Using Stocking Guides to Take Stock of Forest Institutions

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Abstract

We argue that forest stocking indexes are an important and valuable way to look at the effects of forest institutions. This method can be especially useful when doing comparative institutional analysis as it provides a common metric to evaluate such institutions across diverse ecologies. As an example of the application of the method, evidence from Uganda is presented to show how decentralization policies reduced overall stocking in many types of Ugandan forests.

Keywords:

Stocking, Decentralization, Institutional Analysis, Uganda

1 Introduction

According to the UN Food and Agricultural Organization, world deforestation rates continue to be unsustainable especially in tropical regions (FAO, 2007). The average annual rate of world deforestation from 1990-2000 was 0.22 percent, while from 2000-2005 the average annual rate of world deforestation had decreased slightly to 0.18 percent; however deforestation rates varied dramatically across countries (FAO, 2007). While some conversion of forestland to other uses is attributed to efficiency enhancing land transfers, much deforestation occurs because the full benefits of forest services are not capitalized into forest market prices.

Why are forests disappearing in some countries? Part of the reason lies in the fact that the full benefits that forests provide are often not considered because there are no mechanisms to compensate forest users for providing these benefits. Some of these benefits, or ecosystem services, are carbon sequestration to mitigate global warming, the provision of habitat for biologically diverse species, flood control, and watershed protection (Costanza et al., 1997). If the full benefits of forest preservation are taken into account deforestation rates might significantly change. For example, Kremen et al. (2000) analyzed a forest park in Madagascar and found that once accounting for just some of its ecosystem services optimal rates of deforestation for that park decrease substantially.

In order to preserve or conserve the world's forests, international, national, and local forest managers have tried myriad policy interventions. Payments for the ecosystems services that forests provide appear to be more and more popular (Alpízar et al., 2007). Traditional means include regulatory restrictions on harvests and creating national parks or reserves. Starting in the mid 1980s, momentum gained to decentralize forest governance to local communities (Andersson and Gibson, 2007; Agrawal et al., 2008). This trend, at least in part, was driven by multilateral organizations, bilateral donor countries, and external NGOs that found national leaders or park officials corrupt and sought more control over development projects (Agrawal et al., 2008).

Despite the plethora of institutional variation in forest governance, there has been relatively little comparative analysis of institutional performance. That is, it has been difficult to assess what types of institutional arrangements are most effective at assuaging deforestation. This is not for a lack of effort, but rather it is because of two important difficulties of comparing forest outcomes across settings. First, metrics of forest conditions are not easily comparable across different forest ecosystems. Different ecosystems will have, by their very nature, very different levels of biomass, species diversity, and other stand characteristics. Second, it has been challenging to assess these relationships over time because of the expense involved in repeated visits to the same forests. Over time analysis of forest conditions, however, provides a more complete view of any differences in outcomes across forests and ensures that the differences in outcomes are not due simply to preexisting conditions. We argue that gathering data on forest stocking mitigates the first problem of comparative institutional analysis, while gathering data over time helps ensure that institutional effects are detected.

In the next section we review the literature comparing forest outcomes across different ecologies. In section three we present the method of using forest stocking guides and in section four we present evidence from Uganda to assess the effects of decentralization policies in various forest ecosystems. Section five concludes with a discussion of potential future research.

2 Literature Review

A number of different methods have been used to assess the comparative advantages of different institutional forms on forest governance. There has been much recent empirical work investigating these effects. When using non-subjective assessments of forest conditions researchers have generally measured forest outcomes by utilizing the dynamics of forest measurements. That is, researchers assess some baseline of forest conditions and try to measure change from that baseline.

2.1 Forest Cover Dynamics

Recently, Nagendra (2008), analyzed metadata from 49 locations in 22 countries to compare land cover change in protected areas to non-protected areas using remote sensing satellite imagery. The author compares rates of land cover change by assessing rates of change before a site is designated as a protected area to rates of change after designation, as well as using bordering land change as a control group for both time periods. In general, she found that protected areas are effective at limiting land cover clearing in Europe and North America (where protected areas tend to be managed for non-use values), but less effective in Asia, South America, and Africa (where protected areas tend to be managed for multiple purposes). The highest rates of land cover clearing in protected areas, relative to past clearing and bordering areas, were in Asia. Also interesting is the fact that International Union for the Conservation of Nature and Natural Resources (IUCN) categories on land-cover change did not significantly predict change. The author concludes that Asian countries have an especially difficult task in managing protected areas because they deal with both an underinvestment in protected area management as well as local communities living in poverty and with forest dependence.

Andersson and Gibson (2007) apply this method to assess the effects of forest decentralization in Bolivia. The authors argue that most studies of decentralization look solely at intermediate outcomes, such as public participation, rather than actual environmental outcomes. They analyze decentralization policies in Bolivia and find that the process of decentralization differs greatly in the country. Even though decentralization mandates are uniform throughout Bolivia, there is much variation both in the willingness and capacity of local officials to carry out those mandates. The performance of local municipalities that implement the decentralization process is crucial to successful forest management. Specifically, the authors find that municipalities that facilitate forest property rights to previously excluded forest users, have monitors in the field to observe local use, and have a forester on the payroll have far less deforestation than those that do not. These effects are the most powerful in areas that had high deforestation rates before decentralization took place.

There are certainly some important advantages to using forest cover to assess the role of different institutions. Data gathering is comparatively cheaper than deploying teams on the ground to inventory forest conditions. Also, it is possible to take repeat samples continually at relatively modest expense. However, assessing forest cover also has limitation. In particular, the details of the forested area are often obfuscated when taking landsat or aerial photography. Little information is gleaned about the composition of forests, the actual biomass of the forest, and other characteristics of the forested area. In short, this method provides good information as to what areas are forested, but is limited in that it provides little as to the characteristics of the forest.

2.2 Quantitative Group Assessment

Hayes and Ostrom (2005) analyzed 87 forests designated as protected areas and managed by national governments and compare these to 76 areas managed locally or privately. The authors use 5 indicators of forest conditions taken from a series of questions asked of a forester who participated in plot mensuration. The foresters are asked to consider the topography and ecological zone of the forest and to rate, on a five point scale, the density of vegetation, species diversity, commercial value, subsistence value, and conservation measures of the forest.[1] They also used 2 indicators of forest conditions taken from a series of questions asked of local user groups. On the same five point scale the user groups decides how most of the individuals in the user group rate the condition of the forest and also indicate their attitude towards conservation measures in the forest. The authors find no statistical correlation between protected area designation and the rankings of forest conditions. Gibson et al. (2005) extended this analysis to show that regular monitoring and sanctioning did significantly predict the assessed forest conditions using these same measures.

These measures have the obvious advantage of being directly comparable across sites and ecologies. Unfortunately they have two major disadvantages, namely the cost of gathering the information (foresters must be sufficiently familiar with the forest to make the assessment and user groups must be interviewed to find their opinion) and the subjectivity of the measures. What one forester ranks as good conditions another, equally qualified forester, may rank differently.

2.3 Utilizing Dynamics of Forest Change

Within a particular ecology, indicators of forest conditions have been compared across sites. For example, Gibson et al. (2002) assess a number of ecological criteria in Guatemalan forests to show that privatized forests do not outperform community forests including average stem diameter and basal area.

Ostrom and Nagendra (2006) assess changes in biophysical measures over time. They then compare physical changes across diverse ecologies and countries. Specifically, they look at basal area, stem diameter, and stem count to assess if there had been significant change in a particular forest over time. They then assessed if institutional types were correlated with any positive or negative changes in outcomes.

Coleman (2009) extended the analysis by Ostrom and Nagendra to show that even after controlling for a number of potentially intervening socioeconomic, institutional, and ecological variables, there is no statistically significant difference in key forest measures among privately, centrally, and locally managed forests. Using data from 46 forests collected at the International Forestry Resources and Institutions (IFRI) program, Coleman estimated the probability of sustaining key forest measures as a function of a number of variables. Specifically the author looked at the probability of having a significant change in the Shannon Diversity Index (a measure of tree species diversity) and basal area. He shows that there is no statistically significant difference in the probability of sustaining species diversity or basal area between government and community managed forests. Instead, two other variables appear important: first, as socioeconomic conditions improve the probability of sustaining the measures increases and second, communities with active monitoring are more likely to live near forests that sustain the measures than those that do not. In addition, this effect is especially pronounced at low levels of socioeconomic conditions.

The advantage to using these measures is that they give a precise estimate of forest composition on the ground and reflect these conditions well. The disadvantage to using this method is that information is that some information on forest conditions must be discarded. For comparative purposes, observations are coded as either having significantly less (=0) measures over time or not (=1). However, there is no compelling metric to use across diverse ecologies that would indicate *how much* less basal area, species diversity, stem count, or other measure there might be.

3 Forest Stocking

Parallel to the work being done in social science, there has been an incredible amount of work done to understand forest stocking in the forestry science literature. Reineke (1933) was perhaps the first to try and find a baseline from which one could measure forest stand characteristics. Forest metrics needed to be developed so that management practices could be measured and assessed.

Density, as typically used in most forestry literature, is an absolute measure of some desired stand attribute such as the number of stems per hectare, mean stem diameter (tree width), the basal area per hectare(the amount of area covered by trees), or volume per hectare (biomass of trees). These attributes are calculated by randomly sampling plots from a forest stand and measuring the trees in the sampled plots. Sampled measurements are then used to estimate characteristics of the entire stand. Stocking is a relative measure of these attributes (Husch et al. 2003). Stocking is useful because it can be used to reference current forest conditions to potential conditions.

There are a variety of stocking measures used in the forestry literature. The three most common are: 1) Quadratic mean stand diameter indices (Reineke, 1933); 2) Basal area stocking indices (Gingrich, 1967); and 3) Mean stem volume indices (Drew and Flewelling, 1979).[2] Over the last 25 years, numerous researchers have developed quadratic mean stand diameter indices based on variations of Reineke's (1933) original stand density management diagram (e.g., McCarter and Long, 1986; Anta and Gonzalez, 2005; Shaw, 2006). Reineke's (1933) stand density index relies on a maximum density, N_{max}, for a given quadratic mean stand diameter$(\overline{D_q})$ such that:

$$N_{max} = a\left(\overline{D_q}\right)^{1.6} \qquad (1)$$

While parameter a is species-specific, the power coefficient (-1.6) has been shown to be relatively constant across a wide variety of forest species (Shaw, 2006). The above equation describes the theoretical self-thinning trajectory for a given pure species stand. In other words, the above equation describes a maximum density that would, theoretically, be reached without management intervention. In order to express relative stand density, Reineke (1933) expressed stand density standardized to a mean quadratic stand diameter of 10 inches (25 cm) and referred to this as stand density index (McCarter and Long, 1986; Shaw, 2006):

$$SDI = N\left(\frac{\overline{D_q}}{25}\right)^{1.6} \tag{2}$$

SDI provides a measure of stand occupanancy and enables users to compare stands with differing values of stand density (N) and quadratic mean diameter ($\overline{D_q}$). SDI expresses the density (stems per hectare) at which a stand with the reference quadratic mean diameter would need to be at the same level of competition as the observed stand with $\overline{D_q}$and N.

While SDI provides a convenient measure by which to assess and compare stands, many foresters and other resource managers are more familiar with basal area (square meters per hectare) than quadratic mean diameter. Since quadratic mean diameter is the diameter of the tree of mean basal area (Husch et al., 2003), it is relatively straight forward to convert between quadratic mean diameter and basal area (BA) if density is known:

$$\bar{D}_q = \sqrt{\frac{BA}{0.00007854N}} \tag{3}$$

and SDI, expressed in terms of basal area, becomes:

$$SDI = N\left(\frac{BA}{0.00007854N \times 25^2}\right)^{1.6/2} = N\left(\frac{BA}{0.49088N}\right)^{0.8} \tag{4}$$

Stands with similar SDIs have similar levels of competition, and SDI can be used as a measure of stocking. Traditionally, isolines of SDI in $\bar{D}_q - \mathrm{N}$ space are drawn on a log-log scale as shown in Figure 1b. For SDI in the $BA - \mathrm{N}$ space, we draw the isolines in normal Euclidean space as shown in Figure 1a. The shape of the $BA - \mathrm{N}$ lines form the basis of the basal area stocking diagrams proposed by Gingrich (1969).

[FIGURE 1 ABOUT HERE]

All stocking diagrams have a maximum or fully stocked condition used as a reference for calculating relative stocking and designing silvicultural interventions (Gingrich 1969, McCarter and Long 1986). Derivation of maximum stocking is often based on large regional datasets from unmanaged stands (McCarter and Long 1986, Shaw 2006) or can also be derived from Normal yield tables. For the forests examined in this study, limited data are available and no Normal yield tables are known to exist, so we are not able to define maximum stocking; however, the SDI isolines are still a good measure by which to assess stand development and to determine if the forests surveyed in this study are increasing or decreasing in stocking over time. The SDI isolines drawn in $BA - \mathrm{N}$ space are used in this study.

Individual forest values and forest-type averages are followed over time to assess changes in stocking levels. Herein lays the advantage of using stocking guides for comparative institutional analysis. Stocking guides allow one to compare: 1) stocking in forests with different institutional arrangements, and 2) the dynamics of stocking caused by a institutional changes at some point in time. In this paper, we focus on the latter comparison. However, as long as one is comparing forests of similar ecologies, cross sectional analysis can be used to study differences in stocking caused by differences in forest institutions.

4 Decentralized Forest Management in Uganda

In order to add to the existing literature on the dynamics of forest institutions, we use a case study of forest decentralization in Uganda. We will show that decentralization in Uganda had very negative effects on forest stocking across a variety of ecosystems.[3]

Uganda began formal decentralization of forest management in 1993, but these policies and the responsibilities and duties they impose on local governments have expanded and contracted periodically (Bazaara, 2007; Banana et al., 2007). Much of this was caused by the central government's inability or unwillingness to finance the forestry efforts as well as political conflict between local users who wanted more control and the central government's use of forest privatization as patronage to elites (Turyahabwe and Banana, 2008). In 1999 Uganda initiated the Forest Sector Umbrella Programme (FSUP). As most decentralization policies, the stated goals for this program were to simultaneously create a locally accountable institutional environment for sustainable forest use and to increase economic opportunities from the forests to local people, specifically the poor (Andersson et al., 2008).

It is important to note that these policies took place within a broader institutional environment of decentralizing many political, administrative, and fiscal responsibilities to local levels. In 2002, the World Bank quantified the degree of decentralization in all three areas for all African countries and concluded that Uganda had the second highest degree of decentralization of any country on the continent (Ndegwa, 2002). In the forestry sector, this meant that decentralization went so far as to completely abolish the central forestry department in favor of district level departments and a for-profit National Forestry Authority in 2003 (Andersson et al., 2008). Seventy percent of forests in Uganda are now managed by local governments (Andersson et al., 2008).

3.1 The International Forestry Resources and Institutions (IFRI) Program

What effect have these policies had in Uganda? A unique dataset enables us to provide insight into this question. The International Forestry Resources and Institutions (IFRI) program began in 1992 as a longitudinal study designed to build knowledge of the relationships between forest conditions and the rules and strategies employed in community forests around the world. To date, IFRI researchers have conducted over 400 field studies within community forests located in Bolivia, Colombia, Ecuador, Guatemala, Honduras, India, Kenya, Madagascar, Mexico, Nepal, Tanzania, Thailand, Uganda, and the United States (IFRI, 2008). IFRI utilizes a multidisciplinary approach designed to collect both biophysical and social information regarding community forests and forestry practices.

Within each studied forest, researchers conduct forest mensuration within randomly selected plots to identify speciation, density, tree height, as well as other indicators of forest biophysical condition. IFRI researchers also collect social data on the community's history, their reliance on the forest, and other social, economic, political and demographic dimensions. Researchers meet with local forest users throughout their field visits to determine what forest products are used, what rules have been created to govern forest use, who has authority to make the rules, and how the rules are enforced. Both the biophysical and social data are recorded in IFRI survey forms and entered into a database currently housed at the University of Michigan.

3.2 Data from Uganda

IFRI researchers have visited 25 forests in Uganda two or three times. In each of these forests, the first visit was at the initial stages of decentralization (between 1993 and 1995) The second and third visits were made sometime after decentralization process began (1999-2008). In each forest we calculate the average basal area per hectare and the average number of stems per hectare for each forest plot. Basal area is calculated by inventorying each tree above 10 cm in each plot. Stem diameter at breast height is measured and basal area is calculated from a diameter tape. Basal area is then simply calculated as one half the stem diameter squared times π. The basal area for each plot is calculated by summing the basal area for each tree.

As discussed, the Reineke stocking density index is a combination of stems per hectare and basal area (Husch et al., 2003). Unfortunately, we do not have access to stocking density tables for the forests in Uganda. Still, even if precise measures of stocking cannot be made, plotting changes in stocking levels over time is quite informative. Figure 2 shows stocking data for each of the 25 forests, grouped according to ecosystem type. In this figure, each set of arrows represents a separate forest and the year indicated represents the point of time at which the forest was visited and assessed. Each arrow points to subsequent years.

It is clear from these graphs that both stems per hectare and basal area decreases over the time period when decentralization policies were in effect. This is true in every ecosystem and for each of the 25 study sites. This finding holds for every forest studied, which includes all types of forests—government, private, and community. It is clear that stocking is decreasing during the decentralization time period.

[FIGURE 2 ABOUT HERE]

While this evidence is impressive it is not enough to convince us that deforestation is caused by decentralization reforms. The decreases in forest stocking may instead be due to broader historical trends; it is possible that decentralization may have actually decreased the rate of deforestation if the rate of deforestation before decentralization was greater before the policy went into effect. To assess this possibility, Table 1 shows deforestation rates from 1990-2000 and from 2000-2005 in Central African countries. Uganda has one of the highest rates of deforestation, but the rate of deforestation increased even more, by 0.3 percent in the 2000-2005 time period. This rate of increase in the rate of deforestation is the largest rate of increase of any country except that in Comoros and Réunion. Thus, we cannot conclude that there was a general trend in Central Africa for the rate of deforestation to increase as much as the increase in Uganda in 2000-2005 as compared to 1990-2000. Decentralization is the likely cause of Uganda's greater increase in deforestation rates.

3.3 Institutional Causes of Deforestation

Different theoretical arguments can be levered for and against decentralization (Treisman, 2007). Indeed, empirical studies do not generally appear consistently estimate either positive or negative effects of decentralization (Andersson et al., 2004; Coleman, 2009), so there does not appear to be much *a priori* reason to suggest if forest decentralization will cause deforestation. We find that in this case decentralization probably did cause deforestation in Uganda. We provide evidence that decentralization had very negative effects on forest stocking, yet we would also like to speculate about why decentralization had such a strong negative impact in this case. Specific aspects of the decentralization process in Uganda must be unpacked and analyzed to gain a better understanding of why decentralization in this case failed (Andersson et al., 2008).

Banana et al. (2007) analyzed the institutional instability of the early forest decentralization policies (from 19993-1999) in the Mpigi district of Uganda. The Mpigi district had a long colonial history of successful central forest management and was able to adequately respond to a number of disturbances. The authors found that forest cover in local and private forests, however, declined after decentralization. The reason cited for prior success of government managed forests was both upward (to the forestry department) and downward (to local users) accountability. This accountability ensured frequent and consistent monitoring and sanctioning by forestry department officers. After decentralization, however, staffs and budgets of forestry officials were cut and local councils did not replace these positions nor did they allocate budget to district forests. Many members of the local councils even participated in illegal harvesting themselves.

Andersson et al. (2004) show that most of the criticisms of decentralization of natural resources argue that a lack of capacity and accountability are responsible for failed policies. This criticism is similar to what Banana et al. found; lack of funds causes decreasing levels of monitoring and sanctioning and an absence of upward accountability causes illegal harvesting and corruption at the lower levels of government. The question then arises, "can decentralized forest regimes overcome these pressures to realize the benefits of decentralization?"

Figure 3 shows data from the Mpanga Forest Reserve, a tropical rain forest designated as a formal nature preserve whose management has been funded by the European Union for five years (Banana et al., 2007). In this figure, while stocking does decrease because the stems per hectare decrease between years, the basal area is relatively constant. Deforestation in this forest is mitigated, perhaps because of supplemental EU funds that were used for monitoring activities and upward accountability to donors at this site.

[FIGURE 3 ABOUT HERE]

4 Conclusions and Directions for Future Research

In this article we showed how stocking measures can be used to assess the impacts of institutional change. We then applied this method by using data from 25 forests in Uganda, and showed that forest stocking decreased in every forest studied in the country. Without some means to compare forests over time, it would be difficult to make this assertion. However, the stocking measure allows us to visualize this change.

Forest stocking might also be used to compare forests in similar ecologies with different institutions. Our general feeling is that quantitative institutional analysis of the environmental effects of forest policy has been limited because of the great difficulty in comparing forests (See Coleman, 2009). This method opens a potentially fruitful research avenue whereby analysts can begin thoughtful, rigorous institutional analysis.

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Figures

Figure 1. Reineke Stand Density Index and Trajectories of Ugandan Forests.

Figure 2. Forest Stocking in Uganda Over Time

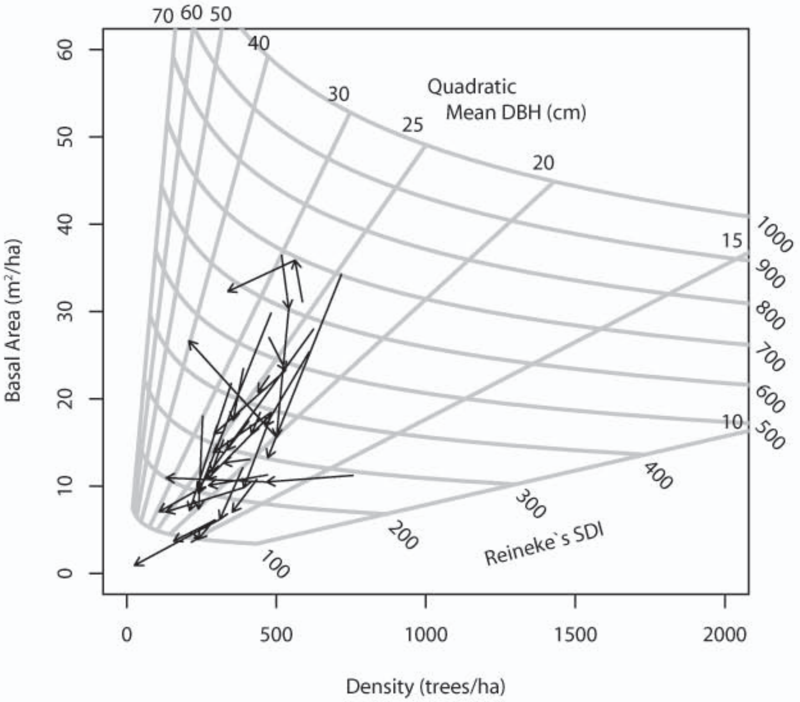
Figure 3. Forest Stocking in the Mpanga Forest Reserve

Notes

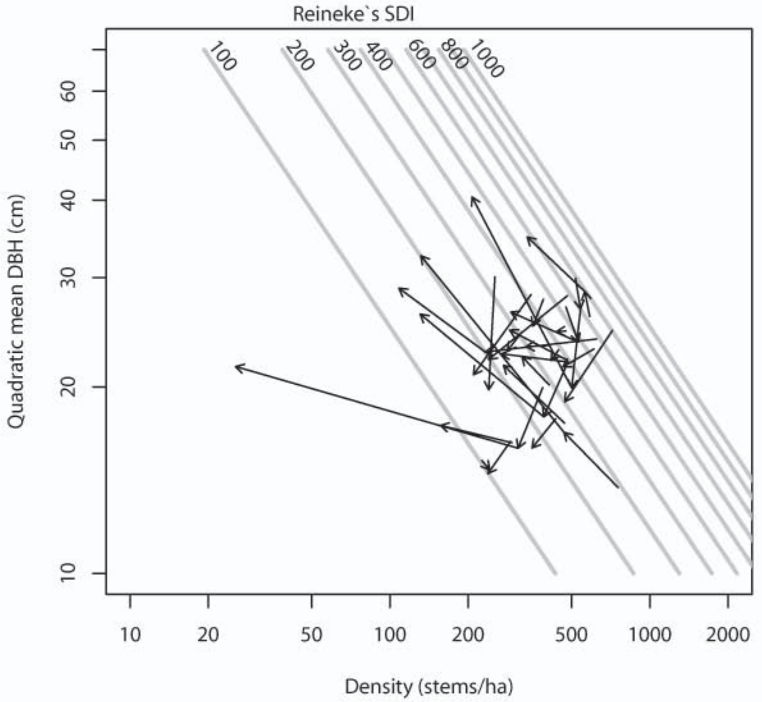
[1] The five point scale is: 1 – Very sparse, 2 – Somewhat sparse, 3 – About normal for this ecological zone, 4 – Somewhat abundant, 5 – Very abundant.

[2] In this article we will be most concerned with quadratic mean stand diameter indices. This is calculated from the trees in the randomly sampled forest plots. Each tree's diameter from every plot is measured (e.g. from a diameter tape, measured at tree breast height, 4.5 feet from the forest floor). Quadratic mean stand diameter is then calculated by taking the quadratic mean from all the sampled trees.

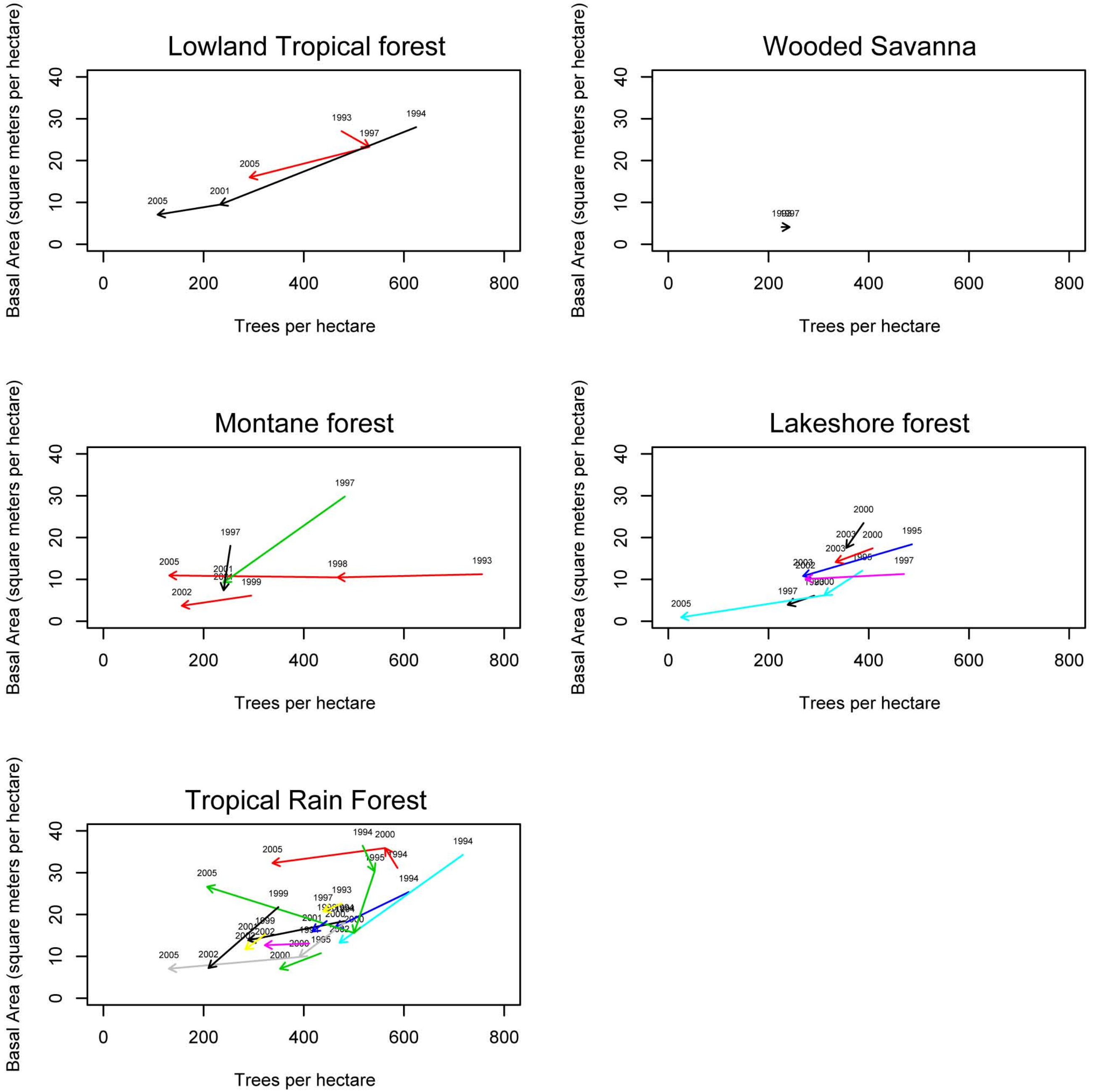
[3] This is not to say, however, that decentralization everywhere, in all circumstances will fail; rather, it is a call to (1) look beyond blueprint thinking that massive restructuring of natural resource policies are effective everywhere at every time (Ostrom, Janssen, and Andereis, 2007) and (2) to invite policy analysts to look carefully consider how to measure the policy effects of decentralization.



1a. Isolines of SDI on log-log Scale



1b. Isolines of SDI on Normal Scale



Lowland Tropical forest
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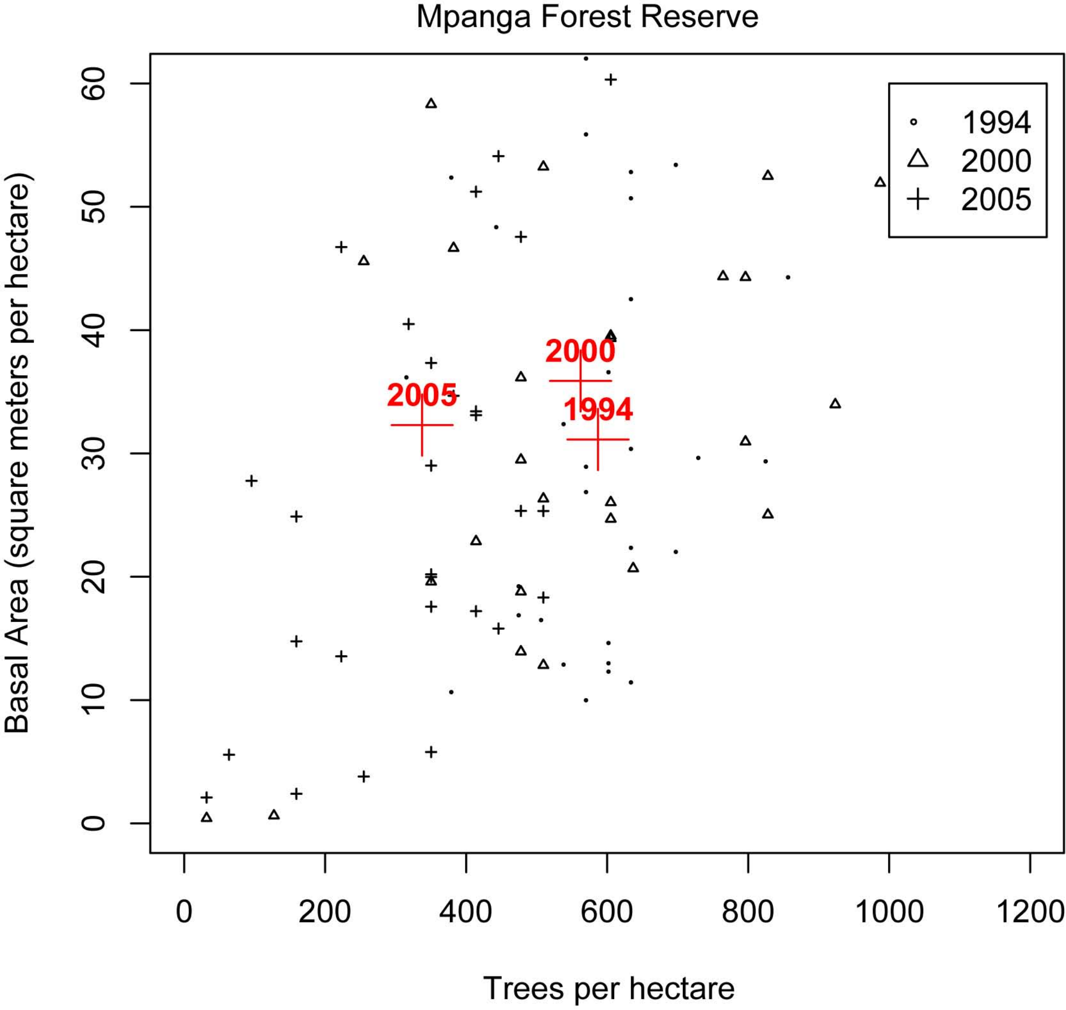

Mpanga Forest Reserve
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Basal Area (square meters per hectare)
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600
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1200
Trees per hectare