

Article

Land cover dynamics and mangrove degradation in the Niger Delta Region

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Supplementary material

Table S1. Mathematical notation for intensity analysis (from Pontius et al. 2013).

Symbol	Meaning
J	number of categories, which equals 3 in our case study
i	index for a category at the interval's initial time point
j	index for a category at the interval's final time point
m	index for the losing category for the selected transition
n	index for the gaining category for the selected transition
C_{ij}	number of pixels that transition from category i to category j
S	total change as percent of domain, which equals the uniform intensity for the category level
G_j	intensity of gain of category j relative to size of category j at final time
L_i	intensity of loss of category i relative to size of category i at initial time
R_{in}	intensity of transition from category i to category n relative to size of category i at initial time where $i \neq n$
W_n	uniform intensity of transition from all non-n categories to category n relative to size of all non-n categories at initial time
Q_{mj}	intensity of transition from category m to category j relative to size of category j at final time where $j \neq m$
V_m	uniform intensity of transition from all non-m categories to category j relative to size of all non-m categories at final time
EG_j	hypothesized commission of category j error at final time
OG_j	hypothesized omission of category j error at final time
EL_i	hypothesized commission of category i error at initial time
OL_i	hypothesized omission of category i error at initial time

Table S2. Confusion matrix of the classification of the Landsat-based metrics centred around the year 1988.

1988		Reference							
		Wa	U	Wo	B	A	G	DM	M
Prediction	Wa	319	5	17	15	33	0	15	8
	U	12	5684	106	9	372	119	3	5
	Wo	10	355	15,936	6	1583	1644	24	416
	B	11	8	0	210	61	0	0	0
	A	20	1448	934	102	16,765	1690	1	9
	G	0	629	1638	0	1878	8345	0	4
	DM	34	16	10	1	6	0	1262	219
	M	33	26	319	0	19	1	326	6476

Table S3. Confusion matrix of the classification of the Landsat-based metrics centred around the year 2000.

2000		Reference							
		Wa	U	Wo	B	A	G	DM	M
Prediction	Wa	270	1	3	6	8	0	23	12
	U	23	8800	88	36	550	120	2	6
	Wo	7	200	12,919	11	917	1047	6	381
	B	6	11	1	156	33	0	0	0
	A	6	1609	751	103	22,055	2295	1	2
	G	5	186	840	5	1548	3875	1	3
	DM	22	4	7	1	4	5	1090	150
	M	22	7	279	2	16	12	269	5236

Table S4. Confusion matrix of the classification of the Landsat- and JERS-1-based metrics centred around the year 2000.

2000		Reference							
		Wa	U	Wo	B	A	G	DM	M
Prediction	Wa	277	1	2	12	13	0	22	12
	U	10	8778	94	40	153	138	3	5
	Wo	8	218	12,920	10	827	1076	9	346
	B	5	21	0	157	40	0	0	0
	A	12	1560	743	98	22,153	2176	1	4
	G	3	200	869	5	1539	3957	0	9
	DM	34	4	10	1	3	2	1097	158
	M	20	7	272	2	11	12	264	5268

Table S5. Confusion matrix of the classification of the Landsat-based metrics centred around the year 2013.

2013		Reference							
		Wa	U	Wo	B	A	G	DM	M
Prediction	Wa	825	11	7	49	19	0	52	24
	U	10	9102	33	288	493	91	1	2
	Wo	28	54	14,634	36	795	1277	18	435
	B	58	102	6	934	101	2	5	2
	A	15	1461	1051	499	27,249	3484	0	0
	G	1	142	1358	41	2339	6260	0	26
	DM	114	1	8	8	0	0	1367	157
	M	61	0	280	14	1	0	151	5649

Table S6. Confusion matrix of the classification of the Landsat-and ALOS PALSAR-2-based metrics centred around the year 2013.

2013		Reference							
		Wa	U	Wo	B	A	G	DM	M
Prediction	Wa	866	10	10	46	15	0	48	18
	U	11	14,877	74	326	755	182	0	1
	Wo	27	119	14,629	32	749	1232	8	440
	B	51	120	9	938	73	2	2	1
	A	16	1544	1088	467	26,943	3395	1	0
	G	1	195	1312	32	2424	6285	0	23
	DM	89	3	13	13	3	0	1382	167
	M	45	0	253	12	2	0	154	5647

Table S7. Transition-level intensity analysis FROM-class TO-class for 1988–2000 and 2000–2013 (all classes except mangrove, which appears in Table 4).

Transitions FROM		Degraded Mangrove		
Time Interval	1988–2000		2000–2013	
TO Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2013 Category
Water	7787	<u>1.32</u>	8937	<u>1.23</u>
Urban	566	<u>0.02</u>	272	0.01
Woodland	579	0.00	209	0.00
Bareland	19	0.02	255	<u>0.23</u>
Agricultural	243	0.00	255	0.00
Grassland	630	0.00	133	0.00
Mangrove	1595	<u>0.03</u>	1818	<u>0.03</u>
Transitions FROM		Grassland		
Time Interval	1988–2000		2000–2013	
TO Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2013 Category
Water	42	0.03	82	0.01
Urban	27,872	0.01	22,895	<u>0.66</u>
Woodland	125,085	<u>1.19</u>	107,460	<u>0.53</u>
Bareland	48	0.05	2980	0.25
Agricultural	148,407	<u>1.22</u>	60,047	<u>0.53</u>
Degraded Mangrove	103	0.01	274	0.02
Mangrove	546	0.01	61	0.00
Transitions FROM		Agricultural		
Time Interval	1988–2000		2000–2013	
TO Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2013 Category
Water	1745	0.30	1259	0.17
Urban	24,552	<u>1.05</u>	51,246	<u>1.47</u>
Woodland	23,369	0.11	34,306	0.17
Bareland	20,984	<u>2.04</u>	865	<u>0.78</u>
Grassland	54,602	<u>0.75</u>	87,124	<u>1.23</u>
Degraded Mangrove	483	0.03	263	0.01
Mangrove	263	0.00	67	0.00
Transitions FROM		Bareland		
Time Interval	1988–2000		2000–2013	
TO Category	Observed Annual Transition	Transition Intensity	Observed Annual Transition	Transition Intensity

	(km ²)	% of 2000 Category	(km ²)	% of 2013 Category
Water	712	<u>0.12</u>	2309	<u>0.32</u>
Urban	633	0.03	270	<u>0.01</u>
Woodland	16	0.00	134	0.00
Agricultural	1248	<u>0.01</u>	180	<u>0.01</u>
Grassland	8	0.00	22	0.00
Degraded				
Mangrove	3	0.00	4	0.00
Mangrove	11	0.00	5	0.00
Transitions FROM Woodland				
Time Interval	1988–2000		2000–2013	
TO Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2013 Category
Water	623	0.11	468	0.06
Urban	14,159	0.60	16,151	0.46
Bareland	236	0.23	1325	<u>1.19</u>
Agricultural	95,219	0.78	53,121	0.47
Grassland	14,784	<u>2.03</u>	85,522	<u>1.21</u>
Degraded				
Mangrove	394	0.03	284	0.02
Mangrove	887	0.01	456	0.01
Transitions FROM Urban				
Time Interval	1988–2000		2000–2013	
TO Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2013 Category
Water	346	<u>0.06</u>	918	<u>0.13</u>
Woodland	281	0.00	155	0.00
Bareland	248	<u>0.24</u>	668	<u>0.60</u>
Agricultural	522	0.00	1389	<u>0.01</u>
Grassland	2647	<u>0.04</u>	31	0.00
Degraded				
Mangrove	444	<u>0.03</u>	746	<u>0.04</u>
Mangrove	535	0.01	171	0.00
Transitions FROM Water				
Time Interval	1988–2000		2000–2013	
TO Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2013 Category
Urban	747	<u>0.03</u>	150	0.00
Woodland	487	0.00	636	0.00
Bareland	228	<u>0.22</u>	616	<u>1.55</u>
Agricultural	667	0.01	1566	<u>0.01</u>
Grassland	54	0.00	45	0.00

Degraded Mangrove	411	<u>0.03</u>	294	<u>0.02</u>
Mangrove	369	<u>0.01</u>	711	<u>0.01</u>

Table S8. Transition-level intensity analysis TO-class FROM-class for 1988–2000 and 2000–2013.

Transitions TO		Mangrove		
Time Interval	1988–2000	2000–2013		
FROM Category	Observed Annual Transition (km ²)	Transition Intensity % of 1988 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category
Water	369	<u>0.08</u>	711	<u>0.12</u>
Urban	535	<u>0.03</u>	170	0.02
Woodland	887	0.00	456	0.00
Bareland	11	<u>0.01</u>	5	0.00
Agricultural	263	0.00	66	0.00
Grassland	546	0.01	61	0.00
Degraded Mangrove	1595	<u>0.12</u>	1818	<u>0.12</u>
Transitions TO		Degraded Mangrove		
Time Interval	1988–2000	2000–2013		
FROM Category	Observed Annual Transition (km ²)	Transition Intensity % of 1988 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category
Water	411	<u>0.08</u>	294	0.05
Urban	444	0.03	746	0.03
Woodland	394	0.00	284	0.00
Bareland	263	0.00	4	0.00
Agriculture	483	0.00	263	0.00
Grassland	103	0.00	274	0.00
Mangrove	23,799	<u>0.38</u>	32,742	<u>0.54</u>
Transitions TO		Grassland		
Time Interval	1988–2000	2000–2013		
FROM Category	Observed Annual Transition (km ²)	Transition Intensity % of 1988 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category
Water	54	0.01	45	0.01
Urban	2646	0.17	31	0.00
Woodland	147,840	<u>0.68</u>	85,522	<u>0.42</u>
Bareland	8	0.01	22	0.02
Agricultural	54,602	<u>0.52</u>	871,237	<u>0.72</u>
Degraded Mangrove	63	0.00	133	0.01
Mangrove	246	0.00	460	0.01
Transitions TO		Agricultural		
Time Interval	1988–2000	2000–2013		
FROM Category	Observed Annual Transition (km ²)	Transition Intensity % of 1988 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category
Water	667	0.14	1566	0.26
Urban	522	1.03	1389	0.06
Woodland	95,219	0.44	53,121	0.26
Bareland	1248	<u>1.26</u>	810	<u>0.79</u>

Grassland	148,470	<u>1.75</u>	60,047	<u>0.82</u>
Degraded				
Mangrove	243	0.02	255	0.02
Mangrove	485	0.01	280	0.00
Transitions TO Bareland				
Time Interval	1988–2000		2000–2013	
FROM Category	Observed Annual Transition (km ²)	Transition Intensity % of 1988 category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category
Water	228	<u>0.05</u>	616	<u>0.10</u>
Urban	248	<u>0.02</u>	668	<u>0.03</u>
Woodland	237	0.00	1325	0.00
Agricultural	2098	<u>0.02</u>	865	0.01
Grassland	48	0.00	280	0.00
Degraded				
Mangrove	19	0.00	255	<u>0.02</u>
Mangrove	39	0.00	221	0.00
Transitions TO Woodland				
Time Interval	1988–2000		2000–2013	
FROM Category	Observed Annual Transition (km ²)	Transition Intensity % of 1988 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category
Water	487	0.10	636	0.11
Urban	281	0.02	15	0.01
Bareland	16	0.02	134	1.13
Agricultural	23,369	0.22	34,305	0.28
Grassland	125,085	<u>1.48</u>	107,460	<u>1.47</u>
Degraded				
Mangrove	579	0.04	208	0.0
Mangrove	505	0.01	1431	0.02
Transitions TO Urban				
Time Interval	1988–2000		2000–2013	
FROM Category	Observed Annual Transition (km ²)	Transition Intensity % of 1988 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category
Water	747	<u>0.15</u>	150	0.03
Woodland	14,159	0.07	16,151	0.08
Bareland	633	<u>0.64</u>	60	<u>0.21</u>
Agricultural	24,552	<u>0.23</u>	51,247	<u>0.42</u>
Grassland	27,872	<u>0.33</u>	22,895	<u>0.31</u>
Degraded				
Mangrove	566	0.04	272	0.02
Mangrove	717	0.01	540	0.01
Transitions TO Water				
Time Interval	1988–2000		2000–2013	
FROM Category	Observed Annual Transition (km ²)	Transition Intensity % of 1988 Category	Observed Annual Transition (km ²)	Transition Intensity % of 2000 Category

Urban	346	0.02	918	<u>0.04</u>
Woodland	623	0.00	468	0.00
Bareland	712	<u>0.72</u>	2309	<u>2.25</u>
Agricultural	1475	0.02	1259	0.01
Grassland	42	0.00	82	0.00
Degraded	7789	<u>0.58</u>	894	<u>0.59</u>
Mangrove	206	0.00	355	0.01
