Author's Response to Reviewers' Comments

Manuscript: essd-2025-583

Global Surface Mining and Land Reclamation Time Series from 1985–2022

Dear Editor and Reviewers,

We are very grateful for the detailed comments and constructive suggestions from both reviewers. These suggestions have led to important improvements in methodology explanation, validation, and documentation. Below we provide a consolidated point-by-point response to all comments. Our replies are shown in blue text. Line numbers refer to the revised manuscript. In addition to addressing the reviewers' comments, we have also made several independent corrections to improve data accuracy and methodological rigor, which are documented at the end of this response.

Response to Reviewer 1

Comment 1: Clarification and Discussion on "Undefined Mines"

Reviewer's Comment: *"The classification of mining activity status is a core contribution of this study. However, the 'Undefined Mines' category requires further revision. Currently, 'Undefined Mines' seems to be defined largely by exclusion. This definition is insufficient for a scientific classification system. Authors should provide a positive definition. In addition, the results indicate that 48.9% of the mining polygons are classified as 'Undefined.' This is a remarkably high proportion. The authors must discuss why this percentage is so high."*

Response: We sincerely thank the reviewer for this insightful critique. We fully agree that a rigorous scientific classification requires positive definitions rather than definitions by exclusion. We have made two key revisions: (1) renaming the category from "Undefined Mines" to "Stable Mines," and (2) providing an explicit positive definition.

The revised terminology "Stable Mines" aligns with established nomenclature in recent literature (e.g., Wang et al., 2025). We now provide a positive definition specifying the conditions under which a mining polygon is classified as "Stable," encompassing: (1) equilibrium-state mines where extraction and reclamation have reached dynamic balance; (2) concurrent extraction-reclamation mines where simultaneous activities in different sectors produce offsetting signals; (3) maintenance-phase mines in transitional or suspended operational states; and (4) low-intensity or artisanal operations with insufficient signal magnitude to exceed statistical significance thresholds.

Regarding the proportion, when placed in context, our results demonstrate enhanced sensitivity. Wang et al. (2025), using single-indicator NDVI-based classification, identified 64.3% of mines as stable. Our multi-indicator approach reduced this to 48.9%—a 15-percentage-point improvement—demonstrating that combining NDVI, BSP, and NTL captures mining dynamics that single-indicator methods miss.

Revised Text: Section 2.3 (Lines 305–319), Section 3.3 (Lines 607–614), and Section 4.3

(Lines 851–879) have been revised accordingly. See highlighted text in the revised manuscript.

Comment 2: Distinctions between Reclamation, Revegetation, and Greening

Reviewer's Comment: *"The manuscript uses the term 'Reclamation' extensively, but the methodology relies on remote sensing indices (BSP and NDVI). There is a conceptual gap that needs to be bridged. The authors should explicitly differentiate between 'Greening', 'Revegetation', and 'Reclamation'."*

Response: We fully agree that there is an important conceptual distinction. We have added clear definitions in Section 2.2 (Lines 250–261):

(1) Greening: an increase in vegetation index values detected by remote sensing, indicating increased photosynthetic activity or vegetation cover, without implying ecosystem functionality; (2) Revegetation: the establishment of plant cover on previously disturbed land, whether through natural succession or active planting; and (3) Reclamation: in its comprehensive sense encompasses soil reconstruction, landform redesign, hydrological restoration, and the recovery of ecosystem structure and function.

We have clarified that what we identify as 'reclaimed area' specifically refers to areas exhibiting vegetation recovery signals—capturing greening or revegetation processes rather than comprehensive ecological reclamation. Corresponding clarifications have been added to Sections 2.2 (Lines 244–262) and 3.2 (Lines 526–530).

Comment 3: Figure 6(a) X-axis Labels

Reviewer's Comment: *"The x-axis labels in Figure 6(a) (Year) are currently stacked and overlapping, making them unreadable."*

Response: We have adjusted the aspect ratio of Figure 6(a) to ensure that the x-axis labels are now clearly visible and properly spaced.

Comment 4: Comparison with Sepin et al. (2025)

Reviewer's Comment: *"The manuscript lacks comparison with more recent and regionally focused high-resolution products. The authors should compare their findings with Sepin, P., Vashold, L. & Kuschnig, N. Mapping mining areas in the tropics from 2016 to 2024. Nat Sustain 8, 1400–1407 (2025)."*

Response: We thank the reviewer for bringing this important recent publication to our attention. We have added a comprehensive comparison with Sepin et al. (2025) in Section 4.1 and included a new Figure 9.

For direct comparison within the overlapping spatial domain (tropical belt, ±30° latitude), we extracted statistics from both datasets for the year 2020. Our tropical subset contains 25,772 polygons covering 37,744 km², while Sepin et al. (2025) contains 16,842 polygons with 66,835 km². Visual comparison at representative mining sites (Fig. 9) reveals that the Sepin et al. predictions exhibit notable omission errors at large-scale industrial mines. We emphasize that the two datasets serve complementary purposes: Sepin et al. provides higher sensitivity for artisanal mining detection, while our dataset offers greater boundary precision, broader geographic scope (global vs. tropical), and substantially longer temporal depth (1985–2022).

Revised Text: A new comparative discussion and Figure 9 have been added to Section 4.1. Reference: Sepin et al. (2025) Nat Sustain, 8, 1400–1407.

Response to Reviewer 2

Major Comment 1: Temporal Analysis Clarifications

1a. Baseline Year Consideration

Reviewer's Comment: *"Is the start time of each mine explicitly considered? Please clarify the baseline year used to define mining-induced disturbance for each mining polygon."*

Response: We adopt a pixel-level disturbance detection approach rather than defining site-specific baseline years for individual mining polygons. Comprehensive data on precise operational start times are often unavailable globally, particularly for historical and artisanal mines. Our approach tracks land cover transitions at the pixel scale (30 m) within delineated mining boundaries from 1985 to 2022. The first detected land-cover transition serves as the disturbance indicator for each pixel, independent of the overall site's operational timeline. This framework captures spatial heterogeneity within individual mining polygons and avoids the propagation of errors from potentially inaccurate site-level operational dates.

Revised Text: Section 2.2, Lines 231–238.

1b. Analysis Window Justification

Reviewer's Comment: *"Do all mines use the same analysis window (2018–2023) for trend assessment? What is the rationale for selecting this period?"*

Response: Yes, all mining polygons were analyzed using the same temporal window to ensure consistency. The Mann-Kendall trend test requires a minimum of approximately four to five data points for adequate statistical power. The primary objective was to assess the current development status of mining areas—whether mines are actively expanding, undergoing reclamation, or in a stable state. A relatively short, recent window better captures the current operational phase, avoiding conflation of historical patterns with present conditions.

1c. Static Boundary Assumption

Reviewer's Comment: *"Does the method account for the fact that mining boundaries expand or contract over time? This assumption should be explicitly stated and evaluated."*

Response: Our methodology employs fixed mining boundaries derived from two existing global datasets (Maus et al., 2022; Tang and Werner, 2023), delineated based on satellite imagery from circa 2020. These boundaries represent the "maximum potential mining disturbance boundary." Mining activities that expanded beyond these boundaries would not be detected (potential underestimation), while areas never actually mined may contribute to overestimation—though our stable green area exclusion procedure mitigates this. We have added explicit discussion of this limitation.

Revised Text: Section 4.3, Lines 827–835.

1d. NDVI Saturation

Reviewer's Comment: *"NDVI saturation may lead to underestimation of recovery trends in medium-to-high biomass areas. What would change if alternative indicators such as NIRv were used?"*

Response: NDVI is not used as the sole indicator; disturbance and reclamation detection primarily relies on the GLC_FCS30D land-cover classification product. MODIS-derived NDVI time series are used for trend characterization of vegetation recovery. In high-biomass environments, NDVI-based trends may underestimate recovery. If NIRv were applied, vegetation recovery in densely vegetated reclamation sites—particularly within tropical biomes—would likely be detected more sensitively. We acknowledge this limitation and highlight NIRv-based trend analysis as a valuable future direction.

Revised Text: Section 4.3, Lines 866–878. New references added: Badgley et al. (2017, 2019); Camps-Valls et al. (2021).

1e. High Proportion of Undefined Mines

Reviewer's Comment: *"Nearly half of the mining polygons are classified as 'undefined'. This proportion is unexpectedly large and suggests limitations in indicator sensitivity or threshold selection."*

Response: Our multi-indicator approach actually demonstrates enhanced sensitivity compared to existing methods. Wang et al. (2025), using NDVI change rates alone, classified 64.3% of mining polygons as "Stable." Our approach reduced this to 48.9%—detecting dynamic trends in approximately 15% more mining areas. The category has been renamed from "Undefined Mines" to "Stable Mines" with a positive definition (see response to Reviewer 1 Comment 1 for complete details).

Major Comment 2: Comparisons and Validations

Reviewer's Comment: *"The dataset is derived from merging two existing mining inventories, but the manuscript does not convincingly demonstrate accuracy improvements. The authors should conduct cross-dataset quantitative comparisons using the same validation samples or adding case-based evaluations."*

Response: We have implemented a stratified cross-validation framework comparing the three datasets (Tang and Werner 2023, Maus et al. 2022, and our refined dataset) using the same validation samples. We designed a four-zone stratified sampling scheme based on spatial overlap relationships:

Zone	Definition	Mining	Non-mining	Total	Mining (%)	Rate
Zone A	Tang + Maus, excluded by Ours	43	107	150	28.7	
Zone B	Three-way consensus	274	26	300	91.3	
Zone C	Maus + Ours, not Tang	122	28	150	81.3	
Zone D	Tang + Ours, not Maus	129	21	150	86.0	

The low mining rate in Zone A (28.7%) validates our refinement process; the high rates in Zones B–D (81.3%–91.3%) confirm that our dataset preserves genuine mining areas. The validation methodology is described in Section 2.4.2 (Lines 320–360), and results are presented in Section 4.1 (Lines 752–776) with new Table 2 and Figures 3 and A1.

Minor Comments

1. Lines 306–312 (figure caption): Methodological details have been relocated to the caption of Figure 3. The entire manuscript has been reviewed for similar instances.

2. Figure 3(a) redundancy: The redundant lower chart has been removed to improve visual clarity.

3. Figure 3(b) y-axis scaling: The figure now displays original NDVI values without artificial scaling.

4. Figure 3(b) image quality: Replaced with Landsat 8 OLI imagery (Collection 2 Level-2 Surface Reflectance) downloaded directly from Google Earth Engine, exported at 10 m resolution through 3× supersampling. See revised Figure 4(b) and caption (Lines 382–392).

5. Percentage formatting: All percentages in Sections 3.2 and 3.3 have been standardized to one decimal place.

6. Dataset documentation: Comprehensive metadata documentation has been prepared detailing the meaning, units, and calculation logic for each field in the dataset. The metadata documentation has been published alongside the updated dataset in the new version on Zenodo, ensuring that users can directly access comprehensive field descriptions, units, and calculation logic together with the data files.

Additional Author Corrections

In addition to the revisions made in response to the reviewers' comments, we have identified and corrected the following issues in the revised manuscript:

Correction 1: NDVI Data Source

Original Text: *"To evaluate the recent developmental trajectories (2018-2023) and current* *status of global surface mining areas, we employed three indicators: NDVI, BSP, and NTL. NDVI was derived from the Sentinel-2 surface reflectance dataset, which provides high-resolution multispectral observations suitable for vegetation monitoring."*

Revised Text (Lines 263–269): "To evaluate the recent developmental trajectories (2019-2023) and current status of global surface mining areas, we employed three indicators: NDVI, BSP, and NTL. NDVI was obtained from the MODIS MOD13Q1 and MYD13Q1 (Collection 6.1) products, and annual maximum NDVI composites at 250-m resolution were generated by combining Terra and Aqua observations for each year. The annual maximum value composite approach was adopted to minimize residual cloud contamination and to better represent peak vegetation conditions."

Rationale: The original text incorrectly stated the NDVI data source as Sentinel-2. The analysis actually used MODIS MOD13Q1 and MYD13Q1 products. The temporal window was also corrected from 2018–2023 to 2019–2023 to accurately reflect the data availability. This correction ensures consistency between the methodology description and the actual data processing workflow.

Correction 2: Statistical Significance Threshold

Original Text: *"The results of the analysis for each dataset are classified as follows: Increasing trend—indicating a significant positive trend ($p < 0.05$); Decreasing trend—indicating a significant negative trend ($p < 0.05$); No trend—indicating no statistically significant trend ($p \geq 0.05$)."*

Revised Text (Lines 280–283): "The results of the analysis for each dataset are classified as follows: Increasing trend—indicating a significant positive trend ($p < 0.1$); Decreasing trend—indicating a significant negative trend ($p < 0.1$); No trend—indicating no statistically significant trend ($p \geq 0.1$)."

Rationale: The significance threshold was adjusted from $p < 0.05$ to $p < 0.1$ to better account for the short time series (5 data points) used in the Mann-Kendall trend test. With limited observations, a stricter threshold ($p < 0.05$) would substantially reduce statistical power and fail to detect meaningful trends. The relaxed threshold of $p < 0.1$ provides a more appropriate balance between Type I and Type II errors for this analysis context, and is consistent with standard practice for short environmental time series.

Correction 3: Revised Study Workflow Diagram (Figure 1)

Change: Figure 1 (Line 162) has been revised to accurately reflect the updated study workflow. The revised diagram now correctly represents the MODIS-based NDVI data source (replacing the previously indicated Sentinel-2), the adjusted temporal analysis window (2019–2023), and the updated significance threshold ($p < 0.1$). All processing steps depicted in the workflow have been verified for consistency with the revised methodology described in the text.

Rationale: Following the corrections to the NDVI data source and statistical significance threshold (Corrections 1 and 2 above), the study workflow diagram required corresponding updates to maintain internal consistency between the visual summary and the textual methodology.

Correction 4: Figure and Table Renumbering

Change: All figures and tables throughout the revised manuscript have been renumbered to ensure sequential ordering. This adjustment was necessary because the addition of new figures (e.g., the cross-validation zone illustration as Figure 3, and the Sepin et al. comparison as Figure 9) and new tables (e.g., Table 2 for cross-validation results) shifted the numbering of subsequent figures and tables. All in-text cross-references have been updated accordingly to match the revised numbering.

Rationale: The incorporation of new visual materials in response to both reviewers' comments required a comprehensive renumbering pass to maintain logical presentation order and correct cross-referencing throughout the manuscript.

Summary of All Changes

No.	Change Description	Location in Revised Manuscript
1	Renamed "Undefined Mines" to "Stable Mines" with positive definition	Sections 2.3, 3.3, 4.3
2	Added terminology clarification (Greening / Revegetation / Reclamation)	Section 2.2 (Lines 244–262), Section 3.2 (Lines 526–530)
3	Fixed Figure 6(a) x-axis label readability	Figure 6(a)
4	Added comparison with Sepin et al. (2025)	Section 4.1, new Figure 9
5	Clarified pixel-level baseline year approach	Section 2.2 (Lines 231–238)
6	Added static boundary limitation discussion	Section 4.3 (Lines 827–835)
7	Added NDVI saturation discussion and NIRv future direction	Section 4.3 (Lines 866–878)
8	Implemented cross-dataset validation framework	Section 2.4.2 (Lines 320–360), Section 4.1 (Lines 752–776), Table 2, Figs. 3 & A1
9	Relocated figure methodology text to captions	Throughout manuscript
10	Removed redundant chart in Figure 3(a)	Figure 3(a)
11	Improved Figure 4(b) image quality (Landsat 8 from GEE)	Figure 4(b), Lines 382–392
12	Standardized percentage formatting	Sections 3.2, 3.3
13	Added dataset user guide / metadata documentation	Supplementary material
14	Corrected NDVI data source (Sentinel-2 → MODIS); temporal window (2018 → 2019)	Lines 263–269

15	Adjusted significance threshold ($p < 0.05 \rightarrow p < 0.1$)	Lines 280–283
16	Revised Figure 1 (workflow diagram) to reflect updated data sources and methods	Figure 1 (Line 162)
17	Renumbered all figures and tables for sequential ordering; updated all cross-references	Throughout manuscript
18	Published metadata documentation on Zenodo (version 2)	Zenodo data repository

We believe that these revisions have substantially strengthened the manuscript and adequately addressed all concerns raised by the reviewers. We are grateful for the constructive feedback and remain open to further suggestions.

Sincerely,
The Authors