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Suitable natural analogue for the restoration of a gold tailings site near Ballarat, Victoria

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ABSTRACT
The closure and restoration of a gold tailings site near Ballarat in Victoria required the selection of a natural analogue to guide the recovery work. The objective of the report is to build up the status of the tailings site into a natural simulated ecosystem through natural analogues and to restore it to a self-sustaining ecosystem status. The new ecosystem will reflect the natural environment with similar chemical, physical and biological characteristics as before. Using data from the Terrestrial Ecosystem Research Network (TERN) and the Australian National Soil Information System (ANSIS), this report identifies suitable natural analogs, sets out criteria for restoration, and discusses potential interventions to guide the restoration process.

KEYWORDS
Tailings remediation; natural analogues; simulated ecological environment; land use

A gold tailings site near Ballarat, Victoria, with an area of 500m X 500m and a pile height of 5m, is ready for closure. The tailings initially have a high moisture content (~70%), but have become dry soil over the mine life of up to 30 years. The tailings are now fixed by the wall and covered with a layer of mine soil (50cm) to reshape into a plane. The determination of the land use plan of the site requires the support of the natural analogue simulation site, which can restore the tailings site to a self-sustaining state based on the natural simulation. It has similar chemical, physical and biological properties to these tailings. The purpose of this report is to screen natural analogues based on detailed information about the tailings site, advise site managers on appropriate natural analogues for tailings rehabilitation, and determine the final land use.

1 Methods

1.1 Selection criteria for natural analogs

In order to identify natural analogues, Two properties, physical and chemical, are essential to the identification of appropriate natural analogs. First, the analogues must have similar pH, salinity and other nutrients to the local tailings site. Local tailings sites with high PH (9) and high salinity (EC 1 dS/m) are key factors influencing the selection. Secondly, the simulation should have similar soil texture and moisture characteristics to local tailings sites, such as high clay content (60%) and low hydraulic conductivity (5×10^{-9} m/s). Typically, the tailings site is characterized with alkaline land with high salinity and arid environment with little vegetation. The selection of natural analogues should take into account the situation in Australia and focus on the arid land in the middle part. In addition, areas with high clay content and slow drainage need to be considered.

1.2 Establish the location of natural analogues

Using TERN's and ANSIS's visual maps and soil data, potential sites with similar properties to local tailings sites were considered, and the distribution of high PH and high clay content areas was outlined through TERN, as shown in the figure below

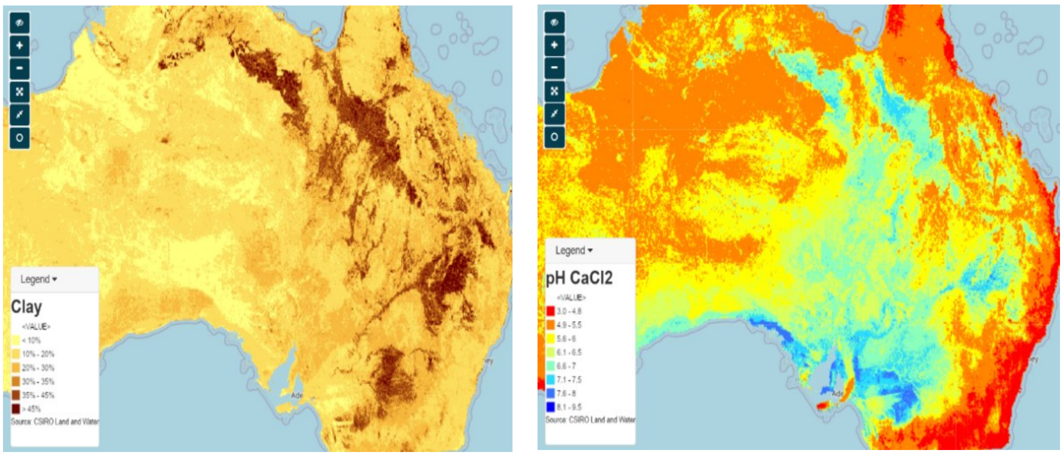

Figure 1 Map of soil PH and clay content in major areas of Australia

As can be seen from the distribution map of PH value and high clay content, the areas of high alkaline and high clay content are mainly distributed in the central and eastern regions of Australia, which should be taken into account, and these areas do have overlapping areas, which is a key factor in finding natural analogues with similar properties to tailings.

Once the approximate location of similar soil characteristics has been determined, the ANSIS visual map is used to find suitable soil sites. For the selection of soil properties, the most important chemical and physical properties were selected as the basis for searching the entire map, and several sites with both high PH and high clay content were selected according to the PH and clay content map layers.

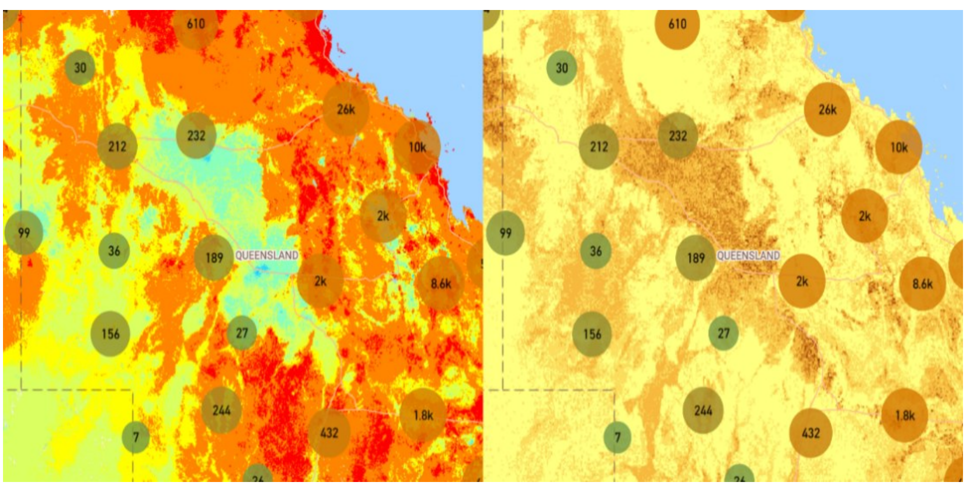

Figure 2 Soil site 1 in central Queensland

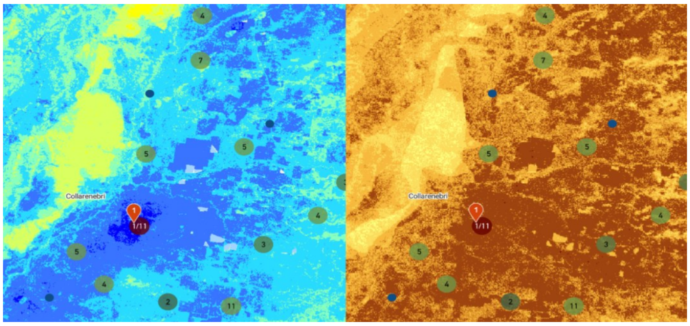

Figure 3 A soil site 2 near Collarenebri, Victoria

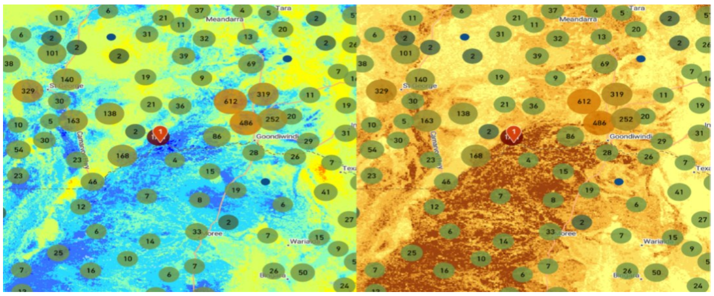

Figure 4 Soil site 3 west of Melbourne, Queensland

1.3 Basis for Selecting and eliminating Sites

Three sites are selected according to PH and clay content. They all have high PH and clay content in common. More details are needed to determine the site, As a strange area, the properties of the land around the tailings are hardly similar, so only the soil site with the closest properties can be selected. More detailed PH value and clay content data of these three sites have been obtained through application, and salinity comparison has been added.

Soil site	PH	EC(dS/m)	Clay(%)
1	9.2	0.17	>45%
2	8.5	0.07	>45%
3	9.0	0.91	>45%

Normally, it is necessary to exclude sites with significantly different PH, organic content and soil structure from tailings sites. Due to the screening conditions, these three sites have similar PH and clay content, but different salinity levels. Moreover, the map shows that site1 and site2 have certain grassland and forest areas, which need some modification to match the nature of the tailings. site3 is recommended as a suitable natural analogue area, where the high PH, salinity and soil conditions can be shared with the tailings site, while demonstrating its arid environment with little vegetation. site3 was selected as a natural analogue site, providing a realistic target for restoration. It helps the chemical and physical challenges of the tailings site to make a more stable transition to the natural ecological environment.

2 Discussion

2.1 Main rehabilitation criteria

- Chemical properties

Focus on monitoring soil pH and nutrient levels (N, P, K). DIIS(2016) recommends that the soil pH should be neutral (5.5-7.5) to ensure that the soil supports native plants and that native plants have access to sufficient essential nutrients (N, P, K).

- Physical properties

Kelder et al (2016) discussed that in the process of mine restoration, overly compact soil structure would restrict the infiltration process of plant roots and water, which would limit plant growth. It is therefore important to assess the porosity and water holding capacity of the soil structure in order for the soil to allow plant root penetration and water containment.

- Biological characteristics

Achieving sustainable vegetation cover and biodiversity is essential for mine remediation. The goal is to establish at least 50%-70% vegetation cover and simulate species composition similar to that of a local tailings site (Kragt et al., 2019). With the establishment of plants and the addition of organic matter, the quality of the soil will be improved, promoting the development of microbial communities. The goal is to increase the microbial Biomass Carbon to 100-400 mg/kg and to increase the organic carbon of the soil to 1-2%. (banning et al., 2010)

2.2 Monitoring Management

- Soil sampling

Soil samples are taken regularly to monitor PH and nutrient levels. At present, the tailings site is a highly alkaline soil (PH=9), and if the PH value is outside the target range (5.5-7.5), acidic substances should be recorded and considered for adjustment. If N, P, K content is insufficient, it can be supplemented.

- Soil compaction

Use tools periodically to measure soil compaction. If soil compaction is too high, consider using tools or adding organic matter to increase porosity, such as deep ripping and blending organic matter to promote successful soil recovery. (DMP and EPA, 2015)

- Vegetation survey

Local species composition and vegetation cover are regularly surveyed and need to be replenished or controlled if vegetation is established too quickly or too slowly. Microbial biomass and respiration rate of soil samples are tested regularly to analyze the long-term development of soil microbial communities. In addition, it is important to ensure the dominance of native species in the site and actively exclude alien species if they are invading.

2.3 Expected evolution of natural analogues

Natural succession will occur over time and be influenced by site restoration work. The site will naturally evolve with the mechanisms that drive these changes. Kelder et al(2016) believes that physical processes such as erosion and weathering will play an important role in the natural evolution of restored sites. The weathering of the minerals in the tailings leads to the release of neutralizing cations, which neutralize the pH and can help stabilize the local soil pH, which is an adjustment of natural processes that the local environment can allow for self-healing. The accumulation of organic matter in plants during decay will facilitate nutrient cycling, and during repair, nutrient levels are expected to gradually approach those found in natural analogues over time, which can support plant growth and biodiversity. In addition, some of the species that merge in the initial stage of restoration became tolerant in the process of natural evolution, and as the ecosystem gradually stabilized, they were able to resist the disturbance of natural factors such as drought and flood, and establish the restoration capacity of the local ecological environment, which will be a key factor in the successful restoration of the tailings site. This means that the site can guarantee its ecological function without human intervention.

2.4 End Land Use Considerations

Determining the most appropriate final land use for the rehabilitated gold tailings site near Ballarat is a key component of the tailings rehabilitation process. After the tailings have been restored to a stable ecosystem similar to their natural analogues, subsequent land use needs to be determined. The surrounding areas of natural analogues are mainly rural areas, which are not suitable for land use reference. Considering the historical background of Ballarat, the area was originally a mining city, and after most of the gold mines were abandoned, it was chosen to transform it into a gold rush theme park, which provided a reference for the future land use. Kragt et al(2019) discussed that it is feasible for final land use to reduce long-term maintenance costs through direct economic returns. The restored land will also incur restoration and maintenance costs, and a certain economic return needs to be planned if the final land use is to be viable in the long run. Developing this tailings site as a tourist attraction typically requires less environmental management than agricultural or industrial land. This reduces long-term costs while still delivering economic and environmental benefits.

3 Conclusion

This report identifies the area around Goondiwindi as a suitable natural analogue for the recovery of a gold tailings site near Ballarat, Victoria, based on relevant literature. Relevant restoration criteria were selected to help guide the site to achieve a stable ecosystem similar to the simulated site. An ongoing regulatory system is critical to the decision making and future direction of tailings remediation. The ultimate goal is to establish ecologically sustainable and economically efficient land use.

References

[1] Banning, N. C., Phillips, I. R., Jones, D. L., & Murphy, D. V. (2011). Development of Microbial Diversity and Functional Potential in Bauxite Residue Sand under Rehabilitation. *Restoration Ecology*, *19*(101), 78–87. https://doi.org/10.1111/j.1526-100X.2009.00637.x

[2] Kelder, J. M., Jasper, D. A., & Fourie, A. B. (2016). Integrating the use of natural analogues and erosion modelling in landform design for closure. *Journal of Environmental Management*, 165, 101-111.

[3] Kragt, M. E., Newham, L. T., & Bennett, J. W. (2019). A review of mine rehabilitation condition setting in Western Australia. *Resources Policy*, 61, 157-166.

[4] Department of Industry, Innovation and Science (DIIS). (2016). Mine Rehabilitation - Leading Practice Sustainable Development Program for the Mining Industry. Australian Government.

[5] Department of Mines and Petroleum (DMP) & Environmental Protection Authority (EPA). (2015). *Guidelines for preparing mine closure plans*. Western Australian Government.