Reviewer #4:

**General Comments:**

**Comment #1**

General comment: The paper is generally well written and provide a useful dataset for the community with reasonable methods. I have only some minor comments below:

**Response #1**

*Thanks for your recognition and constructive suggestions, which make our manuscript stronger. In this version, we have further revised the manuscript and addressed all your concerns. Please see the detailed point-by-point responses below.*

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**Minor Comments**

**Comment #1**

Line 127: "We collected Google Global Landsat based CCDC segments (1999-2019). " I don't understand this. I think CCDC segments were created by the authors. What do you mean by 'collected'? (**Revised**)

**Response #1**

*Thanks for your comment. The global fitting results of CCDC are a major feature of the GFD type in this study. Since CCDC-based fitted datasets have already been produced for most regions worldwide by previous studies, we utilized these existing data directly to reduce computational time and resource requirements, as repeated calculation was deemed unnecessary. For the missing areas in the dataset, we use the same CCDC fitting method to supplement them, to obtain the complete CCDC fitting results for the global forest area. Furthermore, it supports us in identifying the GFD types. We have supplemented corresponding details in the manuscript (Page 7, Line 141-151):*

*"We collected Google Global Landsat based CCDC segments (1999-2019). The dataset was created from the Landsat 5, 7, and 8 Collection-1, Tier-1, surface reflectance time series, using all daytime images between 1999-01-01 and 2019-12-31. Each image was preprocessed to mask pixels identified as cloud, shadow, or snow (according to the 'pixel_qa' band), saturated pixels, and pixels with an atmospheric opacity > 300 (as identified by the 'sr_atmos_opacity' and 'sr_aerosol' bands). We have removed duplicate pixels in the overlapping scenes between the north and south. The results were output in 2-degree tiles for all landmasses between -60 °*

*and +85 ° latitude. We can directly call this dataset [ee.ImageCollection("GOOGLE/GLOBAL_CCDC/V1")] in GEE. The dataset provides extensive coverage of global forest areas, but small number of missing areas occur along the edges of some images, accounting for approximately 6% of the total global forest area. For the missing areas in the dataset, the CCDC algorithm is used to complete them, thereby obtaining vegetation change characteristics covering all forest areas worldwide. Based on the segmented fitting results of these features, we extracted the OC, PDC, and PDP of each pixel separately (Fig. 2)."*

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**Comment #2**

Line 131: deduplicated is very complex word. Try to rephrase. (**Revised**)

**Response #2**

*Thanks for your suggestion. We have revised the expression here (Page 7, Line 145-146):*

*"We have removed duplicate pixels in the overlapping scenes between the north and south. The results were output in 2-degree tiles for all landmasses between -60° and +85° latitude."*

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**Comment #3**

Line 133: what do you mean by "vacant areas"? (**Revised**)

**Response #3**

*Thanks for your comment. It refers to the areas that are not covered in the CCDC dataset we collected, that is, the missing areas. We have revised the wording in the manuscript by replacing 'vacancy areas' with' missing areas' (Page 7, Line 147-150):*

*"The dataset provides extensive coverage of global forest areas, but small number of missing areas occur along the edges of some images, accounting for approximately 6% of the total global forest area. For the missing areas in the dataset, the CCDC algorithm is used to complete them, thereby obtaining vegetation change characteristics covering all forest areas worldwide."*

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**Comment #4**

Line 160: suggest removing drought and pest from Table 1 to avoid potential confusions. Linked to line 181, there it says there are 11 disturbance types. If you remove drought and pest from Table 1, then there remains 10 types. More confusing is that Fig 3 contains 10 types including the Code 0. Could you clarifiy this? (**Explained and Revised**)

**Response #4**

*Thanks for your comment. Our 11 types of perturbations actually include undisturbed types with code 0. For forests, sustained and stable undisturbed forest areas should also be a key area of focus. Therefore, we also set it as a special GFD type. For disturbances such as drought and pests and diseases, although not included in our GFD map, they are indispensable in sorting out the main types of global forest disturbances. This is also to maintain the integrity of the forest disturbance framework. We have supplemented the process of organizing and developing the forest disturbance framework table in the manuscript (Page 2-3, Line 62-75).*

*"The global forest disturbance classification framework is established through a comprehensive synthesis of key disturbance characteristics, including disturbance intensity, disturbance source, forest types affected, disturbance processes, and recovery type. Based primarily on disturbance intensity, disturbances are categorized into negative disturbance (newly added forest, 22), positive strong disturbance, and positive weak disturbance. According to the differences in disturbance sources, such as human activities, natural wildfires, climatic factors, insect and disease outbreaks, and flooding, weak disturbances are further differentiated into drought-induced disturbances (16) and forest pest and disease disturbances (17). Similarly, strong disturbances are subdivided into forest fires (15), flood disasters (19), and human-induced forest disturbances. Depending on post-disturbance recovery status and land use type, human-induced disturbances are further distinguished into built-up area expansion (18) and cropland occupation (19), where forests are not restored. Taking into account the forest type disturbed, human-induced disturbances are also classified into renewal plantation (13) and oil palm expansion (21), both of which involve manual reversion. Based on the presence of short-term agricultural activities during the disturbance process, natural recovery secondary forests are categorized into natural forest deforestation (14) and shifting cultivation (11). Meanwhile, natural forest areas that were logged and then actively restored by humans are identified as forestry replanting (12)."*

*Meanwhile, we have clarified that the GFD map used in this study does not include any disturbances (Page 3, Table1; Page 9, Line 190-195).*

***Table 1: Global forest disturbance classification framework***

| Code | Disturbance type | Disturbance intensity | Disturbance source | Forest type | Disturbance process | Recovery type |
|---|---|---|---|---|---|---|
| 0 | Undisturbed | Undisturbed | - | Natural forests | Undisturbed between 2000 and 2020. | - |
| 11 | Shifting cultivation | Strong | Human disturbance | Natural forests | Residents randomly cut down forests on a small scale and plant crops, then abandon cultivation after 1-2 years. | Natural recovery |
| 12 | Forestry replanting | Strong | Human disturbance | Natural forests | To obtain wood, natural forests were cut down, and later manual planted them. | Manual reversion |
| 13 | Plantation disturbance | Strong | Human disturbance | Plantation | Regular logging and renewal of plantations. | Manual reversion |

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 | Deforestation of natural forests | Strong | Human disturbance | Natural forests | To obtain wood, natural forests were cut down, and later natural recovery. | Natural recovery |
| 15 | Forest fire disturbance | Strong | Natural fire | All forests | The destruction of forests by wildfires. | Natural recovery |
| 16 * | Drought | Weak | Natural climate | All forests | Forest degradation caused by drought. | – |
| 17 * | Forest pests and diseases | Weak | Natural pests and diseases | All forests | Forest degradation caused by pests and diseases. | – |
| 18 | Built-up area expansion | Strong | Human disturbance | All forests | Expansion of built-up areas encroach on forests. | No recovery |
| 19 | Cropland occupation | Strong | Human disturbance | All forests | Expansion of cropland encroach on forests. | No recovery |
| 20 | Flood disaster | Strong | Natural flood | All forests | Flood disasters encroach on forests. | Natural recovery |
| 21 | Oil palm | Strong | Human disturbance | All forests | Expansion of oil palm plantations encroach on forests | Manual reversion |
| 22 | Newly added forest | Negative | Human disturbance | Non forest | Artificially planting forests on non-forest land. | Manual planting |

*Note: * indicates weak disturbance type. Due to the spatial overlap between weak and strong disturbance types, this study did not consider weak disturbances.*

*"For the forest weak disturbance types caused by drought disturbance (16) and pest disturbance (17), their sample point selection needs to refer to high-resolution long-term remote sensing images. Meanwhile, weak disturbances in forest cover are highly time-bound. For example, the decline in vegetation index caused by a period of drought will quickly recover due to an increase in precipitation. At the global scale, it is currently limited by the availability of remote sensing images. We are unable to select relevant sample points through Landsat imagery. Therefore, this study did not consider these two weak disturbance types of drought disturbance and pest disturbance. This will be an independent topic for further research."*

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**Comment #5**

Line 177: 200 should be 2001? (**Revised**)

**Response #5**

*Thanks for your suggestion. We have revised the expression here (Page 10, Line 213):*

*"……considering the dynamic changes of flood inundation areas from 2001 to 2020, the forest areas that have been submerged……"*

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**Comment #6**

Figure 1: Change the disturbance type code to its name ? (**Revised**)

**Response #6**

*Thanks for your suggestion. We have revised the Fig.1 and 3 according to your suggestion (Page 5, Figure 1; Page 12, Figure 3):*

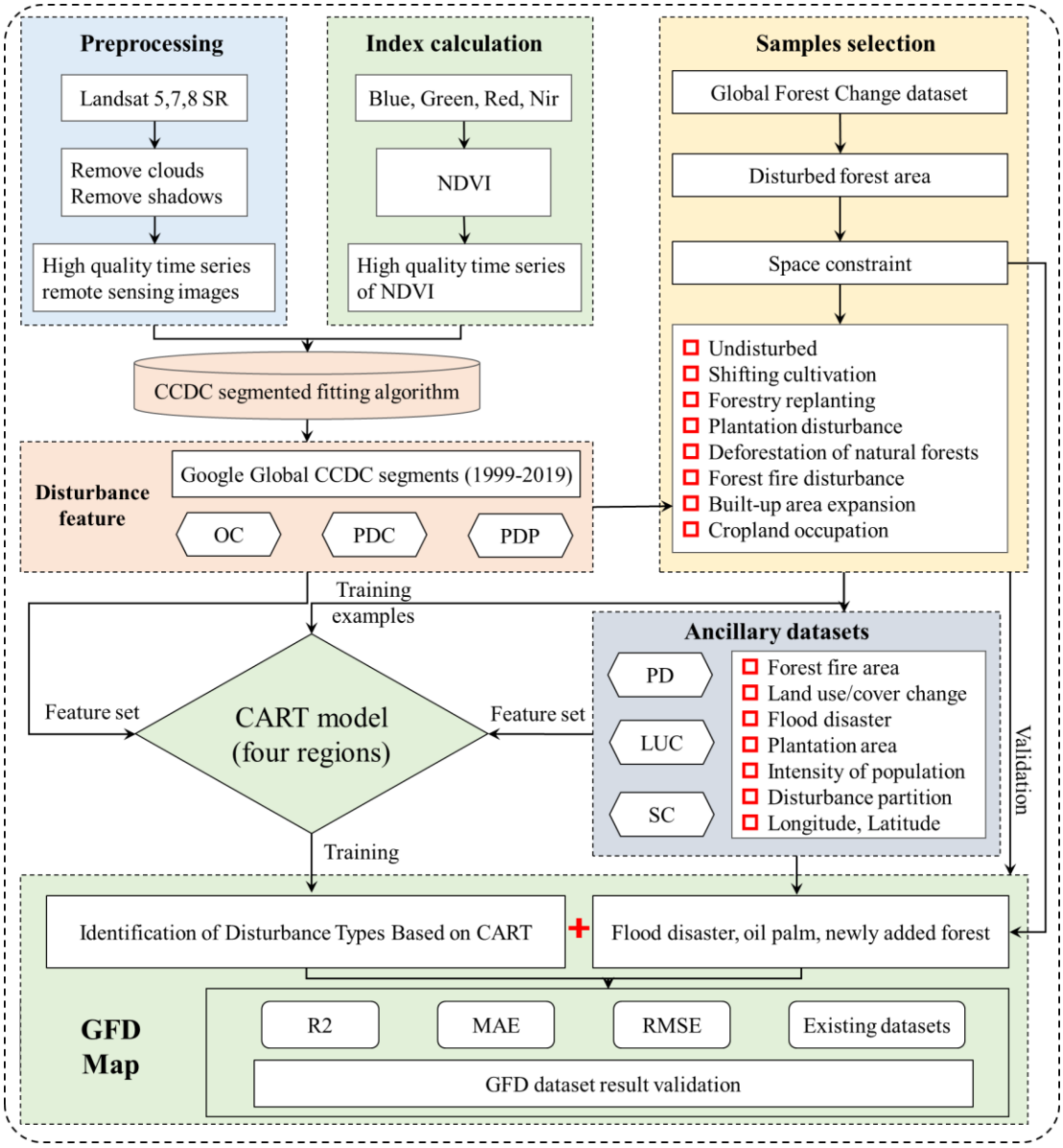
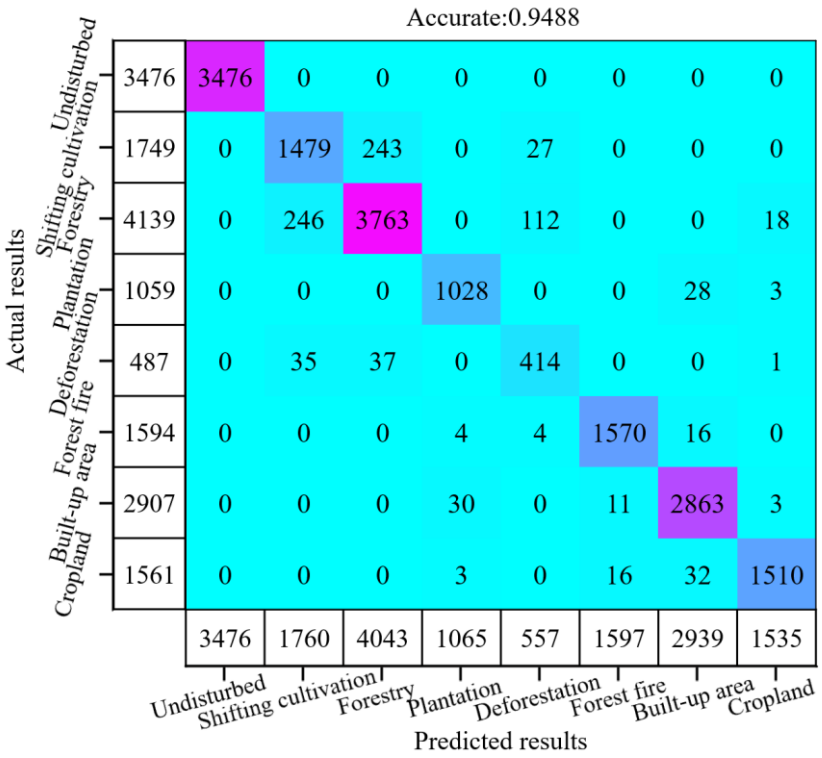



*Figure 1 Study workflow*




*"Figure 3 Confusion Matrix of Global Forest Disturbance Classification"*

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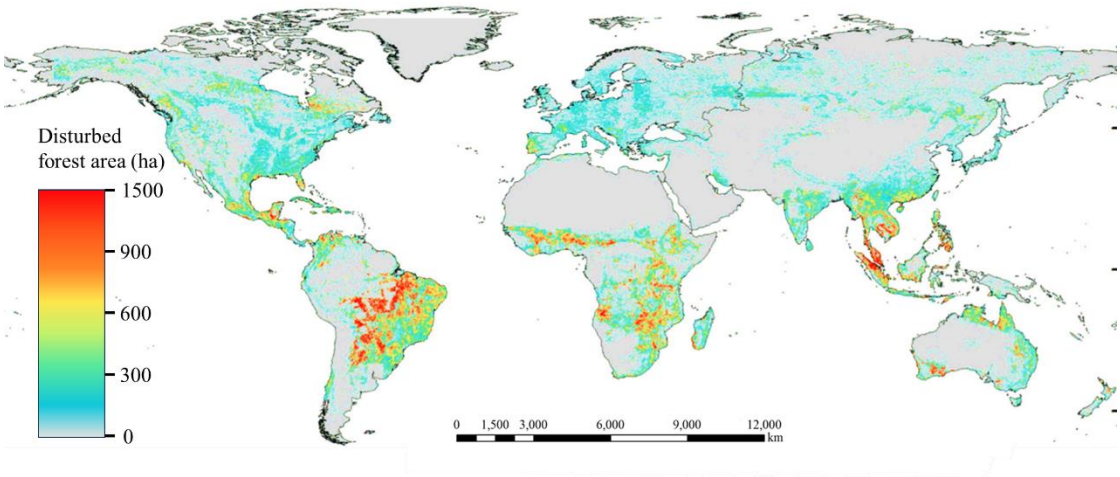
**Comment #7**

Figure 4: what is the spatial resolution of this map? Better to show forest loss and forest expansion independently. If both forest loss and gain occur in the same grid cell of the map, how did you do? The legend shows only the area being 'disturbed' but it does not show the direction of forest cover change. (**Revised**)

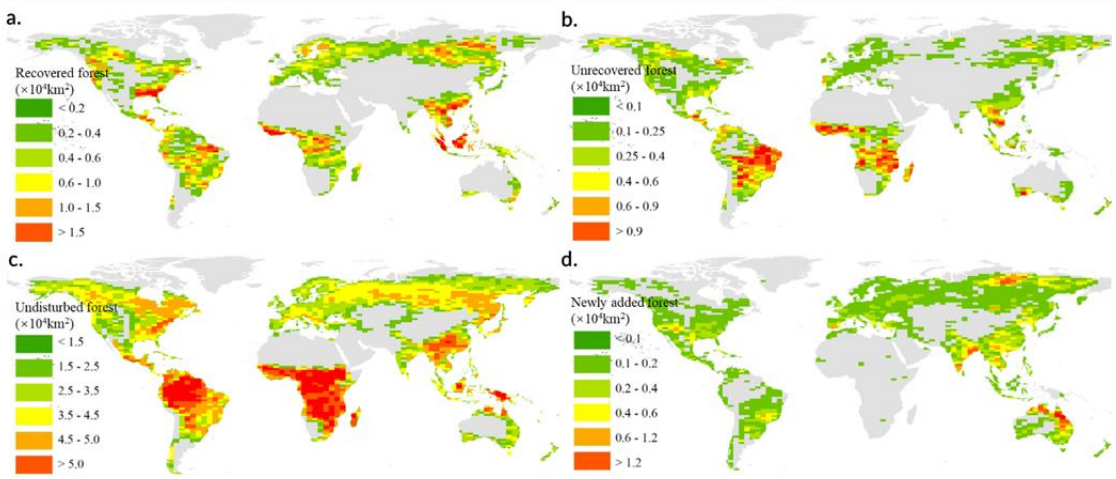
**Response #7**

*Thanks for your suggestion. The resolution of Figure 4 is 5.5km. The forest disturbance identified in this study is the recognition of the entire disturbance process, rather than simply detecting forest loss and gain. Except for permanent deforestation and encroachment, in fact, most types of forest disturbance involve two processes: disturbance and restoration. For example, natural forest deforestation includes both the logging process and the restoration process of secondary forests. If there is no restoration of secondary forests, it belongs to other disturbance types, such as Cropland encroachment, etc. Similarly, the disturbance of plantations includes both the logging of existing forests and the planting of artificial plantations. We have added resolution information in the legend of Figure 4.*




*"Figure 4 Global Forest Disturbance Distribution Map in 5.5km resolution."*

*In fact, we have summarized in Figure 7 where areas have recovered after forest disturbance (loss first, gain later), where areas have not recovered (loss), and where areas have added new forests (gain) (Figure 7).*




*"Figure 7 Global Forest Disturbance Characteristics. a is recovered forest area; b is unrecovered disturbed area; c is undisturbed forest area; d is newly added forest area. These results are presented on a grid of 1.5° × 2.5°, and note varying scales."*

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**Comment #8**

Section titles of 2.4.1 and 2.4.2 can be improved because readers don't know what are 'other types' of forest disturbance in contrast to those been described in 2.4.1. In this sense, the section title of 2.4.1 can be also improved to enhance readability. (**Revised**)

**Response #8**

*Thanks for your suggestion. We have revised the expression here (Page 9, Line 197; Page 10,*

*Line 211):*

***2.4.1 CART-based classification of core forest disturbance types***

***2.4.2 Identification of supplementary forest disturbance types***

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**Comment #9**

Section 2.3 describes how training samples are derived no? This should be made clear in its title. (**Revised**)

**Response #9**

*Thanks for your suggestion. We agree that the original title of Section 2.3 was not precise enough. We have now revised the title to "2.3 Derivation of training and validation sample points" to more clearly reflect the content of this section, which indeed describes the method for deriving the training samples.*

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**Comment #10**

Could you show a map describing the spatial distribution of the training samples? (**Revised**)

**Response #10**

*Thanks for your suggestion. We have presented the map describing the spatial distribution of the training samples in Appendix A (Page 20).*

*"The selection of sample points was primarily based on the time-series changes observed in Landsat images from 2000 to 2020, supplemented by historical high-resolution imagery from Google Earth. Through extensive analysis, eight types of forest disturbances were preliminarily identified: undisturbed (0), shifting cultivation disturbance (11), forestry replanting (12), plantation disturbance (13), deforestation of natural forests (14), forest fire disturbance (15), built-up area expansion (18), and cropland occupation (19). A total of 57,000 sample points representing these disturbance types were visually interpreted. These sample points are evenly distributed across global forest disturbance areas (Fig. A)."*

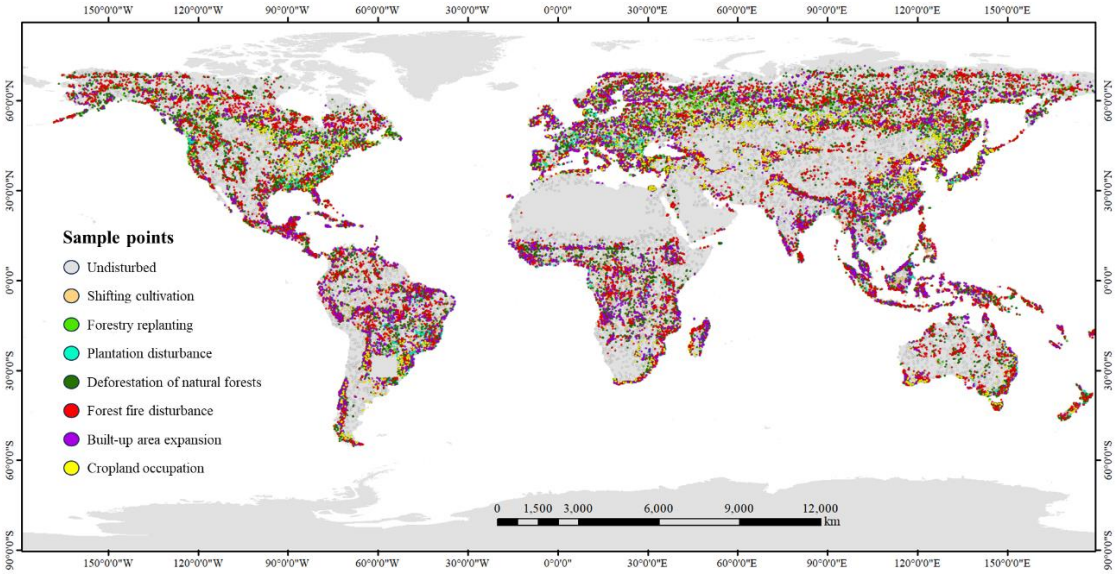


*Figure A Overall spatial consistency comparison with CDGFL under logarithmic scale.*

**Comment #11**

How the samples of 'shifting cultivation' are determined? This is critical because we know that this type is quite challenging. (**Revised**)

**Response #11**

*Thanks for your comments. We fully agree that accurately identifying shifting cultivation samples is among the most challenging tasks in remote sensing-based disturbance mapping. Our approach was designed specifically to address this complexity and ensure high sample purity. We have added a detailed selection process for migration agricultural samples in the manuscript (Page 9, Line 183-190):*

*"For the challenging distinction of 'shifting cultivation', its identification relied on detecting unique cyclical patterns in the time series. Interpreters were trained to confirm three key characteristics within the high-resolution historical imagery. (1) Clear cyclical boundaries: evidence of alternating phases of forest (fallow), clearing/burning (clearance), and crops (cultivation) on the same parcel of land over multiple years; (2) Short-cycle land cover change: a complete cycle typically lasts a few years, distinguishing it from permanent deforestation for agriculture; and (3) Small-scale and fragmented spatial patterns: shifting cultivation plots are usually small, irregularly shaped, and interspersed with patches of mature forest. Sample points were only designated as shifting cultivation if they met multiple of these criteria simultaneously to ensure accuracy."*

**Comment #12**

Fig. 6 & Fig. 7 should also show its spatial resolution. (**Revised**)

**Response #12**

*Thanks for your suggestion. We have added the resolution to the legend in Figure 6 &7. These*

*results are presented on a grid of 1.5° × 2.5° resolution.*

*"Figure 6: Global Typical Forest Disturbance Statistics. a. is the cropland occupation on forests; b. is the disturbance caused by forest fires; c. is the disturbance of shifting cultivation; d. is the disturbance of plantations (excluding oil palm). These results are presented on a grid of 1.5° × 2.5°, and note varying scales."*

*"Figure 7 Global Forest Disturbance Characteristics. a is recovered forest area; b is unrecovered disturbed area; c is undisturbed forest area; d is newly added forest area. These results are presented on a grid of 1.5° × 2.5°, and note varying scales."*

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**Comment #13**

Fig 7: How do you determine the disturbed but not recovered forests? i.e., panel b, by using land cover map time series described in the Methods section? (**Explained and Revised**)

**Response #13**

*Thanks for your comment. Yes, we determined the vegetation change trend after forest disturbance based on CCDC fitting. This is categorized as post-disturbance recovery patterns (PDP) in methods section (Page 4, Line 89-97). The characteristic indicators of this type can be found in Table 2, which can provide detailed information on the recovery of forest disturbances for subsequent machine learning models.*

*"These features were systematically derived from both temporal and spatial dimensions, including: Overall characteristics of forest disturbance (OC), pre-disturbance forest conditions (PDC), post-disturbance recovery patterns (PDP), disturbance potential metrics (DP), land use/cover features (LUC), spatial contextual attributes (SC). All feature variables were pre-processed in GEE and subsequently resampled to correspond with the 57,000 sample points. The classifier was locally trained using Python3.9, with rigorous validation performed at sample point locations. Our classification approach employed a decision tree-based machine learning algorithm (CART), with accuracy metrics quantitatively assessed using independent test sample points (Fig. 1)."*

*Table 2 Global Forest Disturbance Characteristics Indicator*

| Indicator type | Forest disturbance characteristic indicators | | |
|---|---|---|---|
| OC | Disturbance frequency | Average disturbance period | Number of segments |
| PDC | Linear intercept before disturbance | Internal fluctuations before disturbance | Interannual trend before disturbance |
| PDP | Linear intercept after disturbance | Internal fluctuations after disturbance | Interannual trend after disturbance |
| … | … | … | … |

*Methodologically, forests that have been disturbed but not restored are mainly those whose*

*CCDC fitting line segments have not shown an upward trend after disturbance, indicating that vegetation restoration has not been detected. In terms of disturbance types, it mainly includes farmland occupation, built-up area expansion, etc. After forests are cut down, their land use types are directly and permanently changed. Specifically in Figure 7, we combine all types of disturbances that have not been restored after disturbance, resulting in a disturbed but unrecovered forest.*