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Community Controlled Forests, Carbon Sequestration and REDD+

Some Evidence from Ethiopia

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Abstract

REDD+ (Reduced Emissions from Deforestation and Forest Degradation, "plus" afforestration) is a tool that supports forest carbon-enhancing approaches in the developing world in order to mitigate and hopefully reverse climate change. A key issue within REDD+ is to appropriately bring in the almost 25% of developing country forests that are effectively controlled by communities. Many authors have discussed the social aspects of appropriateness, but there is limited analysis of the actual carbon sequestration potential of better-managed community controlled forests (CCFs). Drawing on an analytical framework that relies heavily on the common property and social capital literatures, our paper contributes to closing this research gap and sheds light on whether community forest management structures should be given serious consideration as REDD+ partners in the battle to mitigate climate change. Using household and community level data from four regional states in Ethiopia, we examine whether CCFs with design features known to be associated with better management appear to sequester more carbon than community systems with lower levels of these characteristics. The empirical analysis suggests that the quality of local level institutions may be important determinants of carbon sequestration. Developing country CCFs may therefore play a positive role within the context of REDD+ and other carbon sequestration initiatives. However, because of the nature of our data, results should be considered indicative. Better and smarter data combined with innovative techniques are needed to conclusively evaluate linkages between CCFs, carbon sequestration and REDD+.

Key Words: carbon stock, local institutions, REDD, rural Ethiopia

JEL Codes: Q23, Q54.

Contents

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Introduction

Although international negotiations on climate change have yielded little agreement, and atmospheric carbon concentrations and global average temperatures continue to increase,[1] there has been some agreement on the need to reduce emissions from deforestation and forest degradation in developing countries. Loss of forest biomass through deforestation and forest degradation makes up 12% to 20% of annual greenhouse gas emissions (Saatchi et al., 2011; van der Werf, 2009), which is more than all forms of transport combined. Total carbon stored in forests is estimated at 638 Gt (UNFCCC, 2011), with about 247 gigatons stored in Latin America, Sub-Saharan Africa and Southeast Asia. About 80% is stored above ground (Saatchi et al., 2011).

The idea behind REDD (Reduced Emissions from Deforestation and Forest Degradation) is that providing financial and technical support to developing countries can reduce deforestation and therefore sequester more carbon. The "plus" in REDD+ incorporates afforestration and other activities to enhance forest carbon stocks.[2] This approach may effectively compete with other climate investments as part of a cost-effective climate policy (McKinsey & Company, 2010; Kindermann et al, 2008).

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[1] As of October 2012, there have been 17 conferences of the parties to the UN Framework Convention on Climate Change (UNFCCC). Most mitigation activities are local or regional. (Agrawal et al., 2011). The focus on forest-related sequestration in developing countries began with COP 13, held in Bali, Indonesia in 2007

[2] Resources assembled to support these efforts include the World Bank Forest Carbon Partnership Facility (FCPF) and UN-REDD, which is a United Nations-implemented initiative funded by the Government of Norway.

Using household and community data from 22 communities in four regional states in Ethiopia, we provide one of the few assessments of whether better social coordination around common forest management to reduce forest degradation sequesters more carbon than less well-coordinated systems. In examining this question, we respond to Agrawal and Angelsen (2009), who suggest this issue can be relevant to REDD+. We find that the quality of local institutions may be important determinants of carbon sequestration.

Although our results are strongly indicative, they should be considered preliminary because of potential endogeneity. We analyze the challenging case of management in community-controlled forests (CCFs). CCFs are an example of institutions and property rights over forests – formal, informal, written or unwritten[3]– that are vested in a group of people. CCFs can be considered a type of common property regime that is intermediate between private property, where rights and responsibilities are with individuals, households and firms, and state property, where rights and responsibilities are vested in governments. Such institutions are not purely exogenous treatments. Indeed, going back at least to Heltberg (2001), CCFs have been modeled as emerging from endogenous processes.

As yet, there is little empirical evidence on whether community forest management structures are institutions that should be given serious consideration as REDD+ partners in the battle to mitigate climate change. We therefore attempt to shed light on whether CCFs with design features known to be associated with better management appear to sequester more carbon than community systems with lower levels of these characteristics.

An exception to this lack of evidence is Chhatre and Agrawal (2009), who examine tradeoffs between climate and forest livelihood benefits. Using a worldwide data set, they conclude that, in general, these goals are complementary. In their paper, however, forest quality is measured fairly coarsely and the CCF design principles used are highly aggregated. Indeed, one of the key conclusions of the paper is that more detailed analysis is needed.

Our paper builds on and extends the approach of Chhatre and Agrawal (2009) by incorporating detailed estimates of forest areas, supported by on-the-ground measurements and combined with much more comprehensive and nuanced measures of CCF design principles. We better characterize design and effectiveness using detailed common property design elements that are well established in the literature (Ostrom, 1990, 2000, 2009; Agrawal 2000, 2001;

[3] Property rights refer to the right to the stream of benefits from forests and also the right to control forests.

Agrawal et al., 2008; Shyamsundar, 2008). Using 14 specific measures of CCF institutional elements, we explicitly incorporate the multi-dimensionality and continuity of such institutions that have been part of the recent literature (e.g. Agrawal et al., 2008; Bluffstone et al, 2008; Mekonnen and Bluffstone, 2008).

Understanding the role of CCF management in reducing climate change is important for at least three reasons. First, perhaps 25% of developing country forests are under some type of community control (World Bank, 2009; Economist, 2010b) and the portion in low-income countries is no doubt much higher. If forests are a key source of greenhouse gas emissions and CCFs are about a quarter of world forests, it is difficult to imagine addressing climate change without bringing CCFs into REDD.

Second, CCFs are critical assets to people in rural areas of low-income countries, but the livelihood potential of forests has yet to be even partially tapped, because so many benefits are non-marketed. A key challenge for developing country forestry is therefore to extract value from forest lands without overharvesting timber or converting forest land to other uses, such as agriculture and pasture (Hyde et al, 1996). Meeting this challenge to improve the economic conditions of poor people and preserve forests has proven to be difficult.

Third, in most low-income developing countries, forests provide people a variety of products that are essential to daily life, including fuel wood, forest fruits and vegetables, building materials and animal fodder (Cooke et al. 2008). For example, grazing and fodder benefits derived by communities in Kenya are estimated to be about $33 per hectare per year (Guthiga, 2008). In a country with PPP GDP per capita of $1800 per year, forest benefits are therefore important for villagers.

The reliance of rural households on forest resources has critical climate change ramifications. For example, over two billion people around the world cook with biomass on a regular basis and most of this comes from forests. Though fuel wood is in principle carbon neutral, the black carbon from biomass fuels for cooking and heating is known to be a key contributor to climate change. CO_2 emissions cause 40% of anthropogenic climate change, but black carbon is second with an 18% contribution (Rosenthal, 2009).

In the next section, we provide a brief discussion of the literature at the intersection of REDD+ and CCFs. Our data and methodology are discussed in the section that follows. Next, the findings are presented. The concluding section highlights areas for further work.

REDD+ and Community Controlled Forests

REDD+ refers to reducing emissions both from deforestation and forest degradation and incorporates the role of conservation, sustainable forest management and enhancement of forest carbon stocks in developing countries (UN-REDD, 2010). REDD+ is the focus of the 2010 – 2015 UN-REDD Programme. While most developing country forests are on paper government owned, in practice about one-quarter of forests are actually controlled to important degrees by communities (Agrawal et al, 2008). Since the early 1980s, there has been a worldwide trend in developing countries toward various types of community control and management of forests, at least partly because privately owned and government structures have often proved infeasible. This process may take the form of devolving either ownership and control of forests or only user rights to local users (Sunderlin et al, 2008; Agrawal et al, 2008).

A critical literature for our paper discusses CCF design principles and attempts to disaggregate CCF components. This work suggests that effective CCF systems contribute to better natural resource management (Shyamsundar, 2008) when they empower communities and have clear access and extraction rules, fair and graduated sanctions, public participation, clear quotas and successful monitoring (Ostrom, 1990; Agrawal, 2000, 2001). Recent work also emphasizes the need to analyze the details of CCFs rather than treating CCF as a binomial variable (Jodha, 2008; Shyamsundar, 2008; Agarwal, 2010), but evidence is limited on whether CCF design elements have mainly independent effects or are synergistic. Bluffstone et al. (2008) and Mekonnen and Bluffstone (2008) estimate that design elements are viewed by households as a package rather than having independent effects.

Linking CCFs and REDD+ is seen by many as a natural extension of the worldwide trend toward forest devolution and the development of regional and voluntary carbon markets (e.g. Peskett et al., 2008). For example, the Regional Community Forest Training Center, in collaboration with the Global Alliance for Community Forestry, noted that "Community-based forest management (CBFM) provides a sound framework through which REDD can provide financial and livelihood benefits to forest-dependent communities and indigenous peoples, by acknowledging their essential role in the long-term, sustainable management of forest ecosystems" (RECOFT, 2008, p.1).

Phelps et al. (2010) argue that the scope of REDD should be broadened to include "incentivizing conservation among direct forest managers, including forest-dependent communities...." Venter et al. (2009) agree and argue that particularly biodiverse areas should be targeted for REDD+ payments. Cronkleton et al. (2011) echo Agrawal and Angelsen (2009) and note that REDD+ outcomes could be achieved through the adoption of common property design principles, including secure property rights and strong institutions for forest governance.

Though not directly related to our analysis, an important strand of the literature has raised social concerns about linking REDD+ with CCFs. A particular worry is that local people in developing countries will end up paying the cost of climate change mitigation, rather than benefiting from REDD+ payments (Dyer and Counsel, 2010). Ratsimbazafy et al. (2011) studied the livelihood dimensions of REDD+ in eastern Madagascar. They found that socioeconomically disadvantaged individuals are the most dependent on forests and are the most affected by restrictive measures intended to avoid deforestation and forest degradation. They find that the compensation offered is not enough to recover opportunity costs.

There is particularly limited empirical literature that addresses the question of whether CCFs that include better design principles actually sequester more carbon (Chazdon 2008; Ranganathan et al. 2008). An important analytical challenge in answering this question is effectively dealing with leakage. For example, people living in areas with CCFs that include better design principles and perhaps related REDD+ contracts may simply gather forest products from uncontrolled areas (Robinson and Lokina, forthcoming). To our knowledge, no retrospective empirical studies of CCFs measure and adjust for leakage. We are, unfortunately, also unable to address this issue, though the nature of our data makes leakage unlikely. As already noted, our contribution focuses on effectively measuring forests and suggesting ways to integrate CCF design elements with REDD+ by incorporating a nuanced and contemporary view of CCFs.

Analytical Framework, Data and Empirical Methods

For resources held in common, the literature views better collective action as an important step toward improving natural resource management, and in our case, carbon stocks. The analytical framework we use draws heavily on this body of knowledge and supposes that communities with more social capital are better able to develop natural resource management systems, leading to higher quality natural resources. We do not directly observe social capital, but we instead observe better management and can effectively interpret it, because a large literature has analyzed the components of better community management. We therefore expect better managed CCFs to sequester more carbon.

We are not able to exclude all possible confounding factors, but, as discussed below, we adjust for the major confounders considered in the literature. Reverse causality is always a potential problem and we are not confident that we have good instruments for CCF management. We view reverse causality as unlikely, however, because communities have little reason to invest in better social organization when forests are abundant (Hyde et al, 1996); if there is reverse causality, we therefore expect to find exactly the opposite of our hypothesis that better collective action is associated with more forest carbon.

Finally, though we cannot exclude all possibilities, it is unlikely that a common exogenous variable affects both CCF collective action and carbon stocks. For example, more effective community natural resource management and the social capital that we and the literature believe underpins it are particularly difficult to create from the outside and are instead much more likely to emerge from complicated processes (Ostrom, 2009; Agrawal, 2007) that have very little to do with larger carbon stocks. Indeed, it is difficult to even think of a reasonably likely exogenous shock or stimulus that would affect both forest carbon and social organization. With careful choice of conditioning variables that are potential confounders, we are therefore confident that our analysis adds to the literature.

The data used for this study were collected in 2009 in the Amhara, Oromiya, Southern Nations Nationalities and People (SNNP), and Tigray regional states. These states include all those with sufficient rainfall to support forests and stretch from Kenya to the Eritrean border. The *kebeles* within these regional states are chosen based on certain criteria such as variation in agro-ecology, forest cover, ethnic group and forest management.[4]

Ethiopia currently has an estimated closed canopy forest cover of 4.6% compared with a baseline of perhaps 40% in the 16th century (EFAP 1994; Tumcha 2004). It also has a 0.8% annual deforestation rate and 83% of the 80 million people live in rural areas (World Bank, 2005). Since the year 2000, Ethiopia has increasingly recognized that forest size and quality is important for economic performance and has therefore made increased forest cover a policy priority. For example, a forest proclamation was issued in 2007 and the first-ever federal forest policy was approved the same year. Both of these documents allow for a variety of institutional arrangements for investment in forests, including CCFs, private woodlots, and on-farm trees.

Three types of data are used in this paper. The first data are 15 m^2 ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) satellite images purchased to derive natural and plantation forests within each *kebele* boundary. Second, community characteristics

[4] *Kebele* is the lowest administrative unit, sometimes called peasant association.

were collected from secondary data sources and *kebele* officials. Third, a household survey was conducted to collect household perceptions of CCF management that we believe are superior to previous attempts.

Kebele forest area is estimated based on analysis of satellite imagery and includes both natural and plantation (e.g. eucalyptus) forests. Above ground biomass is then estimated using on-the-ground sampling of average tree height, average diameter at breast height, and species composition within each of the *kebele* forests. With information about the species composition of *kebele* forests, wood density is estimated using the global wood density database (Zanne et al. 2009; Chave et al. 2009). Above ground biomass is estimated using Equation 1, which was developed for tropical countries by Brown et al. (1989) and proposed in Chavan et al. (2010) and Brown (1997). This function is used 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 has the ability to capture characteristics of a variety of ecosystems.

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

Where Y=the aboveground biomass (kg)[5], 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), above ground carbon is a linear function of and assumed to be half the total biomass. This approach is acknowledged to be simplistic in a world where carbon inventory methodologies are themselves fields of study. As we are interested mainly in differences across *kebeles* rather than carbon levels, we believe this approach to be reasonable.[6]

Because our sample areas come from different regional states in the country, they represent a diversity of populations, forest sizes, social and ecological systems. We normalize our carbon estimates for population (carbon per capita) and forest area (carbon per hectare) and, as already noted, take explicit account of forest species diversity in our biomass calculations. As

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5 Biomass is defined as "organic material both above-ground and below-ground, and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc." Above-ground biomass (AGB) consists of all living biomass above the soil, including stem, stump, branches, bark, seeds, and foliage.

6 We would have preferred to estimate village rather than forest area, because it is more closely tied to households. Unfortunately, villages in Ethiopia are not recognized administrative districts. The lowest analyzable level using satellite imaging is the *kebele*. A positive aspect, though, is that by measuring forests at the *kebele* level, leakage is very unlikely. Very few households simultaneously collect from two or more forests.

shown in Figure 1, this diversity translates into a large variance in total *kebele* carbon stocks. The average carbon stock per hectare is 21.53 tons per ha and it ranges from 0.028 to 119.07 tons per hectare.[7]

As outlined in the previous section, based on the literature, there is reason to believe that better coordinated communities have better managed forests and less open access. To measure collective action, a household survey based on systematic random sampling is employed, with a total of 315 households selected randomly from the 22 *kebeles* in 4 regional states. We use data on CCF design elements collected from household heads rather than village "leaders." We take this approach because, in developing countries, on-the-ground realities often correspond poorly with policies. This could be for a number of reasons, including leader mis-assessments, attempts to portray local institutions in positive lights or simple difficulties characterizing social coordination details. For example, we know from the literature on CCF design elements that fairness, clarity of access rules, and appropriate social sanctions are key aspects of successful social coordination. These are subjective and subtle aspects that households are likely to perceive much more accurately than leaders.

Table 1 presents the 14 survey questions used to measure CCF social coordination based on established criteria for well-functioning CCF management (e.g. fairness, clarity, appropriate sanctions, etc.) suggested by Ostrom (1990; 2000; 2009), Shyamsundar (2008), Bluffstone et al. (2008); Agrawal (2001) and Agrawal et al. (2008). These indices are continuous, because forest sector coordination in Ethiopia and much of the lower-income developing world is continuous and evolved locally in response to circumstance (Agrawal et al., 2008; Jodha, 2008). We take the approach of Glaeser et al. (2002) and treat social capital as an asset that is held at the individual rather than the community level, as suggested by Bowles and Gintis (2002).

Many CCF management variables are highly collinear, making it impossible to use all 14 variables in models. We therefore aggregate the information into a higher level index using factor analysis. Based on the results of the factor loadings, we derive one factor with an eigenvalue greater than one. All constituent variables therefore load on a single factor. This

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[7] According to FAO (2010) the estimated biomass stock (above ground and below ground) per hectare in regions with tropical forests in Western and Central Africa is 248.7 tonnes per hectare. The total carbon stock (i.e. all carbon in biomass, dead wood, litter and soils) in forests in Africa is 145.7 tonnes per hectare.

single factor explains 87.7% of the variation, indicating that households appear to treat CCF as a package with several components.[8]

Social coordination is at the household level. So is distance from households to nearest roads, a critical measure of transport costs and market access[9]and a potential confounder. These features imply that our analysis must also be at the household level. Households within *kebeles* are assumed to have equal access to carbon per capita and carbon per hectare in *kebele* forests. We believe this approach is reasonable, because forests are held in common and, as discussed in literature dating back to Gordon (1954), in such situations average stocks are the correct metric. Households extract forest products from these common forests subject to management rules and/or norms. Extraction of biomass by villagers reduces carbon stocks, which are observed along with CCF management features.

Carbon stored in natural and plantation forests is likely affected not only by institutional elements that we hypothesize are important, but also community and ecological variables (Chaiyo et al., 2011). We therefore follow the lead of Chhatre and Agrawal (2009) and include several other variables. These independent variables are listed in Table 2. Physical isolation, because of increased transport costs and reduced market opportunities, is expected to be associated with less extraction of biomass by villagers and therefore more carbon sequestration. This is consistent with the von Thunen model of deforestation (Hyde et al., 1996) and a large literature on geography and development that finds isolation reduces economic activity and therefore development (e.g. Gallup, Sachs and Mellinger, 1999). It is also possible that more isolated *kebeles* have systematically different levels of social coordination than more proximate ones, making isolation a potential confounding factor. Because distance to roads can vary widely within *kebeles*, the average value is not terribly meaningful. As already noted, this variable is therefore measured at the household level.

We use three explicitly ecological variables. Forest carbon is affected by forest altitude and the type of ecosystem, because of variations in temperature, rainfall and resulting densities and species composition. We therefore include average *kebele* altitude and whether *kebele*

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[8] Bluffstone et al (2008) also found that respondents in the Bolivian highlands view CCF design elements as a bundle of characteristics rather than as completely distinct components. Mekonnen and Bluffstone (2008) found similar results for a sample of households in Amhara Regional State of Ethiopia. The factor analysis details can be found in the Appendix.

[9] E.g. see Yesuf and Bluffstone (2009) and Fafchamps and Hill (2005).

ecosystems are classified as *Kola*, which are relative lowlands between 500 and 1500 meters in our models.

Population pressures, because of the need to access direct use values important for subsistence (e.g. fuelwood, fodder and grazing) rather than other forest values should be associated with lower carbon stocks. It is also a potential confounding factor if, for example, more competition for natural resources makes social coordination more difficult. More people per hectare of forest, which is the variable we measure, implies more population pressure on forests, and we therefore expect smaller carbon stocks. We also include total area of forests, because, all else equal, larger forests have more carbon combined with fewer livelihood tradeoffs.

Of course, unobserved regional factors will also influence carbon sequestration in *kebele* forests. A key such factor is average *kebele* rainfall. Such data are not available, however, because outside Ethiopian cities there are very few meteorological stations. To capture this and other unobservables, we include regional state fixed effects, with Oromiya Regional State the omitted regional state.[10] As discussed below, these dummy variables also are likely to pick up unobserved social variables, such as social capital and coordination not captured by our CCF management factor analysis.

Results

We begin our results discussion with an analysis of bivariate Spearman correlations that provide empirical support for our regression models. These are presented in Table 3.

We see that, with the exception of the Amhara Regional State dummy, all variables in our models are significantly associated with our two measures of carbon (PERCAPCARBON and PERHACARBON). SOCIALCOORD, which is the result of factor analysis of our 14 CCF management variables, is positively correlated with forest carbon and significant at greater than the 1% level for both carbon measures (ρ=0.32 and 0.33). Other variables have expected correlations. Households living in more remote areas (DISTOWN ρ= 0.34 and 0.15) and in *kola* regions (ρ=0.20 and 0.09) have higher carbon forests, as do those with larger forest areas (ρ=0.53 and 0.46). Households living in *kebeles* with higher average altitudes have less carbon in their forests (ρ=-0.48 and -0.41) as do those living in areas with greater population pressures (ρ=-0.45

[10] Altitude and agro-ecological zone also capture rainfall effects.

and -0.46). The SNNP Regional State dummy is highly positively correlated with forest carbon (ρ=0.69 and 0.67), reflecting the wetter, more tropical ecological characteristics and larger forest stocks than in hilly regions. Tigray, which is a low rainfall, mountainous regional state in the north of the country, is highly negatively associated with carbon stocks (ρ=-0.50 and -0.54).

Our main interest is in SOCIALCOORD. We see in Table 3 that, in general, other independent variables are either insignificantly correlated with SOCIALCOORD or have correlations close to zero. Only the SNNP and Tigray Regional State dummies are highly and significantly correlated with SOCIALCOORD, with households in SNNP Regional State likely to perceive high levels of CCF social coordination (ρ=0.40) and those in Tigray low levels of SOCIALCOORD (ρ=-0.36). These two regional states have very different social norms, ethnic groups and economies, which appear to be reflected in key unobservable differences in CCF social capital and social coordination. From an econometric standpoint, we need not worry about multicollinearity between SOCIALCOORD and any variables except two regional dummies.

Examining the whole distribution of PERCAPCARBON, PERHACARBON and SOCIALCOORD can mask details. We therefore break the distribution of SOCIALCOORD down into quartiles of 79 observations each and examine correlations and significance levels. These results are presented in Table 4. We see that in all quartiles SOCIALCOORD is significantly correlated with forest carbon. The first quartile is highly negatively correlated with PERCAPCARBON and PERHACARBON (ρ=-0.41 and -0.39). The middle two quartiles are positively associated with forest carbon (ρ=0.23 to 0.34) and the top quartile of the SOCIALCOORD distribution is highly positively correlated with PERCAPCARBON and PERHACARBON (ρ=0.42 and 0.39). This pattern is in accord with our analytical framework in which more social capital leads to higher quality collective action and better environmental outcomes.

Though these results are indicative that CCF social coordination leads to better management and more forest carbon, it is possible that effects are spurious. We therefore present the results of four OLS regression models for each forest carbon measure, all of which include SOCIALCOORD, our variable of interest. The first set of models includes ecological variables. The second adds DISTOWN and PEOPLEPERHA, which are both measures of pressure on forests. The third set of models brings in FORESTAREA and the final model adds regional state dummies. In the final model, due to very high collinearity (R^2 values approaching 1.0) FORESTAREA needed to be dropped. The results are presented in tables 5 and 6. All dependent variables are in logs and standard errors are robust standard errors estimated using the method of White (1981).

The regression models explain a large portion of the variance in carbon. Even with only three variables, we estimate R^2 of about 0.30, rising to 0.92 with regional state fixed effects. These are very high values for cross sectional data. The models therefore appear to be reasonable characterizations of key forest carbon correlates.

Our variable of interest is SOCIALCOORD. We see that, with both definitions of carbon, SOCIALCOORD is positively and significantly correlated with carbon, as long as regional state dummies are excluded. An approximately one standard deviation change in SOCIALCOORD is estimated to increase carbon per capita and per hectare by 45% to 82% depending on the definition of carbon stock and the model. These results hold when any one regional state dummy is included and for PERCAPCARBON when any two regional state dummies are included.

SOCIALCOORD is not significantly correlated with carbon when all regional state fixed effects are included, because SNNP and Tigray dummies are so highly correlated with both carbon and SOCIALCOORD. We believe there are unobserved social capital variables captured by the dummy variables that explain this correlation. Our empirical model, which focuses on CCF management, does not capture all aspects of our analytical framework, because it does not attempt to analyze the relationship between social capital variables and carbon. Our analytical framework proposes that exogenous social capital variables, such as trust, reciprocity, etc., affect observed CCF management, but it does not attempt to directly analyze the effect of those variables on carbon.

The regional state dummies are likely capturing aspects of social capital that correlate with SOCIALCOORD as well as factors unrelated to SOCIALCOORD, such as rainfall. As we are not interested in analyzing these details, however, we do not view this issue as a problem. We, of course, cannot rule out the possibility that the strong empirical effect of the regional state dummies is because of confounders outside our analytical framework. As was already mentioned in our analytical framework discussion, however, it is very difficult to envision exogenous factors that strongly affect both social coordination and forest carbon.

Conditioning variables in general have the expected signs. Increasing average *kebele* altitude by 100 meters from the average of about 1900 meters is estimated to reduce carbon by 10% to 20%, and an increase in forest area of 100 hectares is estimated to increase CARBONPERHA and CARBONPERCAP by about 10%. Carbon is especially sensitive to population pressure, with an increase in population per forest hectare of 10 people associated with reduced carbon of 15% to 50%. More remote areas also tend to have more carbon, with an increase in distance to town of 1 kilometer associated with a 3% to 5% increase in carbon. Amhara and SNNP Regional State fixed effects are associated with 200% to 300% more carbon than that associated on average with households in Oromiya Regional State. Tigray *kebele*s have less than 80% of the carbon of counterparts in Oromiya. KOLA, like SOCIALCOORD, is sensitive to inclusion of the regional state dummies.

Conclusions and Policy Implications

Mitigating and hopefully reversing climate change is one of the key challenges facing humanity today. REDD+, which supports a variety of forest carbon-enhancing approaches in the developing world, is one of the tools under development to try to meet this challenge. A key issue within REDD+ is to appropriately bring in the almost 25% of developing country forests that are effectively controlled by communities. There is limited analysis of the actual carbon sequestration potential of better-managed CCFs. Using an analytical framework that draws heavily on the common property and social capital literatures, satellite imagery combined with on-the-ground carbon estimates, an innovative detailed measure of CCF management, and an empirical model partially inspired by Chhatre and Agrawal (2009), our paper attempts to help close this gap.

We are unable to conclusively say that what the literature has clearly identified as better-managed CCFs sequesters more or less carbon, because of the nature of our data (cross-sectional). As we have indicated, conclusions should therefore be drawn that take account of data limitations. Using two measures of carbon, however, we find strong evidence that better managed CCFs sequester more carbon. Indeed, a one standard deviation increase in our measure of social coordination is associated with 45% to 80% larger carbon stocks, depending on the carbon definition and model.

These findings are not completely robust to inclusion of regional state dummies, which are highly correlated with our measure of CCF management. We believe this result indicates that location dummies capture key unobserved aspects of social capital like trust, experience with cooperation, family linkages and village ties that are consistent with our analytical model. Our inability to control for all key aspects of social capital in our 14 CCF management factor loadings is not unexpected and we argue that this finding does not provide evidence of confounding.

The results of the empirical analysis suggest that the quality of local level institutions may be important determinants of carbon sequestration. Developing country CCFs may therefore play a positive role within the context of REDD+ and other carbon sequestration initiatives. Many, many questions are left for the future and for others. Behavioral economists and others are likely to be interested in making explicit links between the key elements of social capital (e.g. trust) and carbon sequestration. This paper does not address these issues. Also of keen interest is to better understand the set of behaviors actually engaged in by households living in areas with better CCF management. For example, in areas with more controls on forest access and use, households will need to reduce CCF extractions. Where do they get those products, what investments are made, what substitutions occur and what hardships are endured are critical questions that need to be answered if we are to better understand whether CCFs and REDD+ can be appropriately linked.

Better and smarter data combined with a variety of innovative techniques are needed to conclusively evaluate the linkage between CCFs, carbon sequestration and REDD+. Experimental methods should be used whenever possible to more effectively construct counterfactual scenarios. Socioeconomic and precisely measured forestry panel data that helps control for unobservables are also critical to answering some of the above questions. As we precisely link households with particular forests, careful adjustments for leakage will also be critical.

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Figures and Tables

Figure 1. Total Carbon Stock by Kebele ('000 tons)

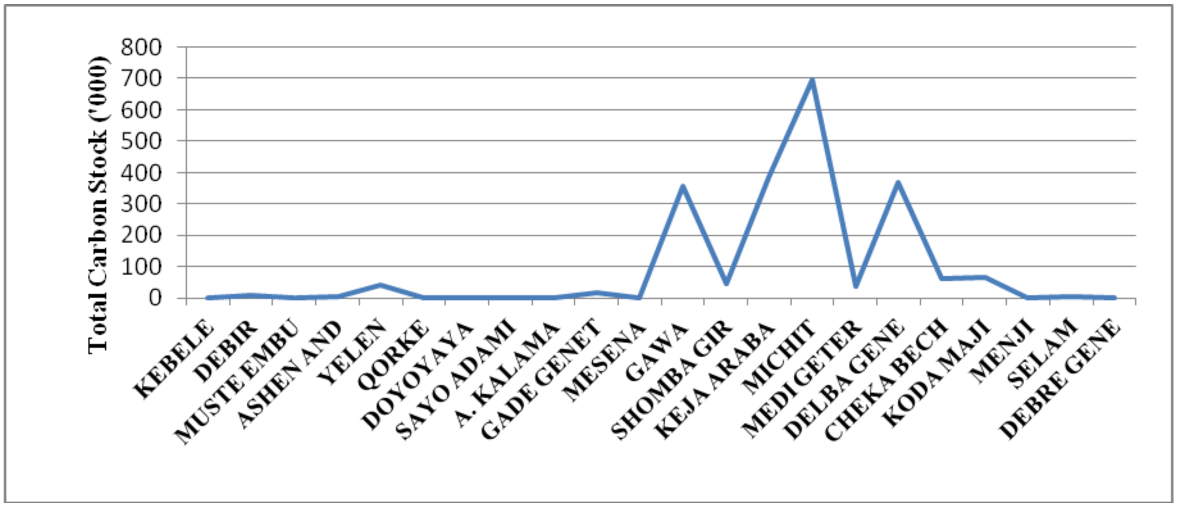

Table 1. Definitions and Descriptive Statistics of Variables used for Constructing SOCIALCOORD Variable (Likert scale 1 = completely disagree with statement, 5 = completely agree)

Variable	Mean	S.D.
The rules of access and forest use are clear	2.17	1.26
The system for deciding who has access to the forest resources is a fair one	2.22	1.19
The existing distribution process is fair and acceptable	2.54	1.27
There are limits on how much fuel wood you can collect from community forests	2.91	1.27
There are limits on how much grazing or fodder collection you can do on common lands	3.07	1.23
You are either formally or informally involved in monitoring the forest	2.95	1.39
Villagers generally watch who takes forest products from common lands.	2.43	1.17
The controllers of common lands (who decide how much each person can take) are democratically chosen.	2.67	1.22
Other villagers would be very unhappy with you if they found that you had taken more than your allotment of fuel wood, fodder or grazing rights.	2.68	1.25
You could lose some or all of your rights to collect forest products from common lands if you were caught taking more than the amounts you are allowed to take.	2.72	1.23
All other households have the same allotment of fodder or grazing rights per year (as your household)	2.29	1.23
If you took more fuel wood from the common lands than you were allowed to take, then you would face some sort of punishment.	2.37	1.24
If you took more fodder or did more grazing from common lands than you were allowed, then you would face some sort of punishment	2.45	1.26
Would you feel embarrassed or bad if you took more than your allotment of fuel wood, fodder or grazing rights?	2.53	1.20

Table 2. Independent Variables (N=315)

Variables	Mean	S. D.	Min	Max
SOCIALCOORD - CCF Social coordination index from factor analysis	0.00	0.98	-1.62	2.55
KOLA Dummy (=1)if the majority of the village is Kola region	0.22	0.42	0	1
ALTITUDE- Average altitude of the *kebele* in meters	1935.56	367.79	1428.5	2754.5
FORESTAREA - Total forest area in hectares	907.15	1007.63	0	3736
PEOPLEPERHA-Number of people in the *kebele*/hectare of forest	15.42	19.29	0.87	66.67
DISTOWN-Distance to nearest town by foot one way (in km)	11.65	9.88	1	47
AMHARA - Dummy for Amhara regional state	0.17	0.38	0.00	1.00
SNNP - Dummy for SNNP regional state	0.50	0.50	0.00	1.00
TIGRAY - Dummy Tigray regional state	0.19	0.39	0.00	1.00
OROMIYA - Dummy for Oromiya regional state	0.14	0.35	0.00	1.00

Table 3. 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	TIGRAY
PERCAPCARON	1.00										
PERHACARBON	0.90	1.00									
	(0.00)										
SOCIALCOORD	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	0.34	0.15	0.05	0.45	-0.44	1.00					
	(0.00)	(0.01)	(0.43)	(0.00)	(0.00)						
FORESTAREA	0.53	0.46	0.06	0.11	-0.21	0.17	1.00				
	(0.00)	(0.00)	(0.28)	(0.05)	(0.00)	(0.00)					
PEOPLEPERHA	-0.45	-0.46	-0.01	0.06	0.19	-0.02	-0.86	1.00			
	(0.00)	(0.00)	(0.85)	(0.26)	(0.00)	(0.77)	(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)	(0.79)	(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)	(0.26)	(0.01)	(0.00)	(0.00)		
TIGRAY	-0.50	-0.54	-0.36	0.04	-0.04	0.20	-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)	

Significance levels in parentheses

Table 4. Spearman Correlations between SOCIALCOORD and CARBONPERCAP and CARBONPERHA by Quartile of the SOCIALCOORD Distribution

	CARBONPERCAP	CARBONPERHA
1ST quartile	-0.41 (0.00)	-0.40 (0.00)
2nd quartile	0.25 (0.02)	0.28 (0.1)
3rd quartile	0.23 (0.03)	0.34 (0.00)
4th quartile	0.42 (0.00)	0.39 (0.00)

Significance levels in parentheses

Table 5. OLS Models of Carbon Stock per Hectare of *Kebele* Forest (CARBONPERHA)

Variables	MODEL1	MODEL2	MODEL3	MODEL4
SOCIALCOORD	0.509***	0.612***	0.454***	0.042
	(0.07)	(0.07)	(0.06)	(0.03)
KOLA	-0.613***	0.011	-0.307**	0.121
	(0.17)	(0.16)	(0.15)	(0.08)
ALTITUDE	-0.002***	-0.002***	-0.002***	-0.001***
	(0.00)	(0.00)	(0.00)	(0.00)
DISTTOWN		-0.027***	-0.037***	-0.033***
		(0.01)	(0.01)	(0.00)
PEOPLEPERHA		-0.030***	-0.015***	-0.035***
		(0.00)	(0.00)	(0.00)
FORESTAREA			0.001***	0.000***
			(0.00)	(0.00)
AMHARA				1.933***
				(0.1)
SNNP				2.605***
				(0.12)
TIGRAY				-0.212*
				(0.12)
Constant	6.046***	6.328***	5.331***	3.480***
	(0.44)	(0.45)	(0.47)	(0.24)
R-squared	0.30	0.43	0.51	0.93
N	315	315	315	315

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

Table 6. OLS Models of Carbon Stock per Capita (CARBONPERCAP)

Variables	MODEL1	MODEL2	MODEL3	MODEL4
SOCIALCOORD	0.643***	0.821***	0.563***	-0.078
	(0.12)	(0.11)	(0.1)	(0.05)
KOLA	-0.820***	-0.694**	-1.212***	-0.310***
	(0.31)	(0.29)	(0.29)	(0.1)
ALTITUDE	-0.003***	-0.002***	-0.002***	-0.001***
	(0.00)	(0.00)	(0.00)	(0.00)
DISTOWN		0.049***	0.033***	0.038***
		(0.0)	(0.01)	(0.00)
PEOPLEPERHA		-0.049***	-0.023***	-0.054***
		(0.00)	(0.00)	(0.00)
FORESTAREA			0.001***	0.000***
			(0.00)	(0.00)
AMHARA				2.093***
				(0.18)
SNNP				3.588***
				(0.17)
TIGRAY				-0.965***
				(0.16)
Constant	9.788***	8.315***	6.691***	4.230***
	(0.75)	(0.70)	(0.76)	(0.48)
R-squared	0.28	0.46	0.54	0.92
N	315	315	315	315

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

Appendix

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

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

Factor loadings (pattern matrix) and unique variances

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Uniqueness
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_PENALITY	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