Warsaw University of Life Sciences WULS – SGGW
in Warsaw
Faculty of Forestry

Eberswalde University for Sustainable Development – HNEE
University of Applied Sciences
Faculty of Forest and Environment

Tobias Seydewitz
Album number SGGW: 178311
Album number HNEE: 15210024

Kompleksowa analiza wylesiania w krajach tropikalnych - bezpośrednie czynniki wylesiania, emisje dwutlenku węgla i równowaga wartości usług ekosystemów

A comprehensive study on deforestation in the tropics - direct deforestation drivers, carbon emissions and ecosystem service value balance

Master's Thesis
on the course of - Forestry

Thesis written under the supervision of
Dr. Prajal Pradhan
Potsdam Institute of Climate Impact Research
Research Domain II - Climate Climate Impacts & Vulnerabilities

Potsdam, 2018

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Zusammenfassung

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Schlüsselwörter: Text

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1 Introduction

1.1 Tropical forest

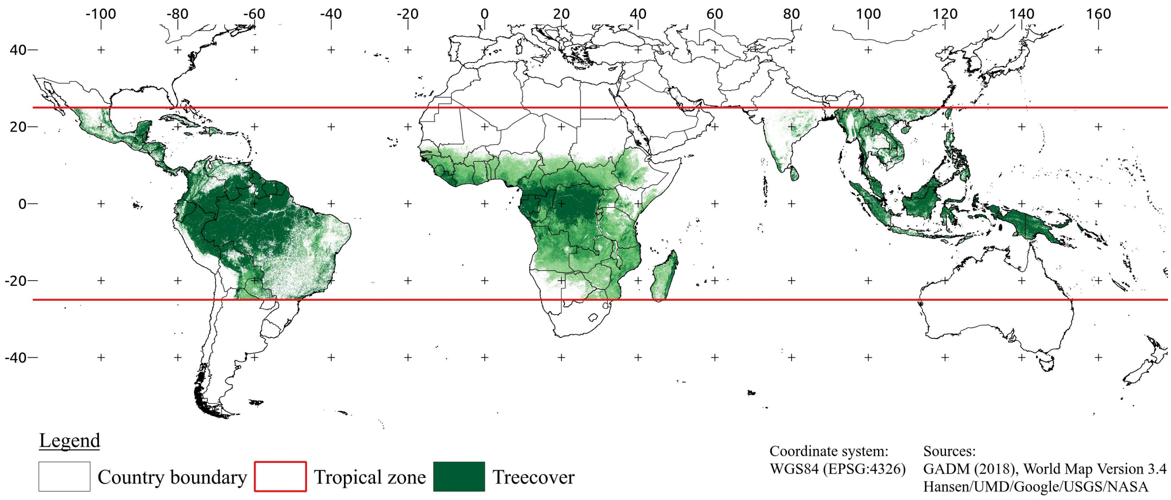

Figure 1.1: Geographic tropical zone framed red and the tropical forest

1.1.1 Current state

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1.1.2 Contribution to climate

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1.1.3 Forest definitions

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1.2 Deforestation

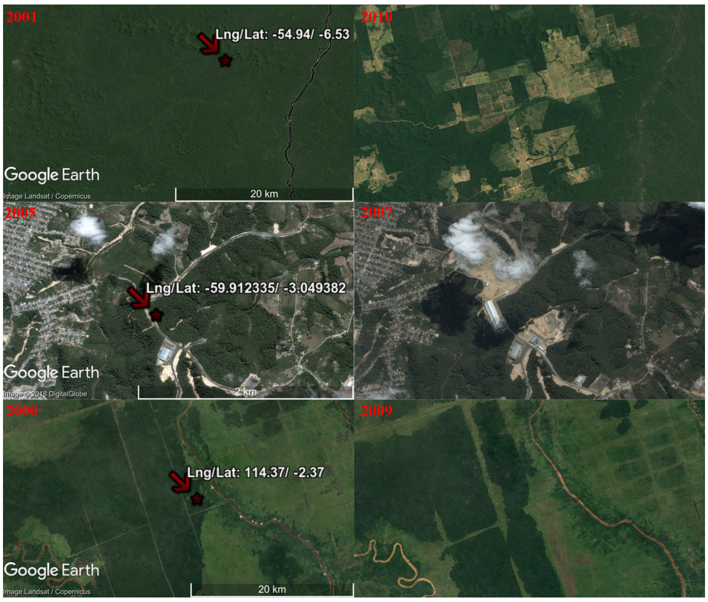

Figure 1.2: Upper Brazil agriculture, middle Brazil urbanization, lower Indonesia large scale palm oil plantations

1.2.1 Land use and land cover change

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1.2.2 Drivers of deforestation

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1.2.3 Emissions trough deforestation

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1.2.4 Removal of AGB

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1.2.5 Soil organic carbon change and soil dynamics

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1.3 Ecosystem services

1.3.1 Ecosystem service values

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1.3.2 Research objective and questions

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2 Data and methods

2.1 Data

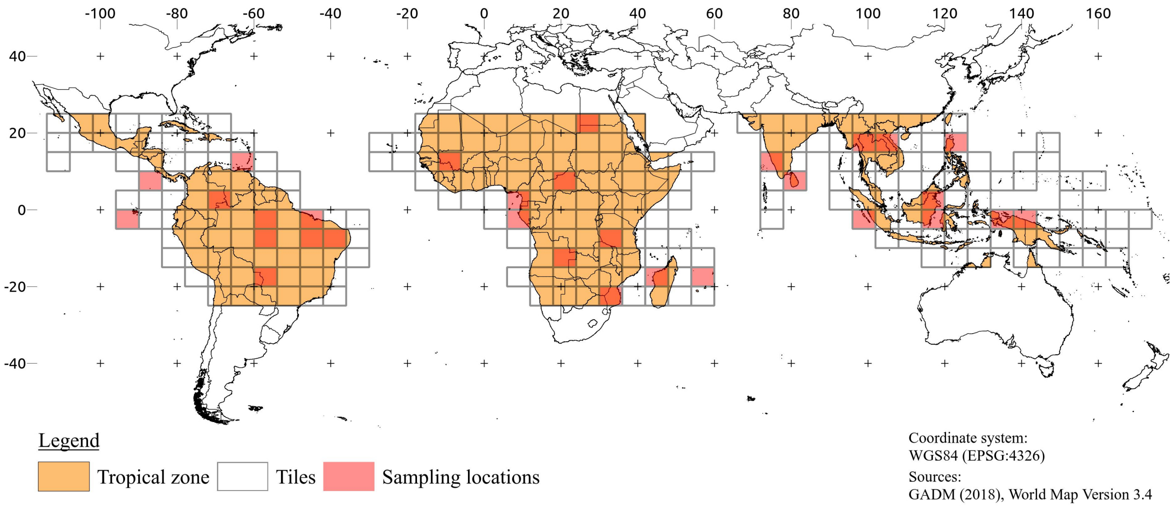

Figure 2.1: Study extent and raster image tiles

2.1.1 Spatial data

2.1.1.1 Global Forest Change

Global Forest Change (GFC) 2000-2012 Version 1.0 is the first high resolution dataset that provides a comprehensive view on the annual global forest cover change between 2000 and 2012 (Hansen et al. [2013a]; Li et al. [2017]). The initial GFC dataset released by Hansen et al. is extended by recent releases which encompass the annual forest cover changes between 2000-2013, 2000-2014, 2000-2015 and 2000-2016, respectively. All versions of this dataset have in common, that they are derived from growing season imagery captured by the remote sensing satellite Landsat 7 Enhanced Thematic Mapper Plus (ETM+) at a spatial resolution of 30 meters per pixel (Hansen et al. [2013b]). On the satellite imagery a time-series spectral metrics analysis is applied to gather the global forest extent at 2000 as well as the annual forest loss and gain. Hence, GFC comprises three independent data layers tree cover, annually forest loss and forest gain divided into 10x10 degree tiles by the geodetic coordinate system World Geodetic System 1984 (EPSG:4326). Furthermore, across the provided layers the pixel data is coded in unsigned 8 bit integers. Hansen et al. defined trees as all vegetation taller than 5 meters for their study. Forest loss is defined as a stand displacement disturbance leading from a forest state to a non forest-state. To compute this losses.

2.1.1.2 GlobeLand30

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2.1.1.3 Intact Forest Landscapes

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2.1.1.4 Aboveground Woody Biomass

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2.1.1.5 Global Soil Organic Carbon

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2.1.1.6 Auxiliary

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2.1.2 Empirical data

2.1.2.1 Soil Organic Carbon

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2.1.2.2 Ecosystem Service Values

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2.2 Methods

2.2.1 Pre-processing

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2.2.2 Deforestation

2.2.2.1 Forest definition

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2.2.2.2 Land use change driver

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2.2.2.3 Accuracy assessment

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2.2.3 Emissions

2.2.3.1 Above ground biomass

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2.2.3.2 Soil organic carbon change

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2.2.4 Ecosystem service values

2.2.4.1 Ecosystem service value loss

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2.2.4.2 Ecosystem service value gain

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2.2.5 Binning analysis

The previous sections were focused on the generation of large scale spatial data. Now, a feasible method must be developed for analyzing, aggregating, interpreting and visualizing the output data. To develop a good approach we must formalize the problem domain. At first we are confronted with large N (many samples) which results in many variables (dimensionality) and complexity of relationships among this variables [Carr 1990]. From a visual/analytical perspective georeferenced raster maps can be interpreted as a multivariate scatter plot of large datasets where longitude and latitude represent the x and y coordinate of an data point and the pixel values (in this case nominal scaled) representing the third dimension as an group coloring. Therefore we have a large multidimensional dataset combined with a scatter plot visualization which leads commonly to over plotting issues and hidden point densities [Carr et al. 1987]. Due to the spatial nature of your data we are also confronted with not equal distributed data some regions show high data densities and other regions have spares to no data. Also a severe problem domain is the frame size of our representation. Goal is to present data on a continental level which intensifies visual problems. Each pixel has a resolution of approximately 30x30m, the continental representation of americas spanning approximately 1200000x120000km2. Therefore small scale isolated changes are hidden and only large scale changes are visual detectable. Which results in hidden details and not perceivable patterns of change.

Goal should be to develop an process who solve this issues and generates satisfying output for our multivariate data. In case of raster data a re-sampling to coarser resolution could solve over plotting and resolution issues as well normalize the unequal distributed data. But the nature of re-sampling (for nominal data a nearest neighbor or majority wins Reference) would negate important spatial patterns as well frequency distributions. Another well known approach is to use binning of the spatial explicit data with a certain kind of regular polygon that is tessellating the plane [Carr et al. 1992]. Polygon tessellations provide numerous opportunities for presenting multivariate statistical summaries. The scaling of the polygon could be used to represent pixel densities within the polygon area, a polygon filling color gradient is applicable to show nominal or ordinal scaled data. Also it is imaginable to use the polygon interior for a pie chart. To use regular tessellation it is important to mention there are only three types of regular polygons tessellate the plane: squares, equilateral triangles and hexagons [Carr et al. 1992]. Square tessellation is the most common approach used for binning in spatial visualization. A raster image is a square tessellation. In a square mosaic each polygon shares 4 edge neighbors and 4 vertex neighbors more explanation error distance disadvantages etc. Hexagons properties, advantages disadvantages of both tessellations, what are your visuals scaled and pie, mention polygon literature

To be flexible at hexagon construction we accept 4 different parameters as construction arguments: D long diagonal (Diameter of the circumscribing circle), d short diagonal (diameter of the inscribed circle), A area the hexagon should span and or e the edge length. One selected parameter of these is used to compute R the radius of the circumscribing circle with respect to input parameter as shown in equation 2.1. R is used to calculate the midpoint $< c_x, c_y >$ of the hexagon located in the first quadrant of the cartesian coordinate system Equation 2.2 and 2.3. Equation 2.4 shows the computation of the hexagon anti-clockwise vertex matrix. Whereas the two leftmost vertices (first and last row of the matrix **H**) are located at koordinatenursprung, will sagen auf deutsch korridanten at x=0 und y=value of matrix. In summary equation 2.1 to 2.4 show the creation of an hexagon at the leftmost corner of first quadrant. The orientation is important for the subsequent mosaic creation.

$$R = \frac{\sqrt{2A}}{\sqrt[4]{27}} = \frac{D}{2} = \frac{d}{\sqrt{3}} = e \tag{2.1}$$

$$c_x = \frac{R\sqrt{3}}{2} \tag{2.2}$$

$$c_y = R \tag{2.3}$$

$$\mathbf{H} = \begin{bmatrix} 0 & c_x & 2c_x & 2c_x & c_x & 0 \\ R\sin\left(\frac{7\pi}{6}\right) + c_y & 0 & R\sin\left(\frac{11\pi}{6}\right) + c_y & R\sin\left(\frac{\pi}{6}\right) + c_y & 2R & R\sin\left(\frac{5\pi}{6}\right) + c_y \\ 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \tag{2.4}$$

A polygon tessellation needs several polygons to create a grid in case of the creation of one hexagon with the presented algorithm needs approximately benchmark but the creation of several N hexagons needs approximately benchmark. Therefore it is much simpler to create only one hexagon with the presented algorithm and to create the grid polygons by copying the coordinates of the source polygon and translating them to their target position with a affine transformation matrix shown in equation 2.5. To create the grid we get the rectangular bounds of the area to tessellate as a matrix $\mathbf{B} \in R^{2\times 2}$ (equation 2.6), where the first column of the matrix contains the lower left corner and the second column the upper right corner of the image. Each subsequent translation in regards of x_{off} is $x_1 + d$

$$\mathbf{T} = \begin{bmatrix} 1 & 0 & x_{off} \\ 0 & 1 & y_{off} \\ 0 & 0 & 1 \end{bmatrix} \circ \mathbf{H} \tag{2.5}$$

Here comes the description of the segmentation process

$$\mathbf{B} = \begin{bmatrix} x_1 & x_2 \\ y_1 & y_2 \end{bmatrix} \tag{2.6}$$

$$R = \frac{\sqrt{2A}}{\sqrt[4]{27}} \tag{2.7}$$

$$y = \frac{P(y_2 - y_1)}{100} + y_1 \tag{2.8}$$

$$f^{-1}(y) = \begin{cases} -\frac{y-y_1}{\tan\left(\frac{\pi}{6}\right)} + \frac{x_1+x_2}{2} & \text{if } y_1 \le y < y_1 + R\sin\left(\frac{5\pi}{6}\right) \\ x_1 & \text{if } y_1 + R\sin\left(\frac{5\pi}{6}\right) \le y < R\left(\sin\left(\frac{5\pi}{6}\right) + 1\right) \\ \frac{y-y_2}{\tan\left(\frac{\pi}{6}\right)} + \frac{x_1+x_2}{2} & \text{if } R\left(\sin\left(\frac{5\pi}{6}\right) + 1\right) \le y \le y_2 \end{cases} \tag{2.9}$$

$$g^{-1}(y) = \begin{cases} \frac{y-y_1}{\tan\left(\frac{\pi}{6}\right)} + \frac{x_1+x_2}{2} & \text{if } y_1 \le y < y_1 + R\sin\left(\frac{5\pi}{6}\right) \\ x_2 & \text{if } y_1 + R\sin\left(\frac{5\pi}{6}\right) \le y < R\left(\sin\left(\frac{5\pi}{6}\right) + 1\right) \\ -\frac{y-y_2}{\tan\left(\frac{\pi}{6}\right)} + \frac{x_1+x_2}{2} & \text{if } R\left(\sin\left(\frac{5\pi}{6}\right) + 1\right) \le y \le y_2 \end{cases} \tag{2.10}$$

$$\mathbf{L} = \begin{bmatrix} f^{-1}(y) & g^{-1}(y) \\ y & y \end{bmatrix} \tag{2.11}$$

Need alternative computational not so intensive approach, do it

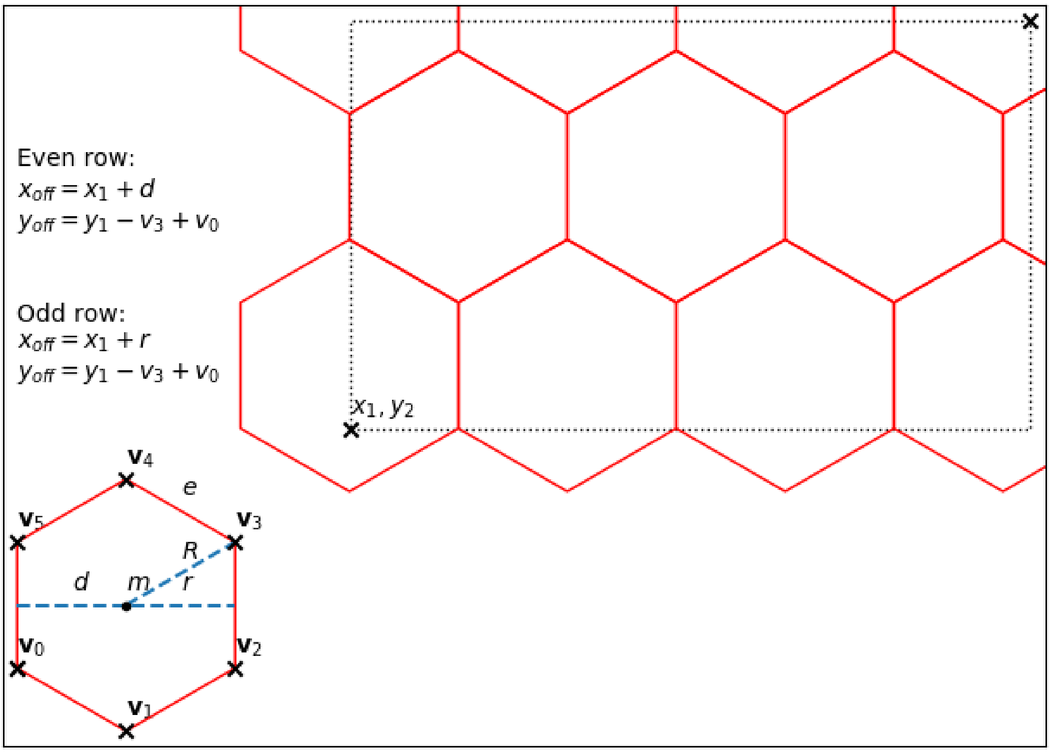

Figure 2.2: Study extent and raster image tiles

3 Results

3.1 Forest definition and accuracy assessment

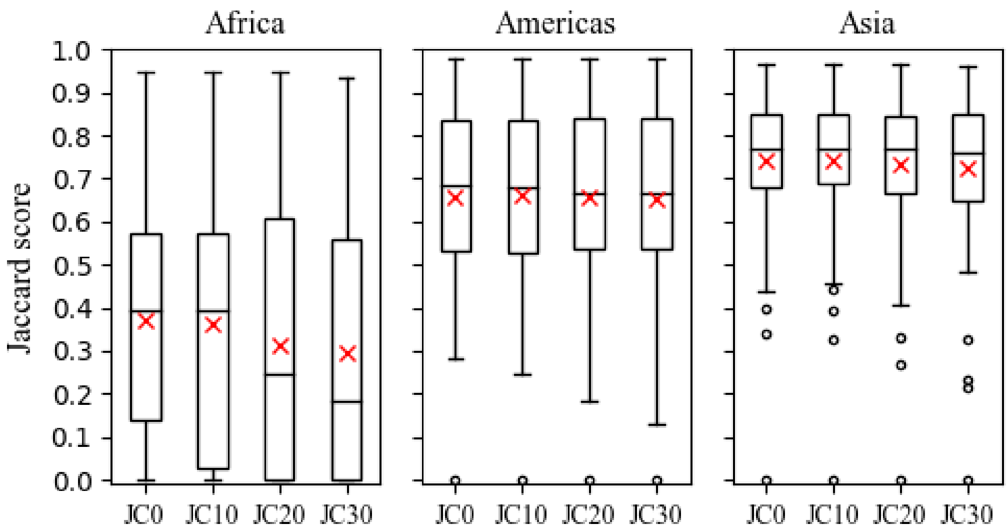

Figure 3.1: Jaccard score to determine tree cover similarity used to develop forest definition

Table 3.1: Confusion matrix for accuracy assessment

		Reference											
	Cls	10	20	25	30	40	50	60	80	90	Tot	UAc	Om
Prediction	10	732	38	62	15	16	2	3	5	0	873	.84	.16
	20	42	751	57	189	31	12	0	17	4	1103	.68	.32
	25	29	202	1155	173	22	10	5	11	4	1611	.72	.28
	30	36	187	32	1466	73	21	0	17	0	1832	.80	.20
	40	14	21	4	41	352	1	1	2	1	437	.81	.19
	50	0	5	3	10	4	50	0	1	0	73	.68	.32
	60	2	1	0	3	0	2	18	2	0	28	.64	.36
	80	3	4	0	1	1	1	0	50	0	60	.83	.17
	90	0	0	0	1	0	0	0	3	5	9	.56	.44
	Tot	858	1209	1313	1899	499	99	27	108	14	6026		
	PAc	.85	.62	.88	.77	.71	.51	.67	.46	.36			OvAc
	Com	.15	.38	.12	.23	.29	.49	.33	.54	.64			.75

3.2 Deforestation drivers

3.2.1 Global

Table 3.2: Absolute in km^2

Type	Class		Americas	Asia	Africa
Agriculture	Cropland	rel.	24.37	18.37	25.01
		abs.	95908	38719	44368
	Grassland	rel.	46.19	8.41	50.46
		abs.	181781	17726	89516
Forestry/Plantations	Regrowth	rel.	14.40	70.27	18.61
		abs.	56671	148111	33014
	Shrubland	rel.	12.69	1.11	3.77
		abs.	49941	2340	6688
Urban/Mining	Artificial	rel.	0.41	0.46	0.71
		abs.	1614	970	1260
	Bareland	rel.	0.10	0.03	0.09
		abs.	394	63	160
Natural	Wetland	rel.	1.50	0.97	1.23
		abs.	5903	2045	2182
	Water	rel.	0.32	0.38	0.13
		abs.	1259	801	231
Forest loss		rel.	3.87	4.68	1.69
		abs.	393550	210774	177400
Forest cover		abs.	10223187	4457940	10496591

3.2.2 Americas

3.2.3 Asia

3.2.4 Africa

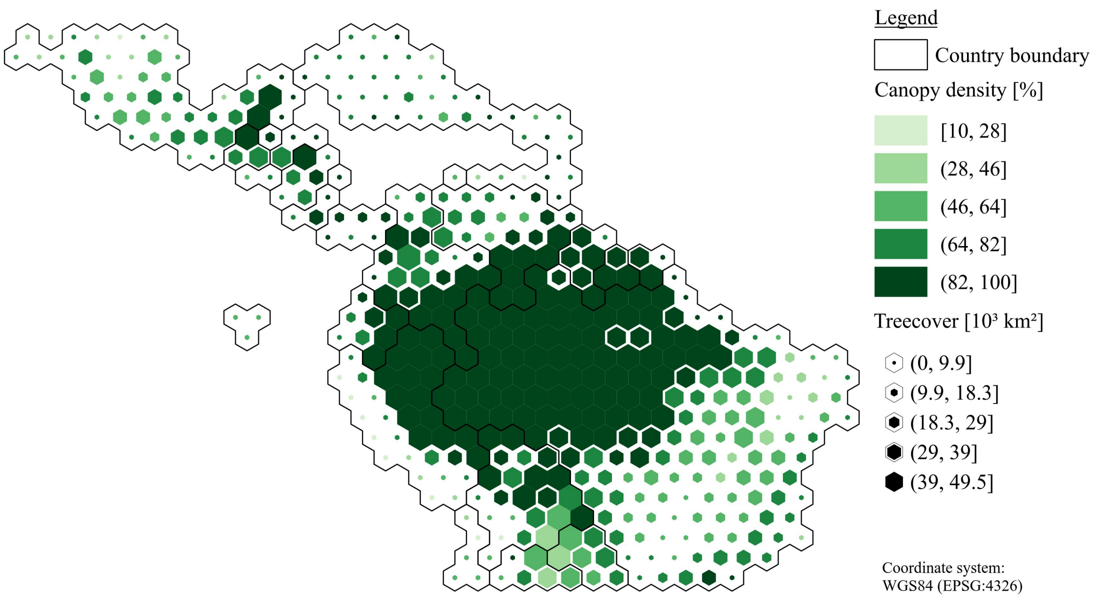

Figure 3.2:

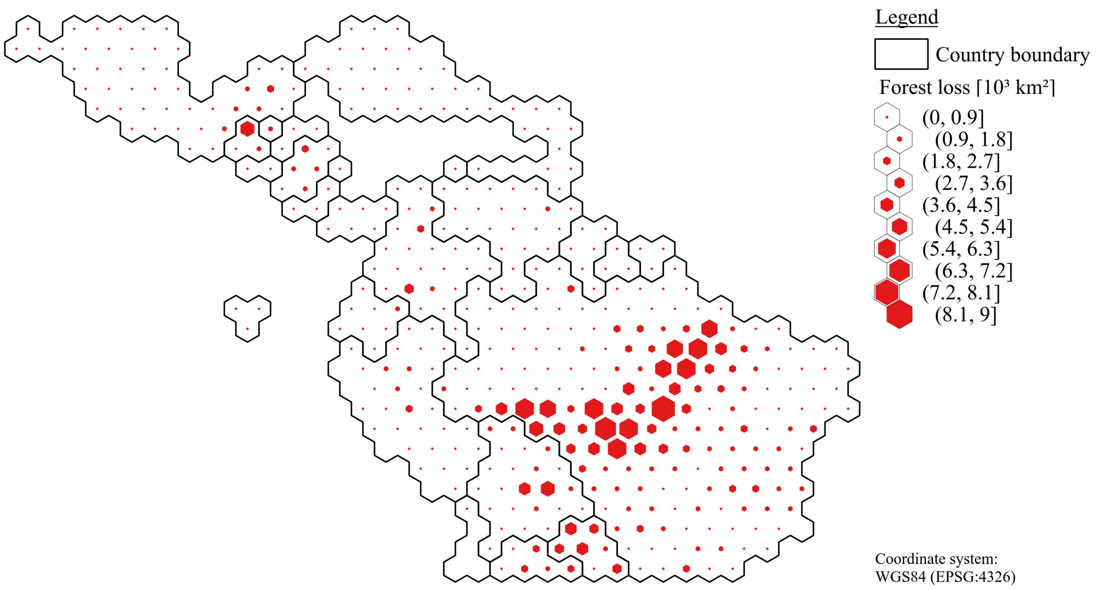

Figure 3.3:

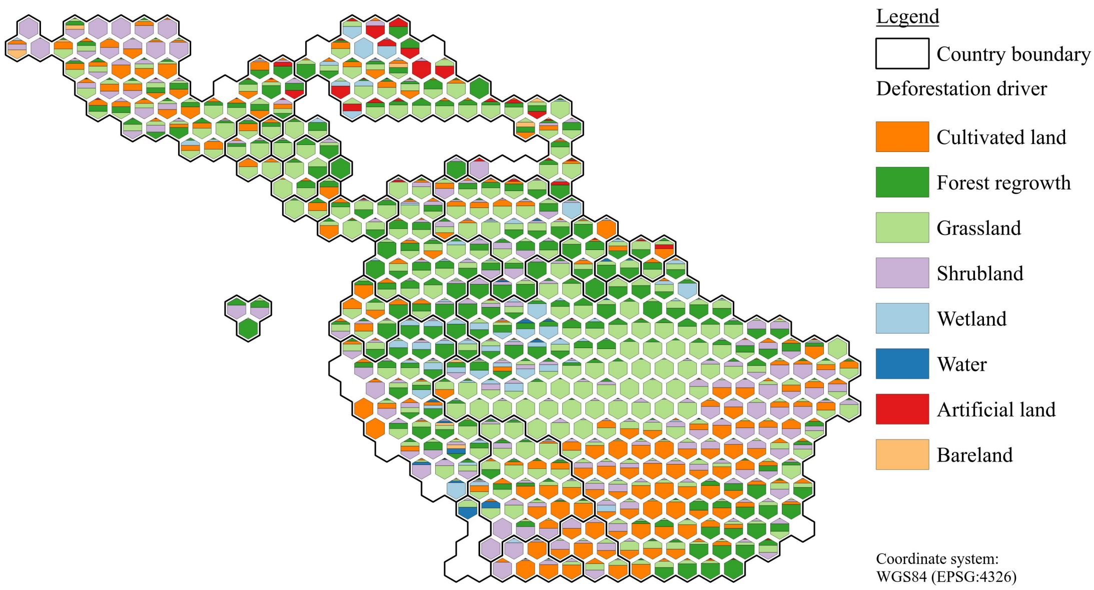

Figure 3.4:

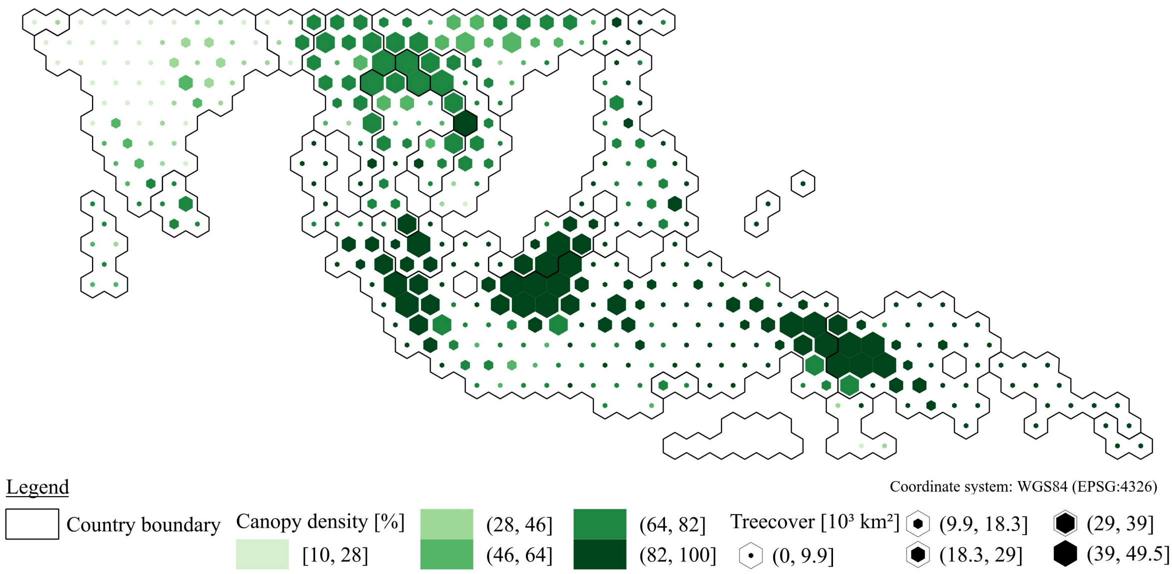

Figure 3.5:

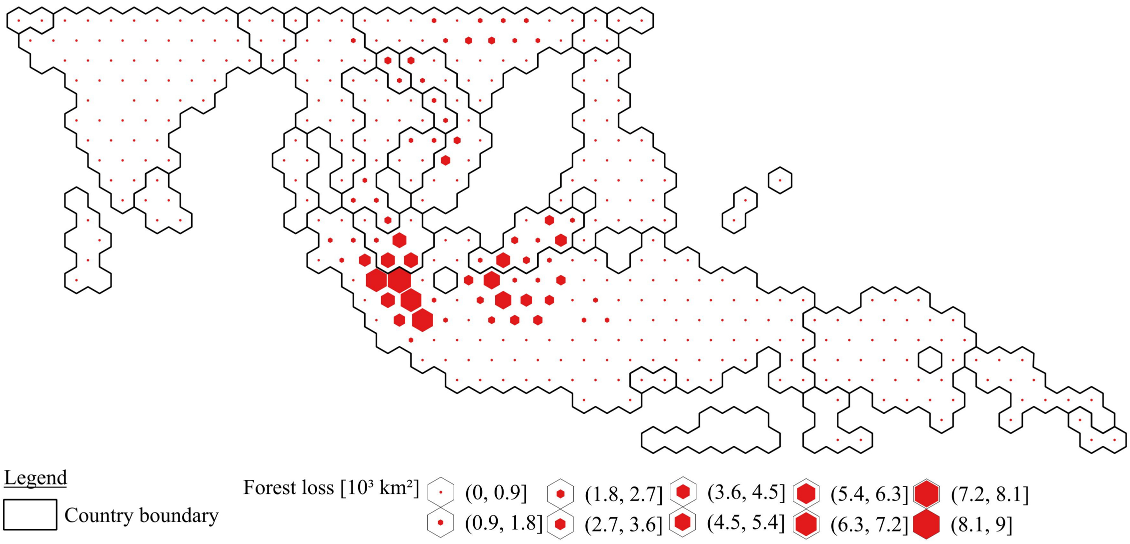

Figure 3.6:

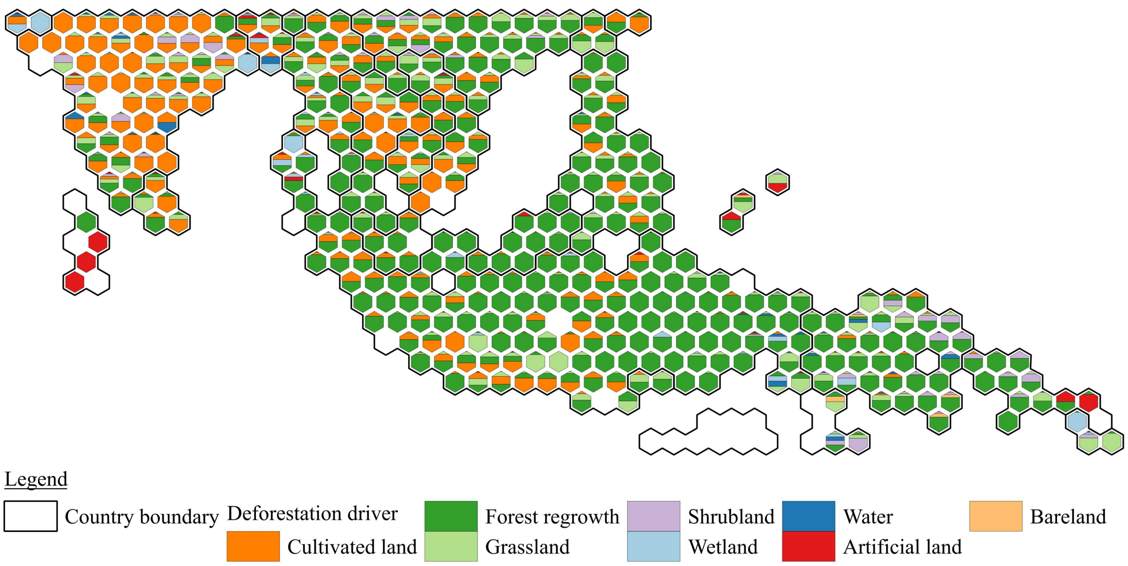

Figure 3.7:

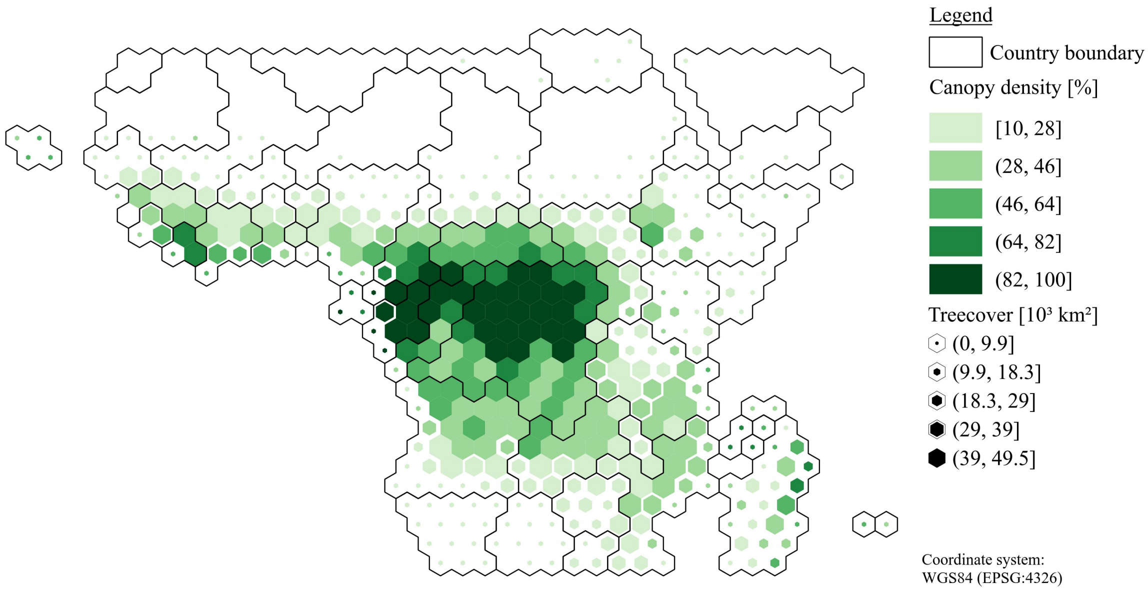

Figure 3.8:

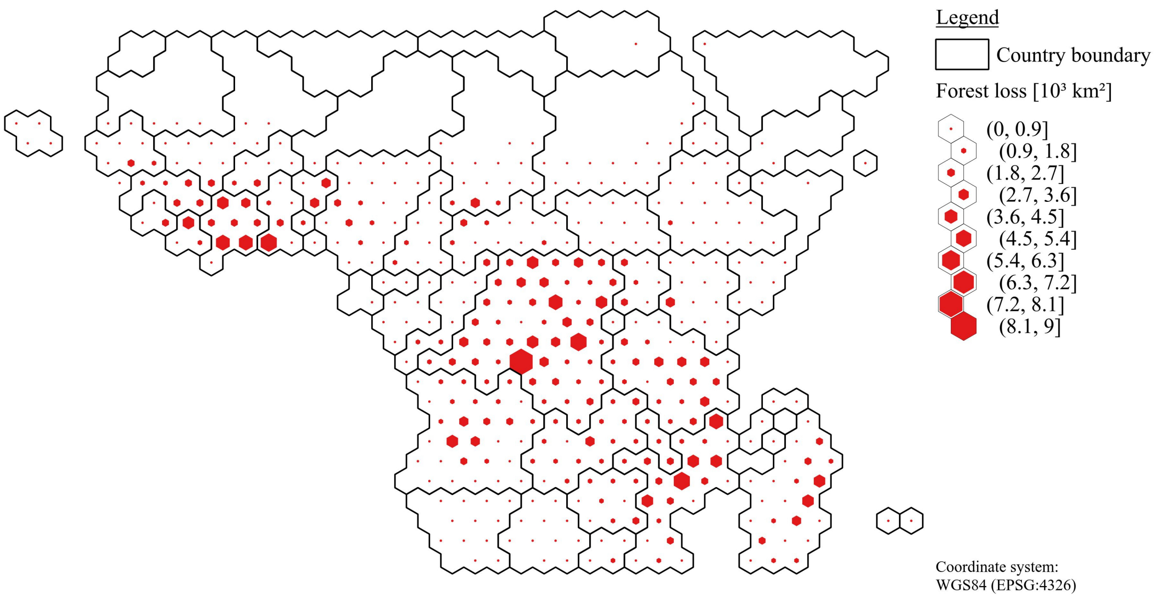

Figure 3.9:

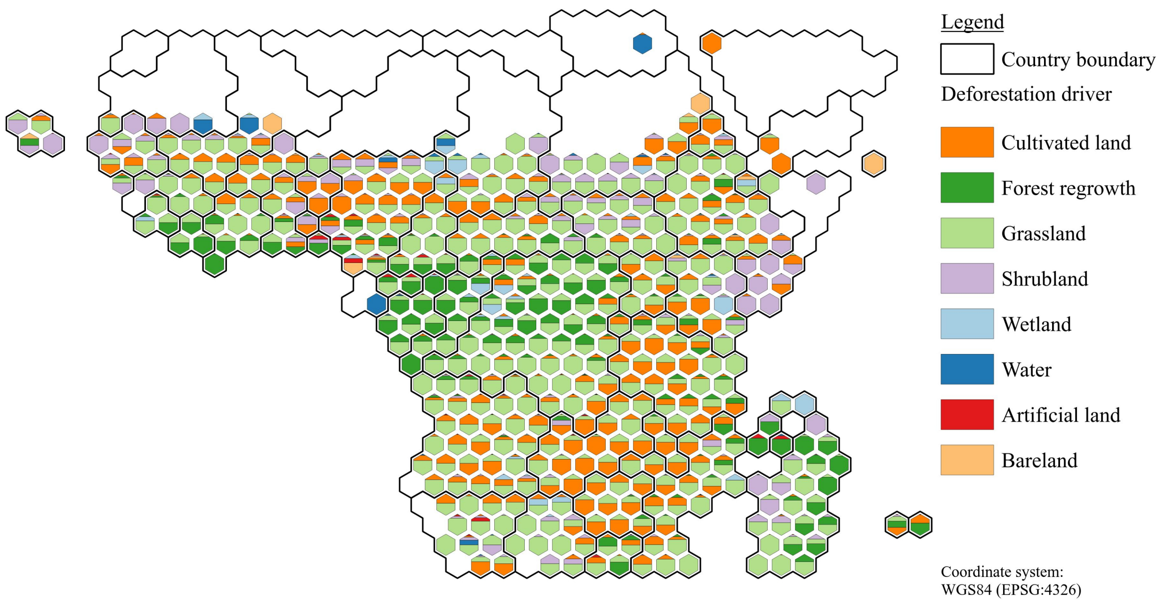
Legend
Country boundary
Deforestation driver
Cultivated land
Forest regrowth
Grassland
Shrubland
Wetland
Water
Artificial land
Bareland
Coordinate system:
WGS84 (EPSG:4326)

Figure 3.10:

3.3 Defore

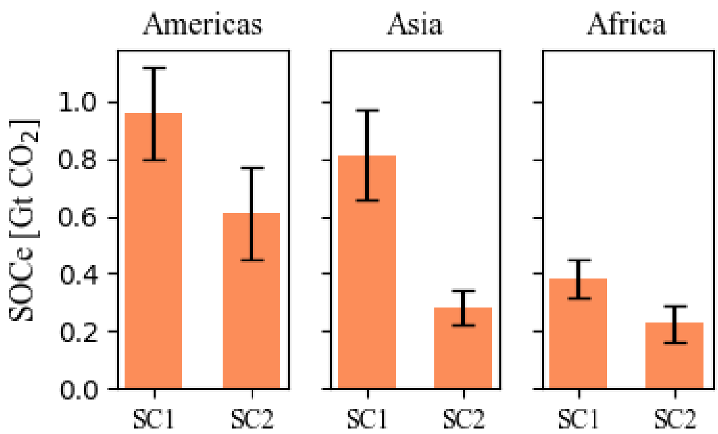

Figure 3.12:

Table 3.3: Soil organic carbon emissions

Region	SC1 [Gt CO_2]			SC2 [Gt CO_2]			SC3 [Gt CO_2]		
	min	mean	max	min	mean	max	min	mean	max
Americas	0.80	0.96	1.12	0.45	0.61	0.77	0.43	0.59	0.76
Asia	0.66	0.81	0.97	0.22	0.28	0.34	0.22	0.28	0.33
Africa	0.32	0.39	0.45	0.17	0.23	0.29	0.16	0.23	0.29

3.3.1 Global

3.3.2 Americas

3.3.3 Asia

3.3.4 Africa

3.4 Ecosystem service value balance

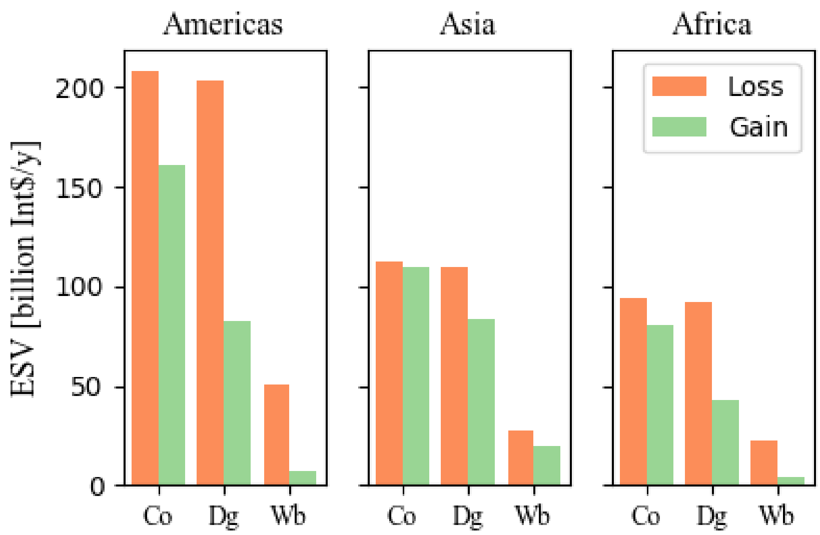

Figure 3.13:

3.4.1 Global

3.4.2 Americas

3.4.3 Asia

3.4.4 Africa

4 Discussion

Acknowledgements

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List of Abbreviations

FAO	Food and Agriculture Organization of the United Nations
GFC	Global Forest Change
GIS	Geographic Information System
GLC30	GlobeLand30
GTiff	Geo-Tiff
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use/Land Cover
POK	Pixel-Object-Knowledge
R-PIN	Readiness Plan Idea Note
R-PP	Readiness Preparation Proposal
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

Appendix

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