Forest Resources Assessment Working Paper 158

CASE STUDIES ON MEASURING AND ASSESSING FOREST DEGRADATION

AN OPERATIONAL APPROACH TO FOREST DEGRADATION

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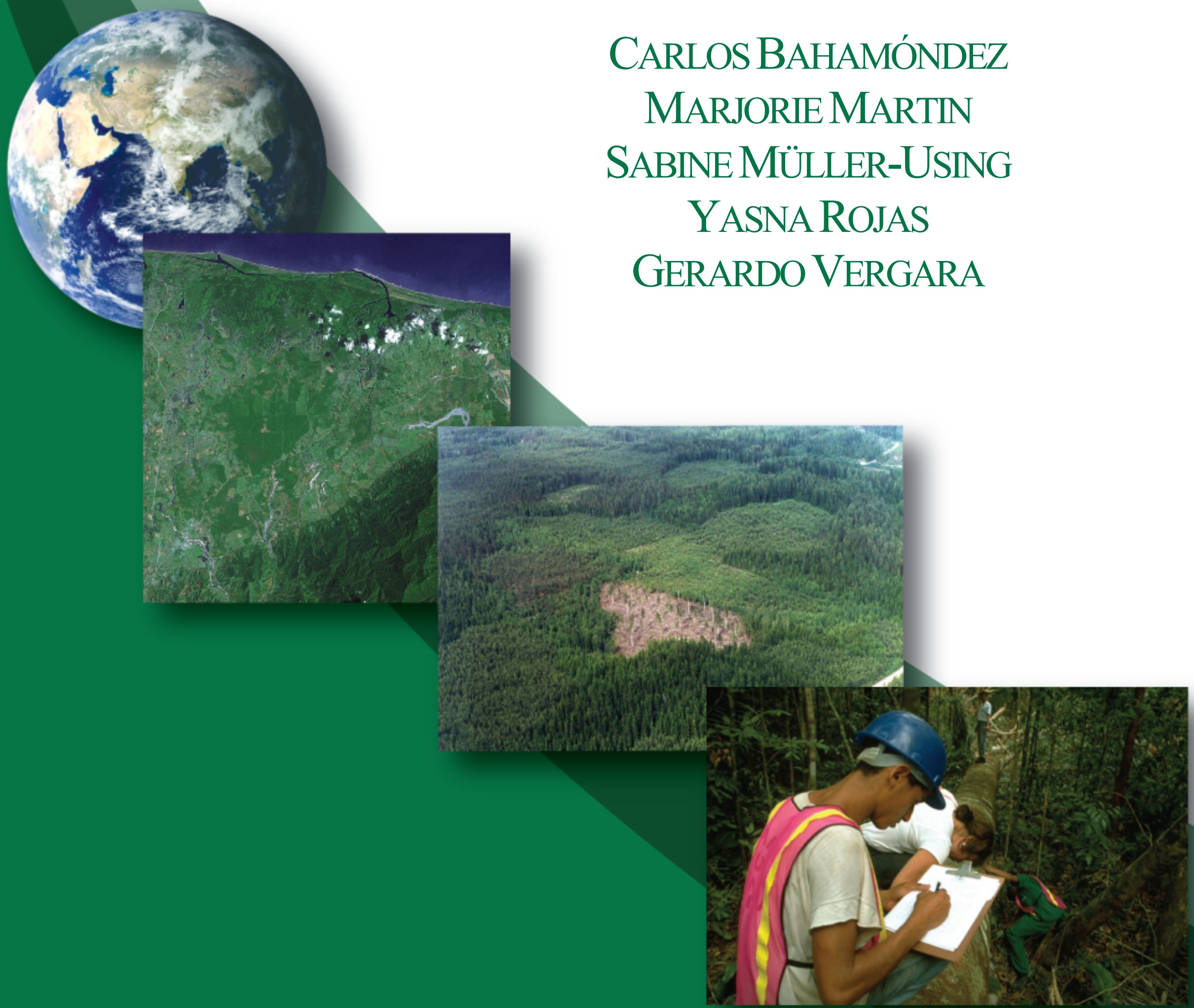

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Sustainably managed forests have multiple environmental and socio-economic functions which are important at the global, national and local scales, and they play a vital part in sustainable development. Reliable and up-to-date information on the state of forest resources - not only on area and area change, but also on such variables as growing stock, wood and non-wood products, carbon, protected areas, use of forests for recreation and other services, biological diversity and forests' contribution to national economies - is crucial to support decision-making for policies and programmes in forestry and sustainable development at all levels.

Under the umbrella of the Global Forest Resources Assessment 2010 (FRA 2010) and together with members of the Collaborative Partnership on Forests (CPF) and other partners, FAO has initiated a special study to identify the elements of forest degradation and the best practices for assessing them. The objectives of the initiative are to help strengthen the capacity of countries to assess, monitor and report on forest degradation by:

- Identifying specific elements and indicators of forest degradation and degraded forests;
- Classifying elements and harmonizing definitions;
- Identifying and describing existing and promising assessment methodologies;
- Developing assessment tools and guidelines

Expected outcomes and benefits of the initiative include:

- Better understanding of the concept and components of forest degradation;
- An analysis of definitions of forest degradation and associated terms;
- Guidelines and effective, cost-efficient tools and techniques to help assess and monitor forest degradation; and
- Enhanced ability to meet current and future reporting requirements on forest degradation.

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Case Studies on Measuring and Assessing Forest Degradation

An Operational Approach to Forest Degradation

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Abstract

An operational approach to Chile's forest degradation from the productive perspective is tested by using relative density (Gingrich et al 1967). Data for building the stocking chart is provided by the National Forest Inventory databases for one of the most common forest types in Chile, namely the Roble-Rauli-Coihue forest type *(Nothofagus oblique-Nothofagus alpine-Nothofagus dombeyii*). It is shown that the resulting stocking chart constitutes a powerful tool for understanding and identifying degraded forest from the stock point of view. The strong need for suitable data provided on a periodic basis by large-scale permanent forest inventories is also recognized. The use of the stocking chart is a feasible way to identify objectively the condition of forest degradation. It has become a potentially important tool for monitoring sustainable forest management practices or policies.

1. Introduction

Background

Forest degradation is nowadays a key issue in the forest scientific community, especially in regards to their relation to Greenhouse Gases (GHG) and the process known as Reduction of Emission due to Deforestation and Degradation and Sustainable Forest management (REDD+) in the climate change context. Degraded forest is a confusing term and current definitions are not necessarily suitable when applied operationally.

Among the most known definitions globally, the Food and Agriculture Organization of the United Nations, Global Forest Resources Assessment (FAO-FRA) 2005 states that forest degradation is "changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services".

Along the same lines the International Tropical Timber Organization (ITTO) (2002) defines degradation as "Long-term reduction of the overall potential supply of benefits from the forest, which include wood, biodiversity and any other product or service".

Attempts at a more explicative definition are those of:

- The United Nations Environment Programme (UNEP) (2001) - "A *degraded forest* is a secondary forest that has lost, through human activities, the structure, function, species composition or productivity normally associated with a natural forest type expected on that site. Hence, a degraded forest delivers a reduced supply of goods and services from the given site and maintains only limited biological diversity. Biological diversity of degraded forests includes many non-tree components, which may dominate in the undercanopy vegetation"

- The Intergovernmental Panel on Climate Change (IPCC) (2003) - "a direct human-induced loss of forest values (particularly carbon), likely to be characterized by a reduction of tree cover. Routine management from which crown cover will recover within the normal cycle of forest management operations is not included". An extensive analysis about definition and human induced causes can be found in the IPCC report on methodological and definition issues on degradation (2003).

All of these definitions share the concept of losing forest structural characteristics which could be interpreted as an implicit reference to forest stock. In this regard, it is claimed in this case study that the forest stock measurement can be efficiently applied as a proxy of forest degradation. In Chile, several years of overexploitation and bad management practices has promoted a stock degradation of forest. Excessive fuelwood cutting from forest is nowadays the main issue in forest degradation, producing under stocked forest and forestland use changes toward grazing areas. In this regard, the definition proposed by Cadman (2008), seems more appropriate to the present case study, stating, forest degradation is "a reduction in the carbon stock in a natural forest, compared with its natural carbon carrying capacity, due to human activities". The usefulness of this definition lies on the implicit concept of "carrying capacity" which can be thought of as fully stocked forest, under the concepts of relative density.

Detecting degradation is difficult when using remote sensing images (Souza 2005), mainly due to the fact that slight changes of density are not captured by medium or large size pixels like those produced by Landsat, SPOT or any similar medium resolution, and that the costs of effective satellite material can be high. On the other hand, indirect approaches to degradation at landscape level have been proposed by using the fragmentation patterns related to land use dynamics (Menaka P. et al, 2008). It is shown that the fragmentation is the starting point for degradation and finally deforestation. The best approach for tracking this type of change is through the presence of permanent measures based on ground data. This highlights the necessary role of large-scale permanent forest inventory.

In this study the possibilities of using relative density concepts to further identify degraded forest from the productive perspective is tested and assessed. This concept has been first proposed by Gingrich et al (1967), and even earlier advanced by Reineke L. (1933). Since then, several authors have used this approach to aid forest management decisions, as can be found in, Gezan S. et al (2007), Chauchard L. et al (1999), Newton P. et al (1987), and Long J. et al (1984) among others.

It is shown that the approach constitutes an important objective tool for identifying degraded forest. Additionally, it is noted the natural connection between this approach and data generated by national or regional forest inventories.

Describing Forest Stock

The forest stock is defined by FAO as "Volume of all living trees more than 'X' cm in diameter at breast height (or above buttress if these are higher) measured over bark from ground or stump height to a top stem diameter of 'Y' cm, excluding or including branches to a minimum diameter of 'Z' cm. This excludes: smaller branches, twigs, foliage, flowers, seeds, stump and roots" (FRA 2005). Forest stock is a common term used by forest managers for depicting the optimal combination of tree size, growth, and numbers of trees in relation to the management objective. The stock is closely related to stand density that implies how the growing space is occupied by trees in the forests. In this regards Reineke`s stand density index (op.cit.) is one of the most common and well-known indices among foresters. Tree area ratio is another measure of stand density proposed by Chisman and Schumacher (1940), and it represents a measure of the growing space for trees in the forests. Another efficient stand density measure is the Crown Competition Factor, first proposed by Krajicek, Brinkman and Gingrich in 1961.

Forest stocking is a term related to the best growth for a specific management goal to achieve and involves an economic connotation, in the sense that productive capacity of the site is enhanced according to management objectives. In this sense forest stocking varies according to company or owner management goals. A stand that is considered as overstocked has a maximum tree number but trees grow under strong competition and mortality is high. On the other hand, an understocked stand does not occupy the full productive potential of the site.

Gingrich (1967) proposed a *stocking chart* for dealing with forest stocking aiding managers to take good and informed management decisions. The chart incorporates and relates in the same figure the following information:

- Number of Trees,
- Basal Area,
- Tree area ratio and
- Crown Competition Factors.

Data to produce the stocking chart come from a forest inventory, specific sampling or other available sample based forest inventories data.

The Stocking chart can be seen in figure 1 below:

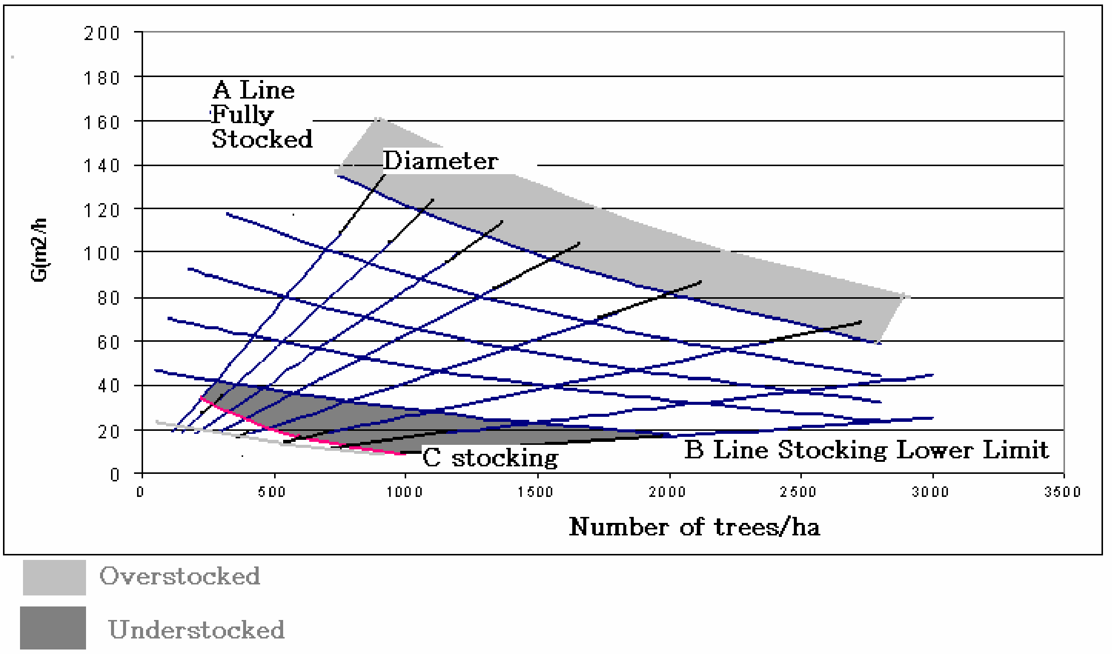

Figure 1. Stocking chart example, light grey area indicates overstocked forests, dark grey indicates understocked forests.

The A-Line depicts the fully stocked line of forests i.e., areas where trees grow under competition and fully occupy the site capacity without mortality. B-Line depicts the limits where trees account with chances to further develop large crowns, and fully occupy the site capacity without competition. C-Line represents the lower stocking achievable to reach the B-line after a period of ten years. Straight lines depict the mean squared diameter class.

The Data

The data and information considered in this case study are based on the Forest Inventory performed periodically by Chile's Forest Research Institute (Instituto Forestal-INFOR) since the year 2000. The National Forest Inventory is a permanent sample based forest inventory, which intends to capture the whole expression of the ecosystem capabilities given by their local site conditions. Its general objective is "*to create the base data and information related to the natural forest ecosystem at regional* *level*". Among its more relevant characteristics, the inventory uses a statistical sampling design. Then, it is implemented under statistically robust and consistent estimators.

More than 90 variables are identified and collected from the field mainly grouped as:

- General scope variables
- Sample plot variables
- Tree size attributes
- Tree health and quality attributes
- Soil variables
- Regeneration and vegetation variables
- Mortality and debris variables

The sampling design related to the inventory considers a systematic layout in clusters sampling units. The sampling unit was defined as three 500 m^2 nested circular plot disposed in a "L" inverted tract. Every circular sample plot is composed as a set of four area equivalent concentric circles.

All the data and information generated by the implementation of the National Forest Inventory sampling design on field, is suitably managed and stored in a specific Data Model and Geodatabase which was designed to produce effective and up to date information and analysis. Given the large amount of data and information generated, as well as, thematic maps and cartography, the data model is a key issue in regards to the application of a consistent data management policy. A commercial, but cost attractive data base engine (SQL Server^{TM}), is used in this context in connection to ARCGIS^{TM} software.

The Study Area

Chile is administratively organized as 15 regions, from North to South. The Forest is mainly located from 38°S to 53°S, the Roble-Rauli-Coihue forest type can be mainly found from 38°S to 41°S covering an area of 1,446,046 ha. Most of the stands of this forest type resulted from early XXth century exploitation and fire, and now constitute an even aged secondary growth forest.

2. Methodology

Objective

The objective for this case study is to test the operational capabilities of stocking chart to identify productive forest degradation.

The methodology involves the following steps:

I. Collecting data from National Forest Inventory Data Base for the forest type

Taking advantage of National Forest Inventory Data Base, the suitable data regarding the Roble-Rauli-Coihue forest type was obtained for further calculation and estimation.

II. Degraded forest from Forest Inventory data

This step involves checking the sample plots recorded[1] from field observation as "*degraded*", given the data collected from field campaign in the context of the Regional Forest Inventory. Also, data coming from forests recorded as productive were collected from the Regional Forest Inventory Data Base for the forest type of interest. For both conditions (degraded and productive), Basal Area/ha (G), Number of Trees/ha (NHA) and average DBH were found for the *Roble-Rauli-Coihue* forest type from the Data Base. A total of 290 sampling clusters are defined as Roble-Rauli-Coihue forest type in the Forest Inventory Data Base.

III. Building the stocking chart

Based on the data provided by the National Forest Inventory, a stocking chart for one of Chile's most important forest types was estimated according to the following expressions:

- Tree Area Ratio

$$Tree.area = \beta_0 n + \beta_1 \sum d + \beta_2 \sum d^2 \qquad [1]$$

Where:

n :Number of trees
β_ι :Regression coefficients
d :Diameter at breast height

- Crown Competition Factor

Crown Competition Factor (Krajicek et al 1961) represents the degree of canopy closure in the forest of average tree in relation to one growing under open condition. Crown Competition Factor is estimated by using Crown Width and Maximum Crown Area as follows:

$$Crown.Width = \beta_0 + \beta_1 d \qquad [2]$$

Where:

β_ι :Regression coefficients
d :Diameter at breast height

$$Maximun.Crown.Area = \beta_0 \left[\beta_1 + \beta_2 d\right]^2 \qquad [3]$$

Where:

β_ι :Regression coefficients
d :Diameter at breast height

[1] Field team uses expert knowledge and a set of heuristic rules to assess degradation.

$$Crown.Competition.Factor = \frac{1}{A}\left[\beta_0 \sum n_i + \beta_1 \sum d_i n_i + \beta_2 \sum d_i^2 n_i\right] \quad [4]$$

Where:

β_ι :Regression coefficients
d_i :Class “i” Diameter
n_i :Number of trees in the class “i”
A :Area (1 if per hectare stand table is considered)

IV. Defining limits of degraded forest

The two main state variables of forest (G, NHA) were embedded within the stock chart, developed for the forest types of interest, in order to further define the boundaries that characterize degradation from the point of view of forest stock. The stocking chart is shown as an example in figure 1. It is expected that the forests classified as *degraded* in the field, can be found on certain particular area of the stocking chart.

3. Results and Discussion

The estimated stocking chart based on National Forest inventory resemble those published by Gezan et al (op.cit.) for Roble-Rauli-Coihue forest type and resulted as depicted in Figure 2.

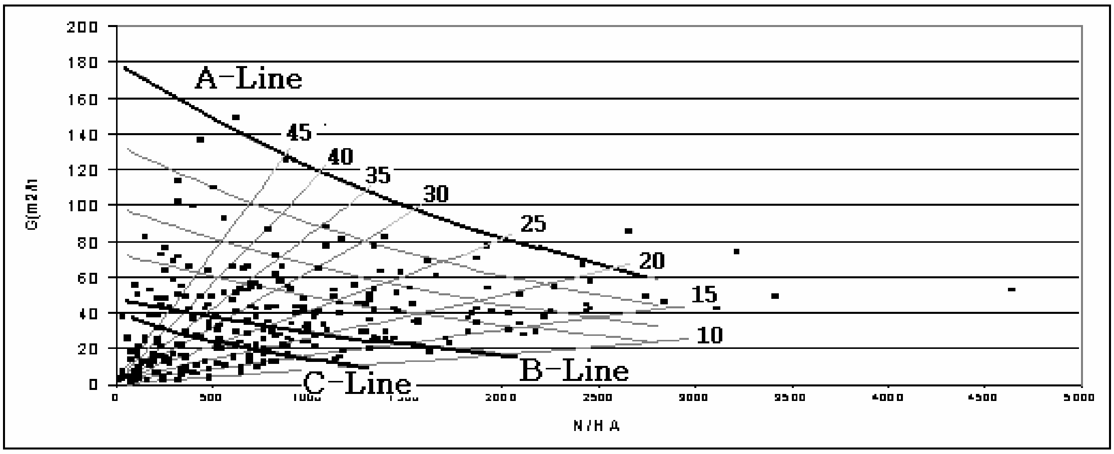

Figure 2. Estimated stocking chart for Roble-Rauli-Coihue forest type.
Dots represent the total available data from National Forest Inventory.

From the 290 available samples, 37 were accounted as *degraded* from field brigades observations, according to records contained on National Forest Inventory Data Base. The location of these 37 sample points on the stocking chart is shown in figure 3.

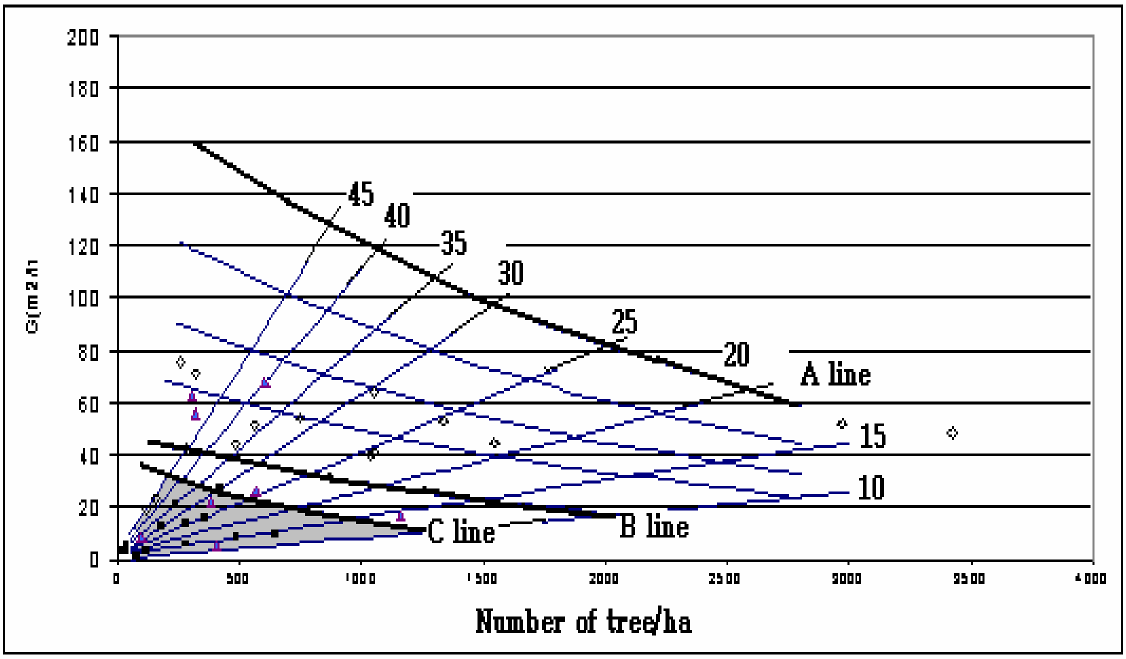

Figure 3. Distribution of data classified on field as degraded by the National Forest Inventory. (Black dots are classified as "*degraded*" by both, the field observation and the stocking chart; triangles represent recently managed forest; Diamonds represents managed forest in the near past)

Considering the 37 data observations classified as *degraded forest* by field brigades; 16 samples were managed forests and not *degraded forest* as originally classified by observations, 5 of those, were verified as recently thinned forests and 11 were verified as managed forest in the near past; it is important however to notice although these samples were recognized as managed, creaming activities were evident, i.e., the thinning extract mainly the best and bigger trees. Finally, 21 sample plots were verified as "*degraded forest*" given their field observed stock and current site condition. If the C-line is taken as the lower limits for differentiating *non degraded forest* from *degraded forest*, these 21 sample plot assigned as *degraded forest* are in coherence with their location within the stocking chart.

Returning to figure 2, it must be noted that a total number of 62 sample plots lie under the C-Line, i.e., 41 additional sample plots were not detected or recorded from field expert analysis as degraded. This means the current estimation for forest degradation based only on field observations from brigades is not accurate enough, given the field observation detected only 21 sample plots as *degraded forests*. This result is a strong justification to apply an objective, replicable and solid methodology for determining degradation of forests.

4. Conclusions and Recommendations

The REDD+ process will certainly require information about baseline (or reference situation) to further monitor and track changes in forest carbon stock. Usually, this type of information is contained in forest inventory databases, especially, those related to large-scale forest inventories, as national or sub national forest inventory.

The proposed approach is based on and requires data coming from large-scale forest inventory, Chile's national forest inventory in this case. The methodology is simple and easy to implement, is independent of site and, as such, can be applied to forest types as the last unit resolution level.

The methodology allows for monitoring changes in growing stock, which may indicate improvement of forest state from a degraded situation to a normal stocked forest or, vice verse. An advantage of this approach is the chance for the user to define their own limits for degradation given a national or sub national participative consensus.

The density chart is an important reference tool for policy assessment, because it gives an objective and comparable measurement with solid ground data support.

Building capacity among field brigades is a key point to avoid misclassification of forests, in particular, the recognition of intensively managed forest or extremely under stocked forests, although, non degraded.

The density chart is not able to discriminate quality of management; it is assumed good practice in thinning.

The method seems promising as a monitoring tool regarding trends toward sustainable forest management assessment from national forest inventory data.

One inconvenience of this methodology is the requirement of ground truth data coming from forest inventory, which are lacking in several countries. This stresses the importance of FAO efforts aiding countries to establish their own national forest inventory initiative.

Another disadvantage of this method is the need for information regarding several forests states of developing condition, which in some cases, are difficult to obtain or simply do not exist in a country.

In the context of REDD+ it is important to manage both processes; deforestation, which is related to area changes; and, degradation, which is related to density, as a whole and not separately, given that reducing deforestation could mean higher rates of degradation (leakage). As such, this methodology should be part of an integrated approach to monitor degradation linked to the deforestation process.

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