Community forests, carbon sequestration and REDD+: evidence from Ethiopia

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ONLINE APPENDIX

Forest plot sampling and carbon estimation methodology

All trees in sample plots were identified and their diameter at breast heights (dbh) and heights were measured. For plantation forests, which are generally uniform, two trees, one small diameter and one big diameter, are considered as representative of height. The size of the plot for plantation forest was $100m^2$ (r=5.64) and $500m^2$ (50*m* by 10*m*) was considered for natural forest. The number of sample plots for plantation forest was determined based on a model developed by the then State Forest Department**:** $n=10+\sqrt{A}$, where n is number of sample plots, A is area in ha of the plantation. But for natural forest, random GPS coordinates were generated and transferred to excel. Sample plots were assigned for each forest in each *kebele* and the total number of sample plots was 152.

With information about the species composition of *kebele* forests, wood density is estimated using the Global Wood Density database (Chave *et al.,* 2009; Zanne *et al.,* 2009). Above ground biomass is estimated using equation 1, which was developed for tropical countries by Brown *et al.* (1989) and used in (Brown, 1997; Chavan *et al.,* 2010). This function is employed because of its relative sophistication compared with other allometric approaches that estimate biomass based only on diameter at breast height. The approach of Brown *et al*. (1989) therefore captures characteristics of a variety of ecosystems.[1]

$$1) \qquad Y = \exp\{-2.409+0.9522\ ln(D^2*H*S)\}$$

where Y = above ground biomass (kg), H=height of the trees in m, D=Diameter at breast height (cm), and S = the wood density (gm/cm^3). In accord with Brown *et al*. (1989) and Chavan *et al*. (2010), above ground carbon is a linear function of and assumed to be half the total biomass. This approach is acknowledged to be simplified in a world where carbon inventory

[1] We thank Sisay Nune for making these estimations.

methodologies are themselves fields of study (e.g. Ravindranath and Ostwald, 2008), but is also standard in the applied literature (e.g. MacDicken, 1997; Pearson *et al.*, 2007).

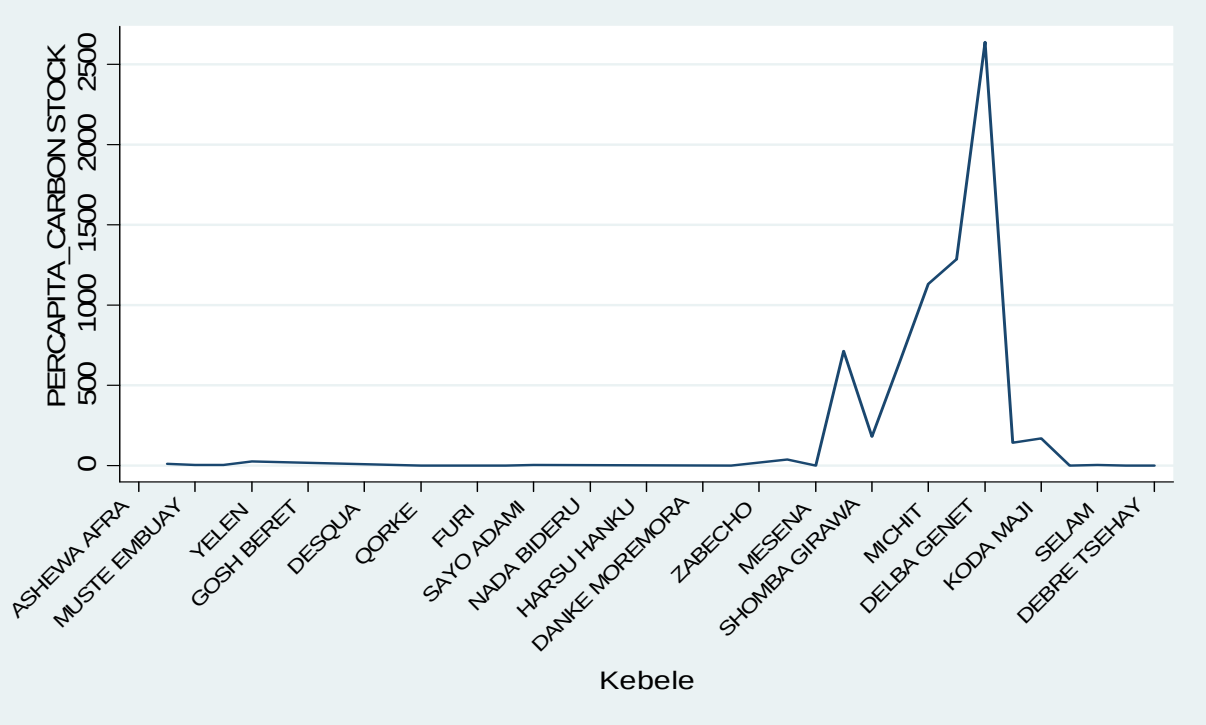

Figure A1. *Carbon stock per capita by Kebele*

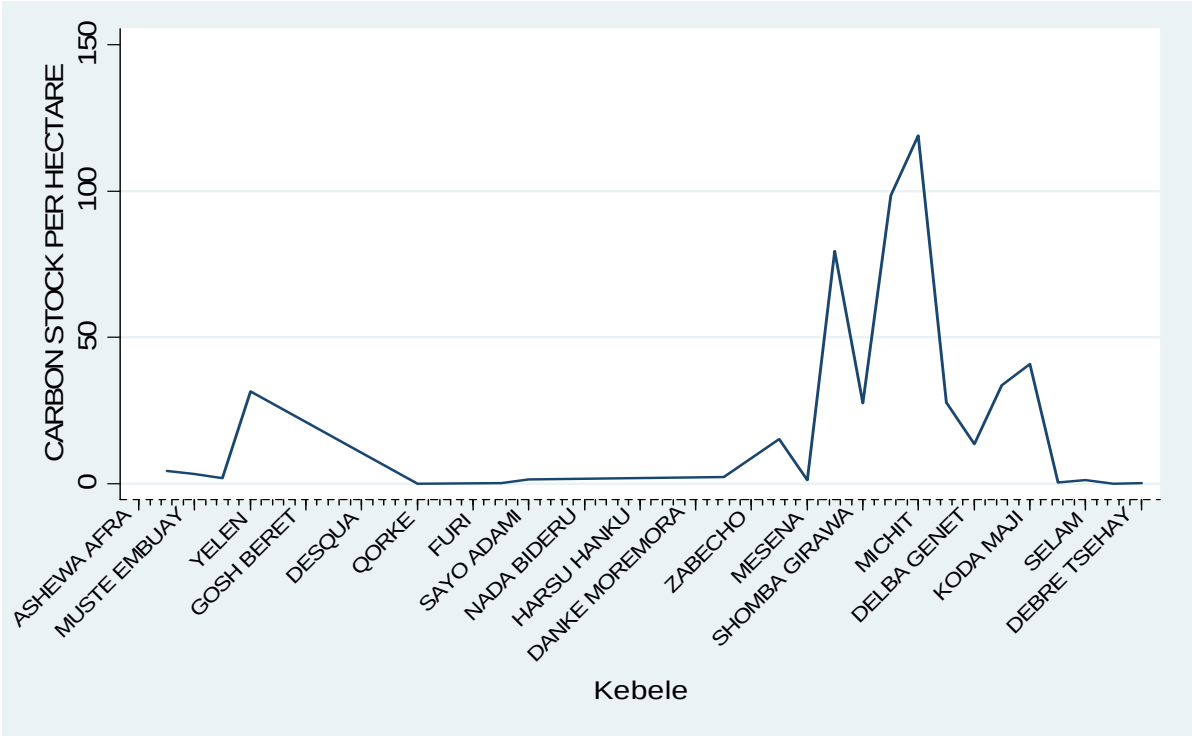

Figure A2. *Carbon stock per hectare by Kebele*

Table A1. *Spearman correlations between variables with significance levels*

	PERCAP CARBON	PERHA CARBON	SOCIAL COORD	KOLA	ALTI TUDE	DIST TOWN	FOREST AREA	PEOPLE PERHA	AMH ARA	SNNP	TIGRA Y	OROMI YA
PERCAPCARON	1.00											
PERHACARBON	0.90	1.00										
	(0.00)											
CA	0.32	0.33	1.00									
	(0.00)	(0.00)										
KOLA	0.20	0.09	0.06	1.00								
	(0.00)	(0.10)	(0.30)									
ALTITUDE	-0.48	-0.41	-0.17	-0.56	1.00							
	(0.00)	(0.00)	(0.00)	(0.00)								
DISTTOWN	0.36	0.14	0.11	0.48	-0.47	1.00						
	(0.00)	(0.01)	(0.05)	(0.00)	(0.00)							
FORESTAREA	0.53	0.46	0.06	0.11	-0.21	0.13	1.00					
	(0.00)	(0.00)	(0.28)	(0.05)	(0.00)	(0.02)						
PEOPLEPERHA	-0.45	-0.46	-0.01	0.06	0.19	0.03	-0.86	1.00				
	(0.00)	(0.00)	(0.85)	(0.26)	(0.00)	(0.61)	(0.00)					
AMHARA	0.00	0.08	0.02	0.30	0.03	0.02	-0.07	0.17	1.00			
	(0.95)	(0.14)	(0.78)	(0.00)	(0.63)	(0.97)	(0.21)	(0.00)				
SNNP	0.69	0.67	0.40	-0.10	-0.29	0.06	0.15	-0.17	-0.46	1.00		
	(0.00)	(0.00)	(0.00)	(0.07)	(0.00)	(0.23)	(0.01)	(0.00)	(0.00)			
TIGRAY	-0.50	-0.54	-0.36	0.04	-0.04	0.19	-0.18	0.10	-0.22	-0.48	1.00	
	(0.00)	(0.00)	(0.00)	(0.51)	(0.43)	(0.00)	(0.00)	(0.07)	(0.00)	(0.00)		
OROMIYA	-0.43	-0.45	-0.19	-0.22	0.44	-0.31	0.07	-0.06	-0.19	-0.40	-0.20	1
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.27)	(0.30)	(0.00)	(0.00)	(0.00)	

Note: Significance levels in parentheses.

Table A2. *Factor analysis details*

Factor analysis/correlation	Number of obs	=	315
Method: principal factors	Retained factors	=	7
Rotation: (unrotated)	Number of params	=	77

Factor	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**
Factor1	7.31917	6.47496	0.8773	0.8773
Factor2	0.84421	0.26555	0.1012	0.9784
Factor3	0.57865	0.41478	0.0694	1.0478
Factor4	0.16387	0.09524	0.0196	1.0674
Factor5	0.06864	0.01414	0.0082	1.0757
Factor6	0.05449	0.01961	0.0065	1.0822
Factor7	0.03489	0.0611	0.0042	1.0864

Note: Likelihood Ratio test: independent vs.saturated:chi2 (91)= 2942.95;Prob>chi2 = 0.0000

Table A3. *Factor loadings (pattern matrix) and unique variances*

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Unique-ness
Q4_CLARITY	0.750	0.366	-0.037	0.018	0.014	0.019	-0.111	0.290
Q5_CLARITY	0.619	0.533	-0.056	0.024	-0.029	0.086	-0.007	0.321
Q9_FAIR	0.664	0.349	0.127	-0.067	0.035	-0.016	0.039	0.413
Q10_QUOTA	0.692	-0.159	0.420	-0.001	0.014	0.039	-0.009	0.318
Q11-QUOTA	0.665	-0.223	0.386	-0.042	0.015	0.069	0.012	0.352
Q12_MONITOR	0.675	-0.025	0.251	-0.026	-0.018	-0.103	-0.040	0.468
Q16_MONITOR	0.634	-0.047	-0.040	0.224	0.145	0.013	0.021	0.523
Q17_PARTICIPAT	0.782	0.050	-0.007	0.028	-0.065	-0.138	-0.008	0.362
Q18_SANCTION	0.761	-0.203	-0.112	-0.013	-0.156	0.063	-0.010	0.339
Q19_PENALTY	0.731	-0.203	-0.127	0.246	-0.060	0.020	0.009	0.344
Q20_ALLOCATION	0.653	0.215	-0.002	0.001	-0.039	-0.036	0.130	0.508
Q21_PENALITY	0.833	-0.082	-0.210	-0.144	0.080	0.022	0.024	0.227
Q22_PENALITY	0.817	-0.200	-0.227	-0.150	0.006	0.035	0.003	0.218
Q23_SANCTION	0.802	-0.219	-0.210	-0.039	0.067	-0.058	-0.033	0.254

Table A4. *Kebele level models of carbon stocks*

Kebele level OLS models of carbon per capita (CARBONPERCAP)

	MODEL 1	MODEL 2	MODEL 3	MODEL 4
CA	0.740	0.805	0.150	-2.260***
	(0.79)	(0.81)	(0.81)	(0.59)
KOLA	-1.318	-1.313	-1.326	0.444
	(1.21)	(1.25)	(1.34)	(0.76)
ALTITUDE	-0.003**	-0.003*	-0.002	-0.004**
	(0.00)	(0.00)	(0.00)	(0.00)
DISTOWN		0.057	0.022	-0.011
		(0.06)	(0.05)	(0.03)
PEOPLEPERHA		-0.040*	-0.014	-0.045***
		(0.02)	(0.02)	(0.01)
FORESTAREA			0.001**	0.001
			(0.00)	(0.00)
AMHARA				2.118**
				(0.85)
SNNP				2.495***
				(0.65)
TIGRAY				-1.613
				(1.76)
AMHARA*CA				-2.741
				(2.57
SNNP*CA				1.666**
				(0.60)
TIGRAY*CA				2.342
				(2.31)
Constant	10.034***	8.601**	6.877*	9.486**
	(3.22)	(3.35)	(3.59)	(3.15)
R-squared	0.2576	0.4123	0.5218	0.9561
N	22	22	22	22

Notes: The dependent variable is in logarithmic form. * Significant at 10%; ** significant at 5%; *** significant at 1%. Robust standard errors are in parentheses.

Table A5. *Kebele level OLS models of carbon per hectare forest* (CARBONPERHA)

	MODEL 1	MODEL 2	MODEL 3	MODEL 4
CA	0.72	0.64	0.23	-1.484***
	-0.44	-0.45	-0.43	-0.37
KOLA	-1.06	-0.49	-0.50	-0.20
	-0.67	-0.61	-0.69	-0.86
ALTITUDE	-0.002**	-0.002*	-0.002*	-0.001*
	0.00	0.00	0.00	0.00
DISTOWN		-0.02	-0.042*	-0.04
		-0.03	-0.02	-0.03
PEOPLEPERHA		-0.024*	-0.01	-0.033***
		-0.01	-0.01	-0.01
FORESTAREA			0.001**	0.00
			0.00	0.00
AMHARA				2.008***
				-0.35
SNNP				2.637***
				-0.39
TIGRAY				-1.11
				-1.37
AMHARA*CA				1.87
				-1.35
SNNP*CA				1.614***
				-0.27
TIGRAY*CA				0.11
				-1.89
Constant	6.157***	6.463***	5.382**	3.587**
	-1.85	-2.06	-2.22	-1.55
R-squared	0.31	0.38	0.49	0.95
N	22.00	22.00	22.00	22.00

Notes: The dependent variable is in logarithmic form. * Significant at 10%; ** significant at 5%; *** significant at 1%. Robust standard errors are in parentheses.

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