation factor (TF) followed the order Rb (9.28)> Sr> P> Ca> K> Ga> Zn> Cu (0.94)> As> S> Mn> Cr> Ni(0.05)> Fe=Ti (0.02).

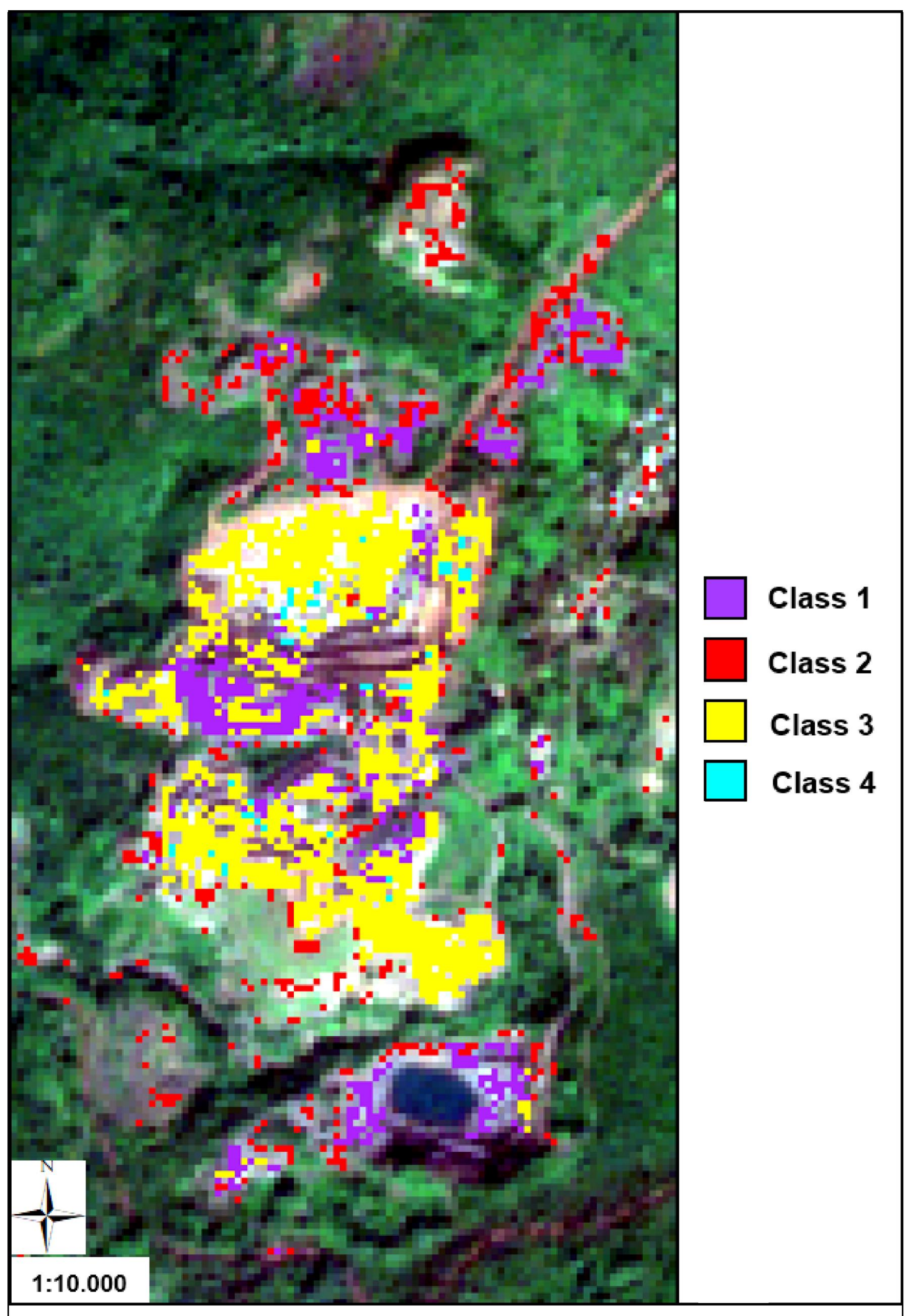

Fig. 3. Fe and Mn mining waste deposits map that shows the spatial distribution of the four mining waste classes overlaid on Sentinel-2A image.

Results are promising, and show that an approach based on both advanced techniques and low cost treatment methods successfully leads to significant potential waste reduction and materials recovery.

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