**Mixed method approaches to evaluate conservation impact: evidence from decentralized forest management in Tanzania**

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**APPENDIX 1**

**ANALYSIS OF FOREST DISTURBANCE**

**Materials and methods**

Four Landsat images were selected with near anniversary acquisition dates and time. The images were selected to cover a two-year period before and after the establishment of decentralized forest management in the two forests.

**Table S1** Overview of the four Landsat scenes chosen for the analysis

|  |  |  |
| --- | --- | --- |
| *Date* | *Time* | *Type of sensor*  |
| 10-02-1999 | 07:23:58 | Landsat 5–TM |
| 07-02-2001 | 07:35:10 | Landsat 7–ETM+ |
| 16-02-2004 | 07:33:53 | Landsat 7 - ETM+ (SLC-off) |
| 21-02-2006 | 07:34:51 | Landsat 7–ETM+(SLC-off) |

The scenes were calibrated by conversion from digital numbers (DNs) in absolute radiance to top-of-atmosphere reflectance. The polygons studied are placed at the centre of the ETM+ scenes and the data gap error caused by the ETM+ Scanline corrector issue (SLC-off) is therefore limited. We applied a single-band triangulation algorithm available for ENVI 4.8 to fill the data gaps in the scenes from 2004 and 2006 (Minara 2009). The scenes from before 2003 were not affected by SLC-off. All scenes were delivered with terrain-corrected quality (L1T) by the United States Geological Survey (USGS 2013). The spatial geometry was approved after visual assessment using known on-the-ground tie-points.

The scenes were atmospherically corrected by dark object subtraction. The forest polygons were covered by *c.* 10% clouds in 2001 and limited cloud cover in 1999, 2004 and 2006. Clouds and cloud shadows were masked with decision tree classification using band 1, 4 and 6.Breakpoints were found for each scene by comparing the mean +/- standard deviation of training pixels representing cloud, shade, wet areas and other ground features. For example clouds in the 2004 scene were defined by band 1 > 0.07 and cloud shade was defined by band 4 < 0.105. A buffer of 180 m was established around the masked clouds to avoid errors from cloud halos. Shade masks were given a 90 m buffer. Cloud masks from all four years were merged and applied to all scenes.

Tasselled cap transformation was applied to reduce the six Landsat bands into three indexes: brightness (B), greenness (G) and wetness (W). The disturbance index (DI) was calculated as a linear combination of the tasselled cap indices by first rescaling B, G and W in each image relative to the scene’s mean forest value (Healey *et al.* 2005). The DI indicates the location of each pixel in tasselled cap space and its position in relation to the predefined forest pixels.

DI = Br − (Gr + Wr) (1)

The re-scaling of each tasselled cap dimension to mean 0 and standard deviation 1 relative to the mean of forest pixels within each scene follows Eqs (2–4).

Br = (B − Bμ)/Bσ (2)

Gr = (G − Gμ)/Gσ (3)

Wr = (W − Wμ)/Wσ (4)

Pure forest pixels were defined as those pixels inside forest area polygons showing Mfyome and Kiwele Village Land Forest Reserves (VLFR) with normalized difference vegetation index (NDVI) above 0.656. The NDVI threshold of 0.656 masks the forest gaps in the area and ensures that non-forest pixels do not influence the normalization of tasselled cap dimensions for DI.

The normalization enables comparison of disturbance indexes across scenes and hence across time, because any disturbance is relative to the pure forest pixels of that particular year. In boreal forests DI thresholds of 2–5 are often applied to define disturbance (Masek *et al*. 2008). We applied DI 3 to define disturbance in this particular area. The choice was verified by visual inspection of ground features using a pan-sharpened Quickbird scene from 2003 (spatial resolution 0.6 m).

We used decision tree classification to establish disturbance maps with DI > 3 and computed change maps and change statistics for 1999–2001 and 2004–2006.

We calculated change statistics for subdivisions inside the forest that relate to various settlements’ use of the forest. This enables further analysis and explanation of the observed changes.

*Description of subdivisions*

* Mfyome VLFR 1: Mfyome’s charcoal production site. Defined by a radius of 3000 m from the southern entry point into Mfyome VLFR from Mfyome settlement.
* Mfyome VLFR 2: The hamlet of Matembo’s extraction area. A radius of 5000 m from the eastern corner of Mfyome VLFR connected to the Matembo settlement.
* Mfyome VLFR 3: The northern part of Mfyome VLFR.
* Kiwele VLFR 1: Kiwele extraction site defined as a 5000 m radius from the south eastern border at the point closest to Kiwele village.
* Kiwele VLFR 2: A radius of 1500 m around the hamlet of Mlambalasi.
* Kiwele VLFR 3: The northernmost part of Kiwele VLFR.

**Results**

There was overall decrease and increase in forest disturbance levels in Mfyome VLFR and Kiwele VLFR, respectively (Table S2).

Table S2 Area affected by new disturbance (Delta DI > 3) in each two-year period per forest and sub-division.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| *Sub-division and forest* |  | *1999–2001* |  | *2004–2006* |  | *Change (ha)* |
| *Forest* | *Total (ha)* |  | *Delta DI > 3 (ha)* | *%**disturbance* |  | *Delta DI > 3 (ha)* | *% disturbance* |  |
| Mfyome VLFR 1 | 859.5 |  | 47.0 | 5.5 |  | 12.7 | 1.5 |  | -34.3 |
| Mfyome VLFR 2 | 1523.7 |  | 100.5 | 6.6 |  | 53.1 | 3.5 |  | -47.4 |
| Mfyome VLFR 3 | 3686.9 |  | 45.6 | 1.2 |  | 81.4 | 2.2 |  | 35.7 |
| Mfyome VLFR total | 6070.1 |  | 193.1 | 3.2 |  | 147.2 | 2.4 |  | -46.0 |
| Kiwele VLFR 1 | 2050.6 |  | 16.4 | 0.8 |  | 66.8 | 3.3 |  | 50.4 |
| Kiwele VLFR 2 | 342.8 |  | 1.3 | 0.4 |  | 14.0 | 4.1 |  | 12.8 |
| Kiwele VLFR 3 | 2515.6 |  | 15.5 | 0.6 |  | 12.0 | 0.5 |  | -3.5 |
| Kiwele VLFR total | 4909.0 |  | 33.1 | 0.7 |  | 92.8 | 1.9 |  | 59.7 |

In Mfyome VLFR, disturbance shifted from former production sites in the southern and eastern parts of the forest (Fig. S1, M1&2) to the north-west corner (Fig. S1, M3). In Kiwele VLFR, the large increase in disturbance in the southern part of the forest (Fig. S1, K1) is partly caused by a difference in forest boundaries as established and marked on the ground with the Kiwele VLFR forest polygon, which was obtained from the Iringa district forest office. The inaccuracy occurred as data based on GPS measurements set for Arc\_1960 was converted to WGS 84 for display with satellite data. This boundary displacement has a crucial impact on the disturbance statistics (Fig. S2). Of the total area of disturbed land in Kiwele VLFR in 2004–2006 (92.8 ha) a large proportion falls within the ‘confusion zone’, namely within an area that people in Kiwele do not consider as part of the PFM forest. Second, there has been a steep increase in disturbance around the hamlet Mlambalasi (Fig. S1, K2). Yet, this is caused almost entirely by a planned expansion of the settlement in 2002 (Fig. S3).

Figure S1 Geographic placement of DI > 3 pixels in (*a*) 1999–2001 and (*b*) 2004–2006. The VLFRs are divided into sub-areas for interpretation of the change in disturbance. For example, M1 is the charcoal extraction area in Mfyome and K2 is an expanding settlement in Kiwele.

Figure S2 Demarcation of the ‘confusion zone’ in the south eastern corner of Kiwele VLFR.

Figure S3 Disturbance (Delta DI > 3) in 2004–2006 with demarcation of the ‘settlement expansion zone’ in Kiwele VLFR 2.

**References**

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