

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

Oświadczenie promotora pracy

Oświadczam, że niniejsza praca została przygotowana pod moim kierunkiem i stwierdzam, że spełnia warunki do przedstawienia tej pracy w postępowaniu o nadanie tytułu zawodowego.

Declaration of the promoter

I declare that this thesis was prepared under my supervision and I state that it meets the conditions for presenting such a body of work in the process of obtaining a professional title.

Erklärung des Betreuers

Hiermit erkläre ich, dass die vorliegende Arbeit, unter meiner Leitung erstellt wurde und ich bestätige, dass sie die Bedingungen zur Verleihung des Abschlussdiploms erfüllt.

Data	Podpis promotora pracy
Date	Signature of the promoter
Datum	Unterschrift des Betreuers

Oświadczenie autora pracy

Świadom odpowiedzialności prawnej, w tym odpowiedzialności karnej za złożenie fałszywego oświadczenia, oświadczam, że niniejsza praca dyplomowa została napisana przeze mnie samodzielnie i nie zawiera treści uzyskanych w sposób niezgodny z obowiązującymi przepisami prawa, w szczególności ustawą z dnia 4 lutego 1994 r.o prawie autorskim i prawach pokrewnych (Dz. U. Nr 90 poz. 631 z późn. zm.).

Oświadczam, że przedstawiona praca nie była wcześniej podstawą żadnej procedury związanej z nadaniem dyplomu lub uzyskaniem tytułu zawodowego test. Lorem ipsum dolores anno sacntum

Oświadczam, że niniejsza wersja pracy jest identyczna z załączoną wersją elektroniczną. Przyjmuję do wiadomości, że praca dyplomowa poddana zostanie procedurze antyplagiatoowej.

Declaration of the author

Aware of the legal liability, including criminal liability for submitting a false statement, I declare that this thesis was written by myself alone and does not contain content obtained in a manner breaking applicable laws, in particular the Act of February 4, 1994 on copyright and related rights (Journal of Laws, no. 90, item 631, as amended).

I certify that the work has not previously been the basis for any procedure in connection with obtaining a diploma or professional title.

I declare that this version of the work is identical with the attached electronic version.

I acknowledge that the thesis is subject to anti-plagiarism procedures.

Erklärung des Autors

Gesetzlicher Haftpflicht, besonders der strafrechtlichen Verantwortlichkeit für Abgabe der falschen Erklärung bewusst, erkläre ich hiermit, dass vorliegende Diplomarbeit selbständig angefertigt wurde und keinen Inhalt enthält, der widerrechtlich erworben wurde, insbesondere nicht mit dem Gesetz über Urheberrecht vom 4. Februar 1994 (GB. Nr. 90, Pos. 631 mit späteren Änderungen) übereinstimmend.

Ich erkläre auch, dass die Arbeit bisher keiner anderen Prüfungsbehörde vorgelegt wurde.

Der Durchführung einer elektronischen Plagiatsprüfung stimme ich hiermit zu. Die eingereichte elektronische Fassung der Arbeit entspricht der eingereichten schriftlichen Fassung exakt.

Data	Podpis autora pracy
Date	Signature of the author
Datum	Unterschrift des Autors

Streszczenie

Tytuł: Text

Text

Słowa kluczowe: Text

Summary

Title: Text

Text

Keywords: Text

Zusammenfassung

Titel: Text

Text

Schlüsselwörter: Text

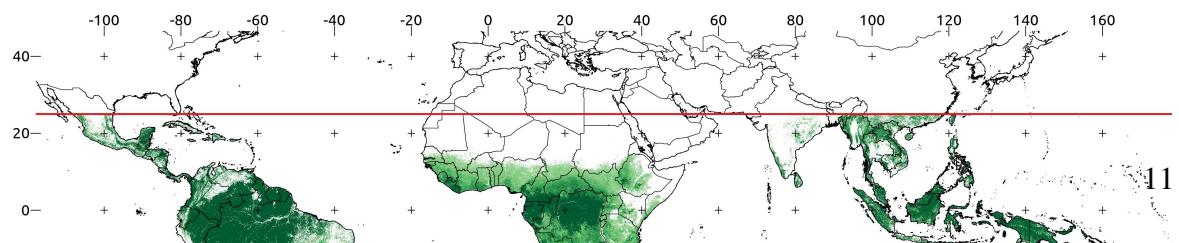
Contents

1	Introduction	11
1.1	Tropical forest	11
1.1.1	Current state	12
1.1.2	Contribution to climate	12
1.1.3	Forest definitions	12
1.2	Deforestation	12
1.2.1	Land use and land cover change	12
1.2.2	Drivers of deforestation	12
1.3	Emissions through deforestation	12
1.3.1	Removal of AGB	12
1.3.2	Soil organic carbon change and soil dynamics	12
1.4	Ecosystem services	12
1.4.1	Ecosystem service values	12
1.5	Research objective and questions	12
2	Data and methods	13
2.1	Data	13
2.1.1	Spatial data	13
2.1.1.1	Global Forest Change	13
2.1.1.2	GlobeLand30	13
2.1.1.3	Intact Forest Landscapes	13
2.1.1.4	Aboveground Woody Biomass	13
2.1.1.5	Global Soil Organic Carbon	13
2.1.1.6	Auxiliary	13
2.1.2	Empirical data	13
2.1.2.1	Soil Organic Carbon	13
2.1.2.2	Ecosystem Service Values	14
2.2	Methods	14
2.2.1	Pre-processing	14
2.2.2	Deforestation	14
2.2.2.1	Forest definition	14
2.2.2.2	Land use change driver	14
2.2.2.3	Accuracy assessment	14
2.2.3	Emissions	14
2.2.3.1	Above ground biomass	14
2.2.3.2	Soil organic carbon change	14
2.2.4	Ecosystem service values	14
2.2.4.1	Ecosystem service value loss	14
2.2.4.2	Ecosystem service value gain	14
2.2.5	Binning analysis	15
3	Results	16
3.1	Forest definition and accuracy assessment	16
3.2	Deforestation drivers	17
3.2.1	Global	17

3.2.2	Americas	17
3.2.3	Asia	17
3.2.4	Africa	17
3.3	Deforestation emissions	23
3.3.1	Global	24
3.3.2	Americas	24
3.3.3	Asia	24
3.3.4	Africa	24
3.4	Ecosystem service value balance	24
3.4.1	Global	24
3.4.2	Americas	24
3.4.3	Asia	24
3.4.4	Africa	24
4	Discussion	25
	Acknowledgements	26
	References	I
	List of Figures	II
	List of Tables	II
	List of Abbreviations	II
	Appendix	III

1 Introduction

1.1 Tropical forest



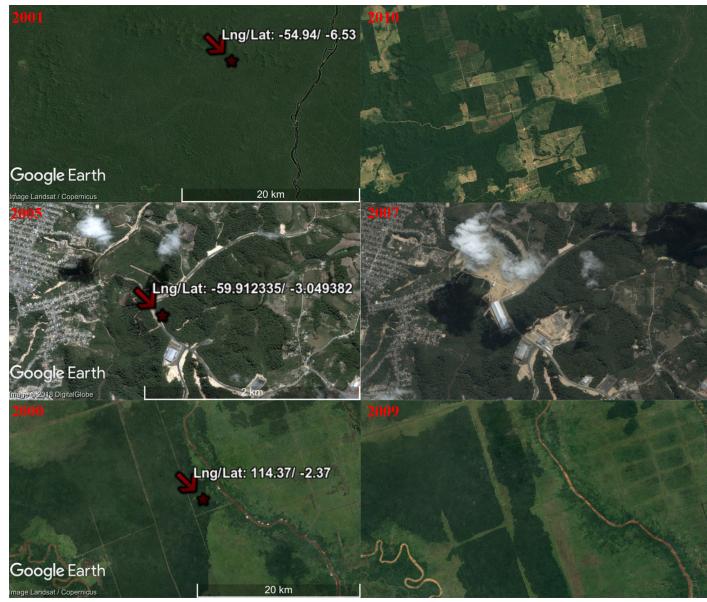


Figure 2: Upper Brazil agriculture, middle Brazil urbanization, lower Indonesia large scale palm oil plantations

1.1.1 Current state

1.1.2 Contribution to climate

1.1.3 Forest definitions

1.2 Deforestation

1.2.1 Land use and land cover change

1.2.2 Drivers of deforestation

1.3 Emissions through deforestation

1.3.1 Removal of AGB

1.3.2 Soil organic carbon change and soil dynamics

1.4 Ecosystem services

1.4.1 Ecosystem service values

1.5 Research objective and questions

2 Data and methods

2.1 Data

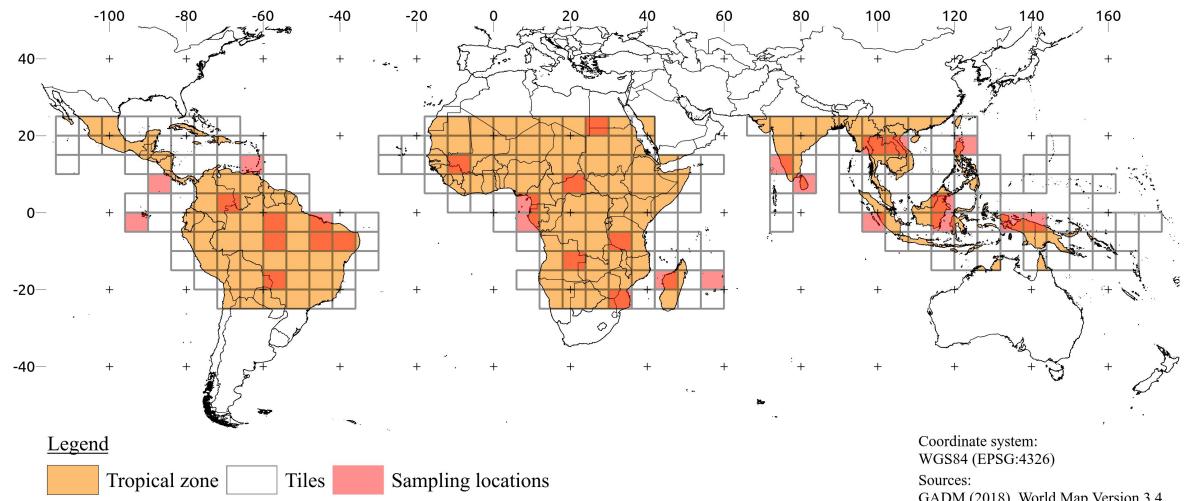


Figure 3: Study extent and raster image tiles

2.1.1 Spatial data

2.1.1.1 Global Forest Change

2.1.1.2 GlobeLand30

2.1.1.3 Intact Forest Landscapes

2.1.1.4 Aboveground Woody Biomass

2.1.1.5 Global Soil Organic Carbon

2.1.1.6 Auxiliary

2.1.2 Empirical data

2.1.2.1 Soil Organic Carbon

2.1.2.2 Ecosystem Service Values

2.2 Methods

2.2.1 Pre-processing

2.2.2 Deforestation

2.2.2.1 Forest definition

2.2.2.2 Land use change driver

2.2.2.3 Accuracy assessment

2.2.3 Emissions

2.2.3.1 Above ground biomass

2.2.3.2 Soil organic carbon change

2.2.4 Ecosystem service values

2.2.4.1 Ecosystem service value loss

2.2.4.2 Ecosystem service value gain

2.2.5 Binning analysis

$$R = \frac{\sqrt{2A}}{\sqrt[4]{27}} = \frac{D}{2} = \frac{d}{\sqrt{3}} \quad (1)$$

$$c_x = \frac{R\sqrt{3}}{2} \quad (2)$$

$$c_y = R \quad (3)$$

$$\mathbf{H} = \begin{bmatrix} 0 & c_x & 2c_x & 2c_x & c_x & 0 \\ R \sin\left(\frac{7\pi}{6}\right) + c_y & 0 & R \sin\left(\frac{11\pi}{6}\right) + c_y & R \sin\left(\frac{\pi}{6}\right) + c_y & 2R & R \sin\left(\frac{5\pi}{6}\right) + c_y \\ 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \quad (4)$$

$$\mathbf{T} = \begin{bmatrix} 1 & 0 & x_{off} \\ 0 & 1 & y_{off} \\ 0 & 0 & 1 \end{bmatrix} \cdot \mathbf{H} \quad (5)$$

$$\mathbf{B} = \begin{bmatrix} x_1 & x_2 \\ y_1 & y_2 \end{bmatrix} \quad (6)$$

$$R = \frac{\sqrt{2A}}{\sqrt[4]{27}} \quad (7)$$

$$y = \frac{P(y_2 - y_1)}{100} + y_1 \quad (8)$$

$$f^{-1}(y) = \begin{cases} -\frac{y-y_1}{\tan(\frac{\pi}{6})} + \frac{x_1+x_2}{2} & \text{if } y_1 \leq y < y_1 + R \sin\left(\frac{5\pi}{6}\right) \\ x_1 & \text{if } y_1 + R \sin\left(\frac{5\pi}{6}\right) \leq y < R(\sin(\frac{5\pi}{6}) + 1) \\ \frac{y-y_2}{\tan(\frac{\pi}{6})} + \frac{x_1+x_2}{2} & \text{if } R(\sin(\frac{5\pi}{6}) + 1) \leq y \leq y_2 \end{cases} \quad (9)$$

$$g^{-1}(y) = \begin{cases} \frac{y-y_1}{\tan(\frac{\pi}{6})} + \frac{x_1+x_2}{2} & \text{if } y_1 \leq y < y_1 + R \sin\left(\frac{5\pi}{6}\right) \\ x_2 & \text{if } y_1 + R \sin\left(\frac{5\pi}{6}\right) \leq y < R(\sin(\frac{5\pi}{6}) + 1) \\ -\frac{y-y_2}{\tan(\frac{\pi}{6})} + \frac{x_1+x_2}{2} & \text{if } R(\sin(\frac{5\pi}{6}) + 1) \leq y \leq y_2 \end{cases} \quad (10)$$

$$\mathbf{L} = \begin{bmatrix} f^{-1}(y) & g^{-1}(y) \\ y & y \end{bmatrix} \quad (11)$$

3 Results

3.1 Forest definition and accuracy assessment

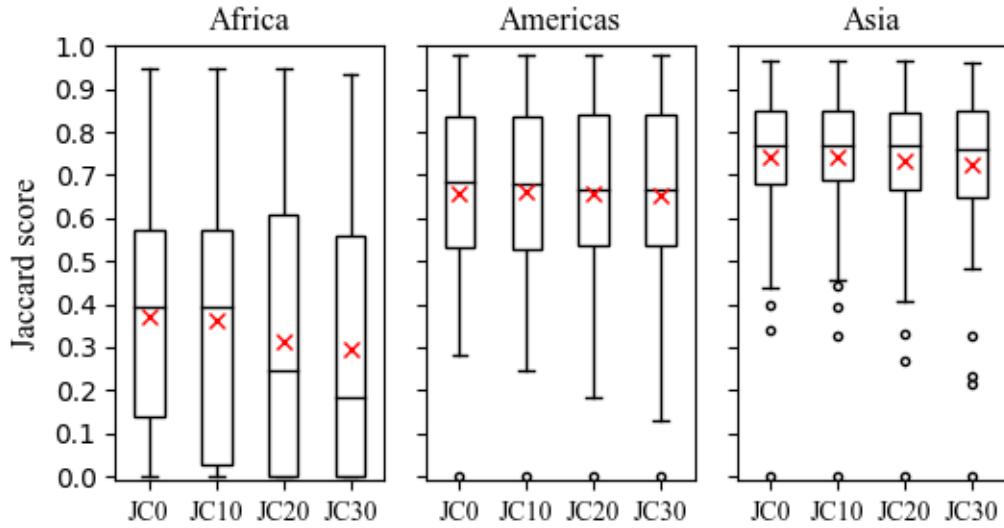


Figure 4: Jaccard score to determine tree cover similarity used to develop forest definition

Table 1: Confusion matrix for accuracy assessment

Cls	Reference									Tot	UAc	Om
	10	20	25	30	40	50	60	80	90			
Prediction	10	732	38	62	15	16	2	3	5	0	.84	.16
	20	42	751	57	189	31	12	0	17	4	.68	.32
	25	29	202	1155	173	22	10	5	11	4	.72	.28
	30	36	187	32	1466	73	21	0	17	0	.80	.20
	40	14	21	4	41	352	1	1	2	1	.81	.19
	50	0	5	3	10	4	50	0	1	0	.68	.32
	60	2	1	0	3	0	2	18	2	0	.64	.36
	80	3	4	0	1	1	1	0	50	0	.83	.17
	90	0	0	0	1	0	0	0	3	5	.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 2: Absolute in km²

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

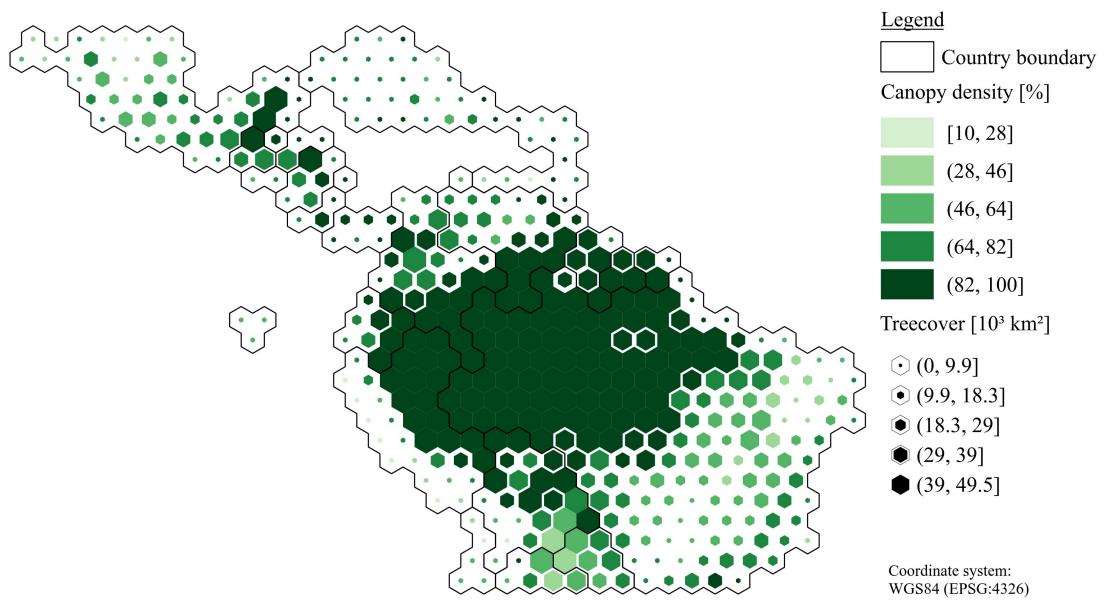


Figure 5:

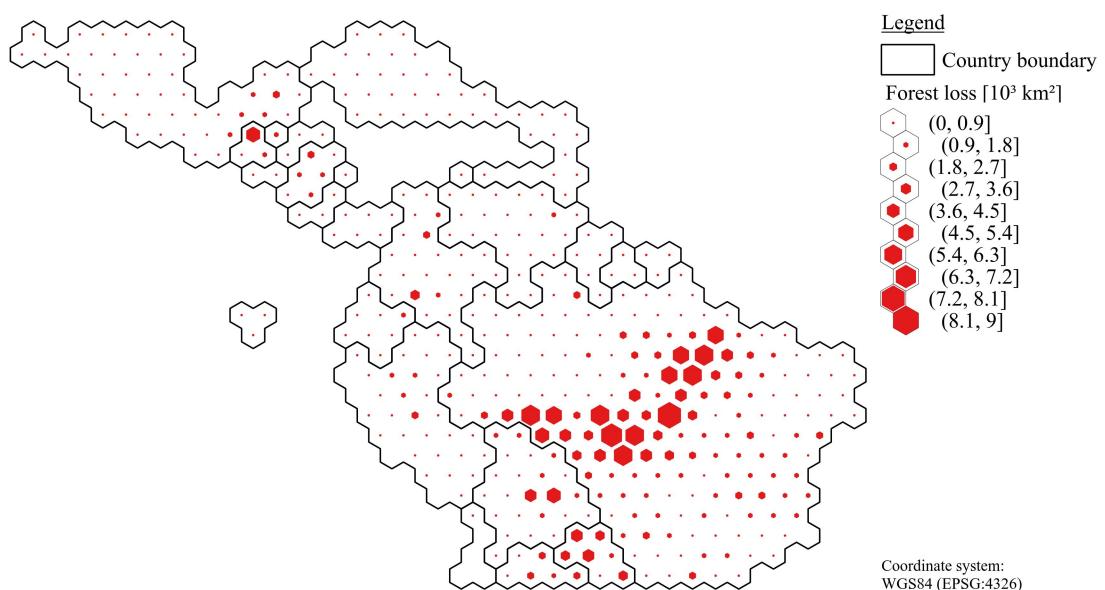


Figure 6:

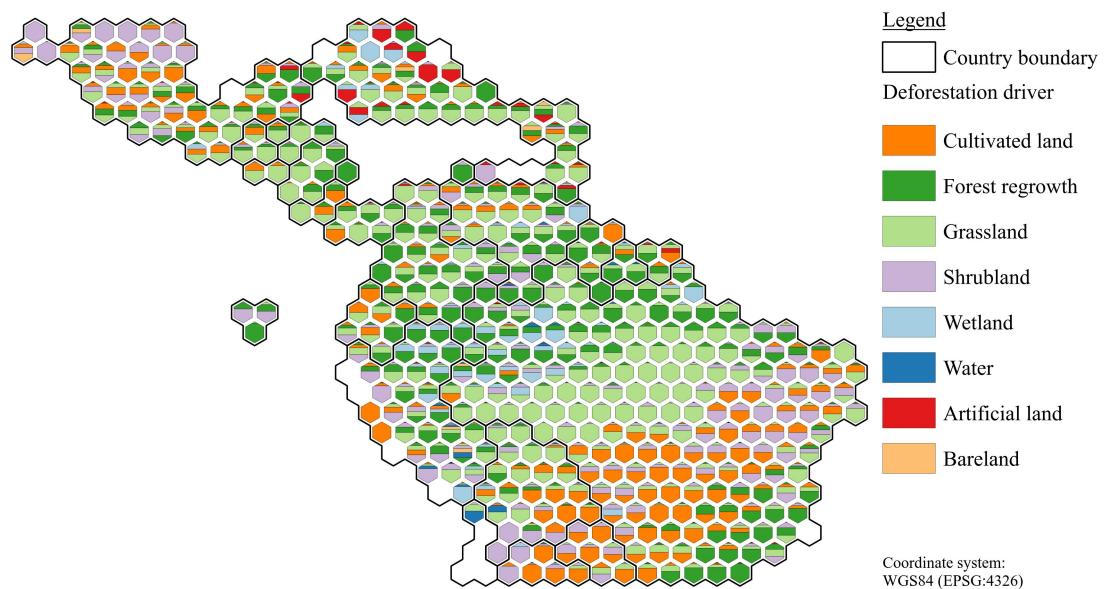


Figure 7:

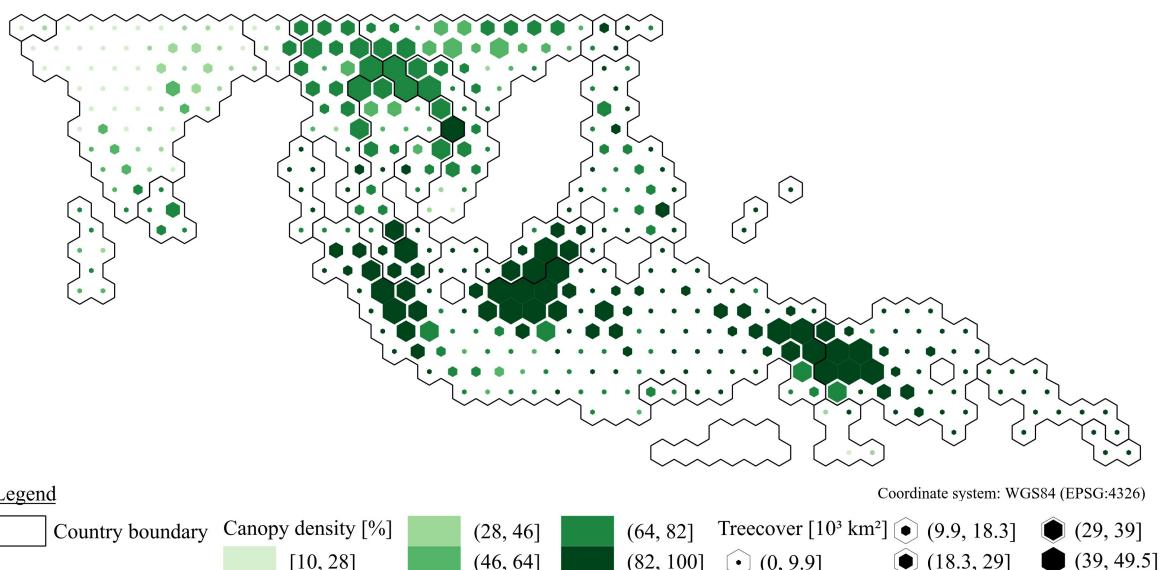


Figure 8:

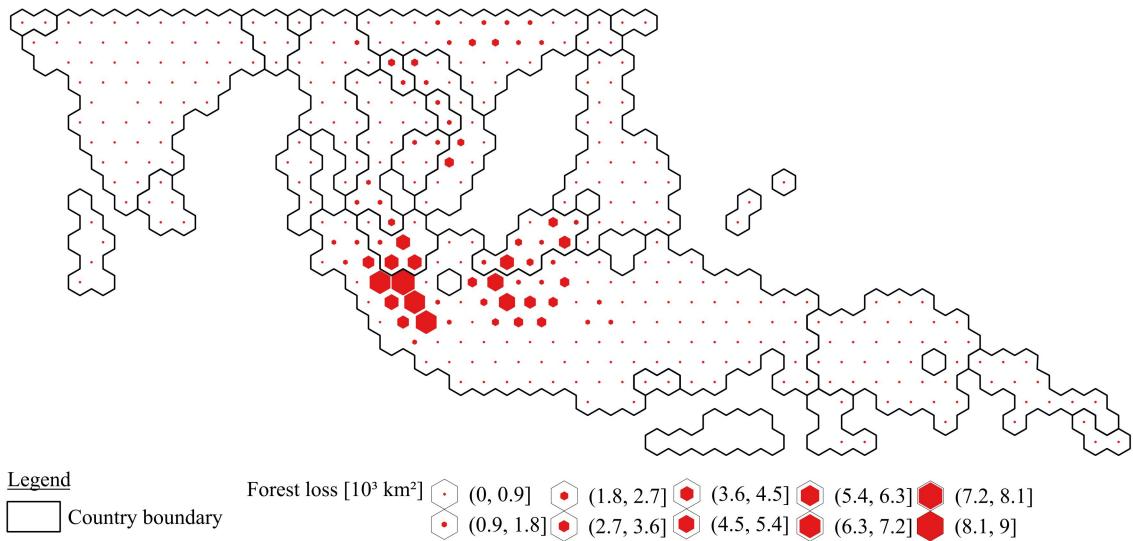


Figure 9:

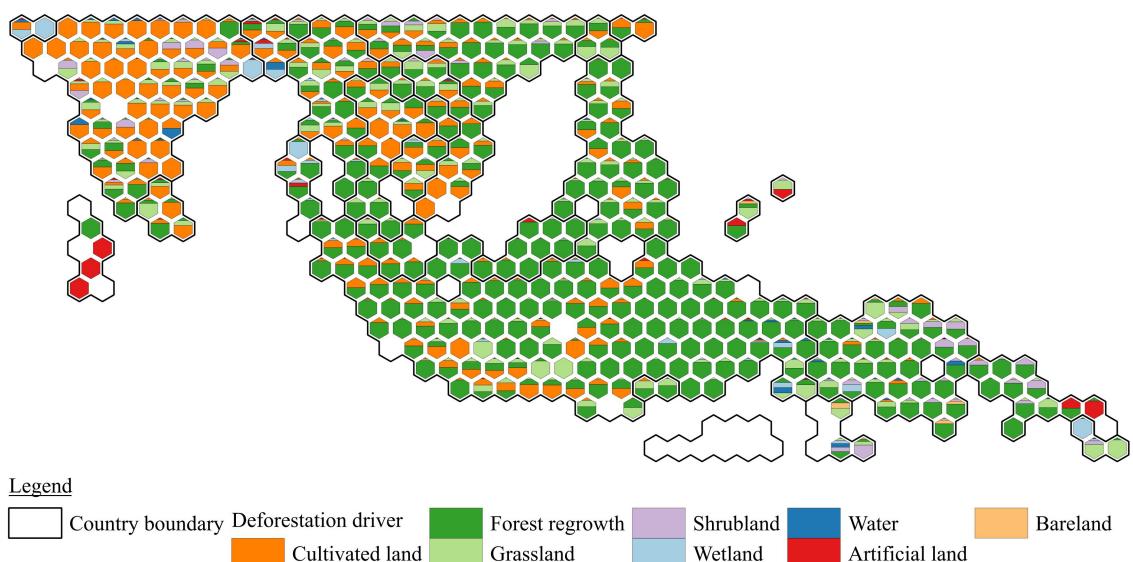


Figure 10:

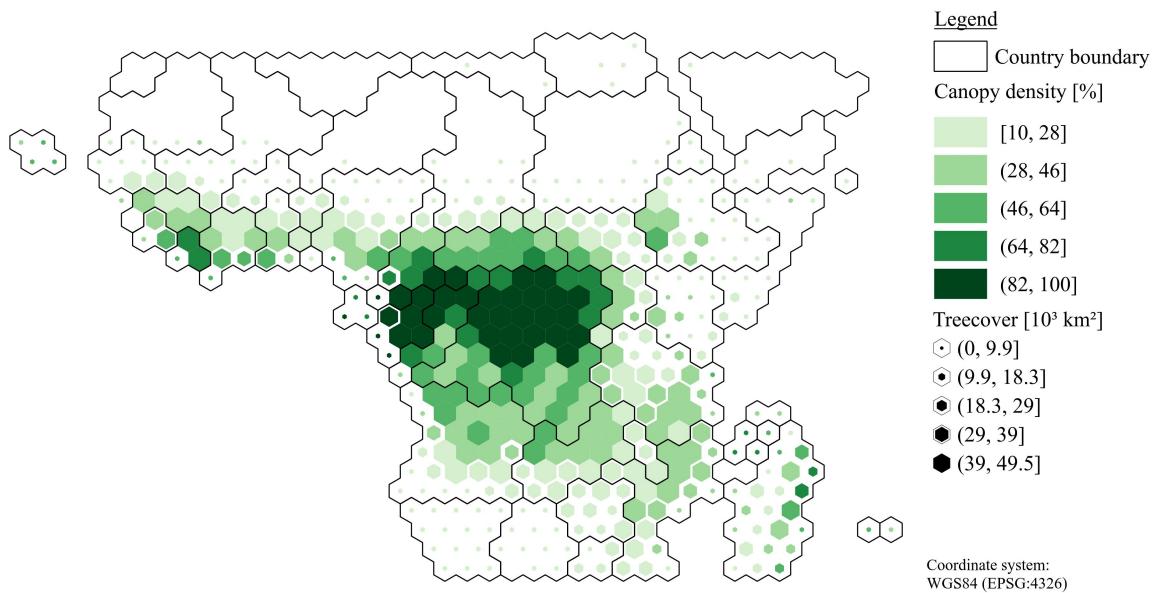


Figure 11:

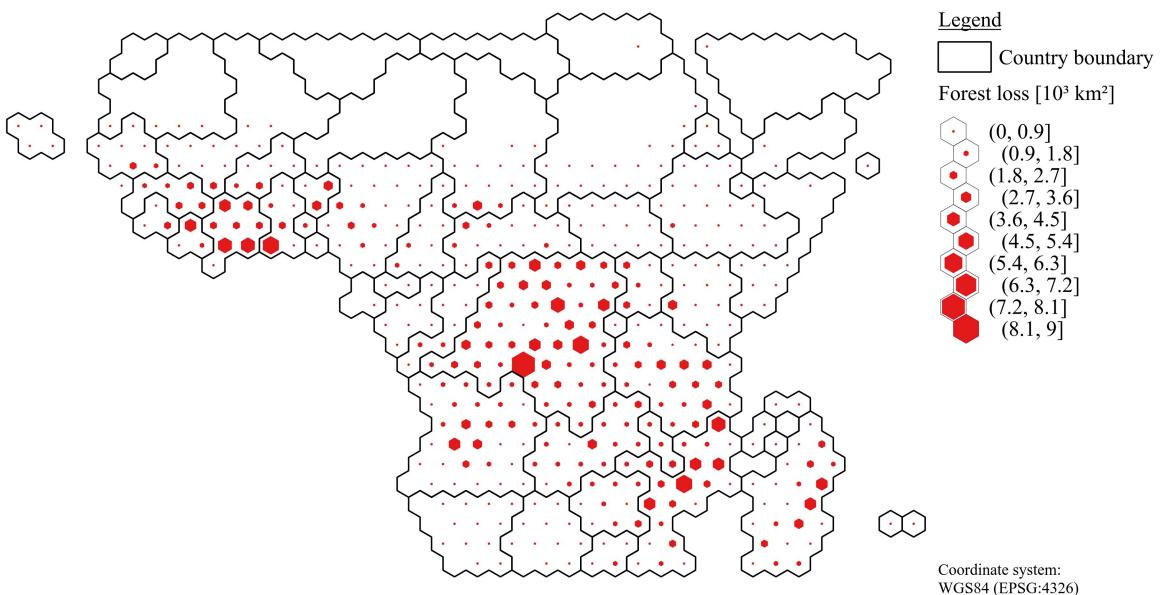


Figure 12:

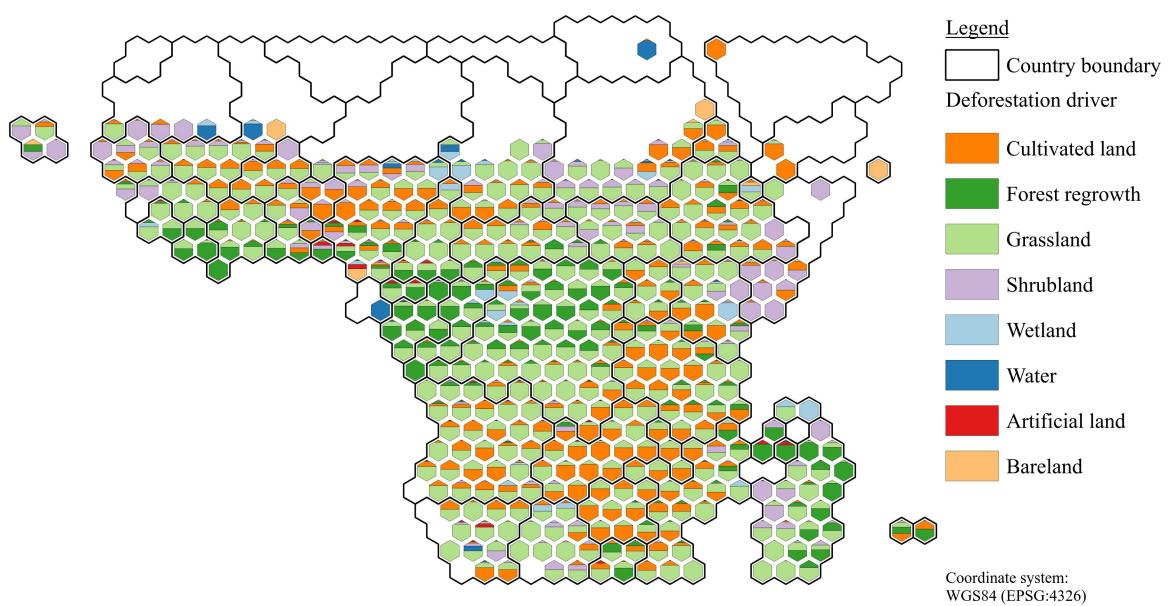


Figure 13:

3.3 Deforest

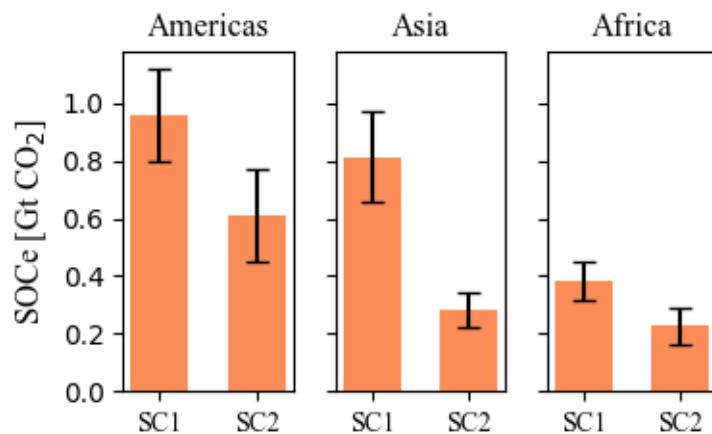


Figure 15:

Table 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

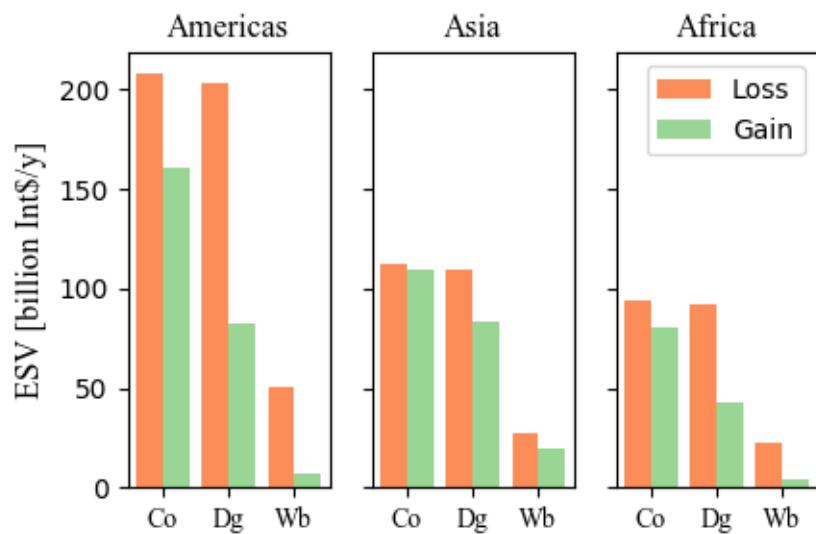


Figure 16:

3.4.1 Global

3.4.2 Americas

3.4.3 Asia

3.4.4 Africa

4 Discussion

Acknowledgements

References

- Arsanjani J. J., See L., and Tayyebi A. Assessing the suitability of GlobeLand30 for mapping land cover in Germany. *International Journal of Digital Earth*, 2016a. doi: 10.1080/17538947.2016.1151956.
- Arsanjani J. J., Tayyebi A., and Vaz E. GlobeLand30 as an alternative fine-scale global land cover map: Challenges, possibilities, and implications for developing countries. *Habitat International* xxx, pages 1–7, 2016b. doi: 10.1016/j.habitatint.2016.02.003.
- Baccini A., Goetz S., Walker W., Laporte N., Sun M., Sulla-Menashe D., Hackler J., Beck P., Friedl M., Samanta S., and Houghton R. Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps. *Nature Climate Change*, 2, March 2012. doi: 10.1038/nclimate1354.
- Baccini A., Walker W., Carvalho L., Farina M., and D. Sulla-Menashe R. A. H. Tropical forests are a net carbon source based on aboveground measuremeasure of gain and loss. *Science*, September 2017. doi: 10.1126/science.aam5962.
- Chen J., Chen J., Liao A., Cao X., Chen L., Chen X., He C., Han G., Peng S., Lu M., Zhang W., Tong X., and Mills J. *30-meter Global Land Cover Dataset - Product Description*. National Geomatics Center of China, May 2014.
- Chen J., Chen J., Liao A., Cao X., Chen L., Chen X., He C., Han G., Peng S., Lu M., Zhang W., Tong X., and Mills J. Global land cover mapping at 30 m resolution: A POK-based operational approach. *ISPRS Journal of Photogrammetry and Remote Sensing*, 103:7–27, 2015. doi: 10.1016/j.isprsjprs.2014.09.002. URL <http://www.globallandcover.com>.
- Chen J., Cao X., Peng S., and Ren H. Analysis and Applications of GlobeLand30: A Review. *International Journal of Geo-Information*, 6(230), July 2017. doi: 10.3390/ijgi6080230.
- Hansen M. C., Potapov P. V., Moore R., Hancher M., Turubanova S. A., Tyukavina A., Thau D., Stehman S. V., Goetz S. J., Loveland T. R., Kommareddy A., Egorov A., Chini L., Justice C. O., and Townshend J. R. G. High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science*, 342(6160):850–853, November 2013a. doi: 10.1126/science.1244693. URL https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.0.html.
- Hansen M. C., Potapov P. V., Moore R., Hancher M., Turubanova S. A., Tyukavina A., Thau D., Stehman S. V., Goetz S. J., Loveland T. R., Kommareddy A., Egorov A., Chini L., Justice C. O., and Townshend J. R. G. Supplementary Materials for: High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science*, 342(6160):1–32, November 2013b. doi: 10.1126/science.1244693. URL <http://science.sciencemag.org/content/suppl/2013/11/14/342.6160.850.DC1>.
- Potapov P., Hansen M. C., Laestadius L., Turubanova S., Yaroshenko A., Thies C., Smith W., Zhuravleva I., Komarova A., Minnemeyer S., and Esipova E. The last frontiers of wilderness: Tracking loss of intact forest landscapes from 2000 to 2013. *Science Advances*, 3, 2017. doi: 10.1126/sciadv.1600821. URL <http://www.intactforests.org/>.

List of Figures

1	Tropical zone	11
2	Deforestation examples	12
3	Study extent	13
4	Boxplot of Jaccard scores	16
5	Ecosystem service values	18
6	Ecosystem service values	18
7	Ecosystem service values	19
8	Ecosystem service values	19
9	Ecosystem service values	20
10	Ecosystem service values	20
11	Ecosystem service values	21
12	Ecosystem service values	21
13	Ecosystem service values	22
14	Ecosystem service values	23
15	Ecosystem service values	23
16	Ecosystem service values	24

List of Tables

1	Accuracy assessment	16
2	Deforestation driver	17
3	Soil organic carbon emissions	23

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

Wyrażam zgodę na udostępnienie mojej pracy w czytelniach Biblioteki SGGW w tym w Archiwum Prac Dyplomowych SGGW.

I agree to share my work in the reading rooms of the SGGW Library, including the SGGW Theses Archive.

Ich erteile meine Zustimmung zur Veröffentlichung meiner Arbeit in der Bibliothek der SGGW (Warschauer Naturwissenschaftliche Universität), einschließlich des Archivs der Diplomarbeiten.

.....
*(czytelny podpis autora pracy)
(legible signature of the author)
(lesbare Unterschrift des Autors der Arbeit)*