

Supplementary Materials

Table S1. Confusion Matrices.

LULC 2024

	CrL	ShBu	FL	BL	GrL	Se	WB	Total (User)	User Accuracy	Producer Accuracy	Overall Accuracy	Kappa coefficient
CrL	175	0	0	23	0	0	0	198	88.4	75.1		
ShBu	18	172	0	6	3	0	0	199	86.4	91.5		
FL	2	4	111	0	1	0	0	118	94.1	96.5		
BL	21	4	0	75	0	0	0	100	75	65.2	85.3	82
GrL	11	7	4	2	72	0	0	96	75	94.7		
Se	6	0	0	9	0	84	0	99	84.8	100		
WB	0	1	0	0	0	0	18	19	94.7	100		
Total (Producer)	233	188	115	115	76	84	18	829				

LULC 2014

	CrL	ShBu	FL	BL	GrL	Se	WB	Total (User)	User Accuracy	Producer Accuracy	Overall Accuracy	Kappa coefficient
CrL	178	1	0	19	0	0	0	198	89.9	73.6		
ShBu	17	172	0	9	1	0	0	199	86.4	92.0		
FL	1	0	112	5	0	0	0	118	94.9	99.1		
BL	20	2	0	78	0	0	0	100	78.0	63.4	84.7	81.3
GrL	10	12	0	0	74	0	0	96	77.1	97.4		
Se	16	0	0	12	0	71	0	99	71.7	100		
WB	0	0	1	0	1	0	17	19	89.5	100		
Total (Producer)	242	187	113	123	76	71	17	829				

LULC 2004

	CrL	ShBu	FL	BL	GrL	Se	WB	Total (User)	User Accuracy	Producer Accuracy	Overall Accuracy	Kappa coefficient
CrL	177	17	0	4	0	0	0	198	89.4	84.3		
ShBu	21	163	5	7	3	0	0	199	81.9	81.9		
FL	0	0	117	1	0	0	0	118	99.2	95.9		
BL	8	0		92	0	0	0	100	92	78	87	83.9
GrL	0	19	0	1	76	0	0	96	79.2	96.2		
Se	4	0	0	13	0	51	0	68	75	100		
WB	0	0	0	0	0	0	11	11	100	100		
Total (Producer)	210	199	122	118	79	51	11	790				

LULC 1984

	CrL	ShBu	FL	BL	GrL	Total (User)	User Accuracy	Producer Accuracy	Overall Accuracy	Kappa coefficient
CrL	155	31	0	10	2	198	78.3	71.8		
ShBu	20	173	0	6	0	199	86.9	82.8		
FL	9	2	104	2	1	118	88.1	100	83.3	78.4
BL	21	1	0	76	2	100	76	80.9		
GrL	11	2	0	0	84	96	87.5	94.4		
Total (Producer)	216	209	104	94	89	711				

Table S2. LULC categories during the study periods.

LULC Type	1984		2004		2014		2024		2034		2044	
	Area km ²	%	Area km ²	%	Area km ²	%	Area km ²	%	Area km ²	%	Area km ²	%
CrL	1828	36	2258	44	2460	48	2570	50	2749	54	2733	53
ShBu	1668	32	1945	38	2153	42	2082	41	1955	38	1965	38
FL	164	3	117	2	111	2	103	2	70	1	71	1
BL	956	19	497	10	158	3	187	4	168	3	169	3
GrL	520	10	283	6	215	4	113	2	102	2	103	2
Se	0	0	35	1	38	1	78	2	88	2	91	2
WB	0	0.00	1.4	0.03	2	0.03	3	0.06	3	0.06	3	0.06
Total area = 5135 km ²												

Table S3. LULC decadal changes between the study periods.

LULC Type	LULC decadal changes													
	1984-2004		2004-2014		2014-2024		1984-2024		2024-2034		2034-2044		2024-2044	
	ΔArea (km ²)	%	ΔArea (km ²)	%	ΔArea (km ²)	%	ΔArea (km ²)	%	ΔArea (km ²)	%	ΔArea (km ²)	%	ΔArea (km ²)	%
CrL	430	24	202	9	110	4	742	41	179	7	-16	-0.58	163	6
ShBu	277	17	208	11	-71	-3	414	25	-127	-6	10	0.51	-117	-6
FL	-47	-29	-6	-5	-8	-7	-61	-37	-33	-32	1	1.43	-32	-31
BL	-459	-48	-339	-68	29	18	-769	-80	-19	-10	1	0.60	-18	-10
GrL	-237	-46	-68	-24	-102	-47	-407	-78	-11	-10	1	0.98	-10	-9
Se	35	3400	3	9	40	105	78	7700	10	13	3	3.41	13	17
WB	1	100	0	7	2	100	3	300	0	0	0	0.00	0	0

Table S4. Transition matrix for 2004-2014 LULC change.

	0	1	2	3	4	5	6
0	0.164902	0.157337	0.003026	0.025719	0	0.03177	0.617247
1	0.000265	0.766515	0.000618	0.006706	3.78E-05	0.002597	0.223263
2	0.000713	0.000475	0.164473	0.014185	0.104073	0.626337	0.089745
3	0.000811	0.012241	0.00312	0.331044	0.036726	0.381938	0.234121
4	0.000241	0.000486	0.008283	0.070942	0.168758	0.68843	0.062859
5	0.000236	0.000524	0.009014	0.038061	0.04306	0.693649	0.215455
6	0.000187	0.028721	0.003433	0.057536	0.002053	0.196873	0.711197
Rate of total area change = 35%							

Table S5. Transition matrix for 2014-2024 LULC change.

	0	1	2	3	4	5	6
0	0.497350993	0.079470199	0.172847682	0.005298013	0.031788079	0.139072848	0.074172185
1	0.001815832	0.606626246	0.001092577	0.018727687	0.001046411	0.065431491	0.305259756
2	0.00062645	0.000208817	0.690649652	0.000858469	0.027424594	0.195359629	0.08487239
3	0.000451949	0.00692988	0.002602397	0.158120012	0.026854024	0.298584485	0.506457254
4	0.000561308	0.000133645	0.020784442	0.031684513	0.38178047	0.463870461	0.101185162
5	0.000163026	0.000161547	0.013827605	0.018683995	0.045403195	0.745371329	0.176389304
6	0.000417064	0.016157962	0.007063966	0.008865873	0.005660837	0.270590899	0.691243399
Rate of total area change = 33%							

Table S6. Transition matrix for 2004-2024 LULC change.

	0	1	2	3	4	5	6
0	0.686838	0.077156	0.025719	0.013616	0.007564	0.108926	0.080182
1	0.000492	0.58215	0.002546	0.00484	0.001487	0.110188	0.298297
2	0.000689	0.000713	0.239011	0.007176	0.067861	0.5211	0.163451
3	0.000521	0.007348	0.006994	0.198116	0.100166	0.251368	0.435487
4	0.00022	0.000245	0.026478	0.068038	0.219122	0.510963	0.174934
5	0.000387	0.000819	0.017628	0.014416	0.038371	0.670263	0.258115
6	0.000388	0.030521	0.008714	0.010528	0.008843	0.322599	0.618406

Rate of total area change = 40%

Table S7. Transition matrix for 2024-2044 LULC change.

	0	1	2	3	4	5	6
0	0.980531636	0	0	0	0.000374392	0.011980532	0.007113441
1	8.41E-06	0.69889986	0.001169109	1.68E-05	0.000336434	0.105043148	0.194526217
2	0	3.39E-05	0.964762335	0.000880659	0.001208084	0.019509992	0.013605058
3	0	4.52E-05	0.003440177	0.914198823	0.003425122	0.057820569	0.021070143
4	1.38E-05	1.38E-05	0.00199819	7.35E-05	0.888946563	0.070299545	0.038654644
5	3.52E-07	1.13E-05	0.003495098	5.45E-05	0.00025573	0.986931022	0.009252019
6	1.04E-05	4.83E-05	0.002414337	1.70E-05	0.002120266	0.075626597	0.919763108

Rate of total area change = 5.3%

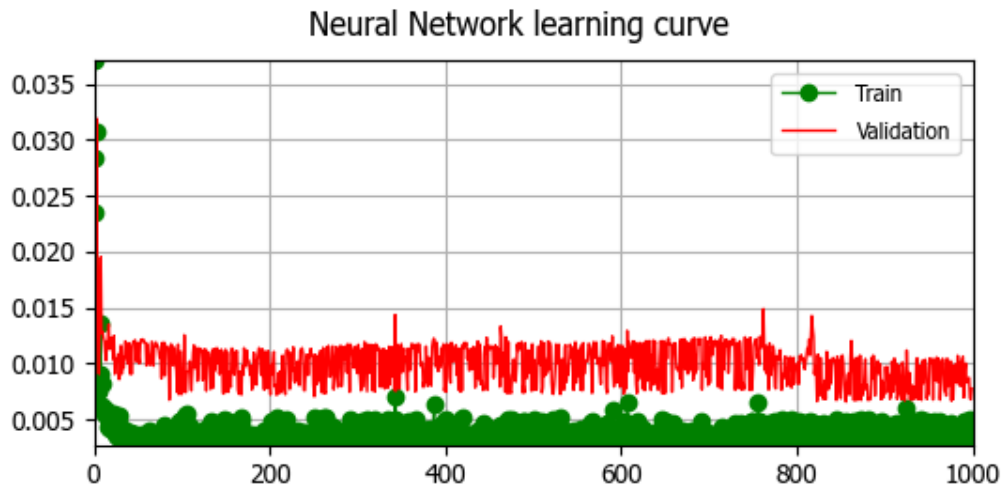
**Figure S1.** Neural network learning curve.



Figure S2. LULC change from shrubs and bushes in 2008 (left) to cropland and settlements in 2024 (right) near to the main Giba bridge, western of Mekelle city (UTM: 539893 m E, 1504244 m N).



Figure S3. Transformation of the shrubs and bushes in 2006 (left) to cropland and settlements in 2024 (right) south of Wukro town (UTM: 562915 m E and 1517369 m N).



Figure S4. Transformation of degraded hillslopes in 2004 (left) to considerably increased vegetation cover in 2024 (right) in the northern tip of the Giba basin (UTM: 547272 m E and 1573964 m N).



Figure S5. LULC change from vegetated hillslopes in 2011 (left) to cropland in 2024 (right) in the middle part of the Giba basin (UTM: 562162 m E and 1532559 m N).