Pilot forest inventory in Costa Rica

for the

Global Forest Survey (GFS)
Initiative of FAO FRA

Report to FAO FRA

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And, our thanks go, of course, also to the many land owners contacted who (mostly) were extremely interested and cooperating, and permitted us to access their lands to carry out the field measurements. Many of them were also ready to be interviewed and allowed us to collect systematic information on their view of the forest and tree resource.

Our sincere thanks go also to the FRA team in FAO for entrusting us with this pilot inventory work and for the permanent and efficient feedback. We extend our particular thanks to Mr. Mohamed Saket, our direct counterpart, for an excellent cooperation and to Dr. Peter Holmgren, who was the overall coordinator.

INTRODUCTION

The GFS pilot inventory in Costa Rica was carried out under a Letter of Agreement (LoA) between FAO FRA and CATIE where SINAC, the Costa Rican authority among others in charge of the forests was principal counterpart on the national level.

Background is the idea of the FRA program to introduce new approaches into the generation of global forest and natural resources information, focusing on the enforcement of capacity on a national level which is considered the key to improving forest information quality.

In many tropical countries, including Costa Rica, the need for up-to-date information on the natural resources is generally accepted , and Costa Rica is a country in which a whole series of corresponding activities has been carried out. There is actually no deficit in figures on forest area,. However, figures are frequently contradictory, and what is called “forest inventory” turns practically generally to be out to be a satellite imagery based mapping study. To the knowledge of the authors, however, no study has been carried out recently that includes a comprehensive field phase, and that allows to come up with estimations of classical forest mensurational attributes like species composition, basal area, volume, biomass or carbon stored on a country level.

In addition the actual focus in forest policy and planning looks more and more towards the land owner’s attitude to forest, so that it was considered relevant to not only concentrate on the traditional biophysical attributes, but to also include as one of the novel components of the exercise some attributes that are related to the use of the forests.

OBJECTIVES OF PILOT STUDY

Overall objective is generating concrete experiences in installing an inventory on national level that combines biophysical and forest use aspects, that may serve as an example in other countries.

Under this general objective, there are several major technical objectives:

- Plan, prepare, carry out, and analyze a field inventory of biophysical attributes.
- Establish a cooperation with institutions in Costa Rica.
- Capacity building of and awareness building among national forest experts in forest assessments and forest inventory techniques.
- (*Plan, prepare, carry out, and analyze a field inventory of forest use attributes: this under the responsibility of an external consultant*)

PREPARATION

COORDINATION WITH SINAC AND ORGANIZATION OF STAFF

Cooperation with SINAC was continued as described in the report to LoA I. All important decisions were taken after communication and in coordination with SINAC officials. SINAC helped actively in identification of the "forest use" consultant, instructed their local and regional offices to help our field crews and issued formal permits that are required to enter National Parks.

Frequent meetings were hold in SINAC headquarters in San José, and some times also in CATIE. Overall, interest of and cooperation with SINAC was entirely successful. The understanding of the study's intentions and objectives, and the enthusiasm of the professionals in charge of the pilot study makes one confident that the idea of a permanent inventory remains alive and will be pursued actively.

In CATIE, technical staff was contracted to cover all aspects of planning, supervision, analysis and reporting. One forest engineer on a MSc level was contracted to work as technical coordinator of the study. Three foresters (BSc level) assisted in office and field work (preparation of materials for field crews, participation in supervision field trips, interpretation of aerial photographs, data checking and preparation of analysis). Two further colleagues helped part time in document preparation, image printing etc.). CATIE then contracted forest consultants (6 in total) for field work. These field crew leaders had good local experience as they usually are contracted by forest owners to write management plans for them. These consultants (field crew leaders) received thorough training, in house and in the field, and were then responsible, permanently in contact with the CATIE staff and also with SINAC, for all aspects of field inventory, including the measurement of the biophysical data set and the interviews. They hired the field helpers and used their own transport and measuring equipment.

LAND USE CLASSIFICATION APPLIED

The classification of land use that was finally applied had been elaborated by professionals of FAO, SINAC, UNA and CATIE on the occasion of the GFS workshop held in Costa Rica in November 2000.

A multi-level approach was chosen, where the FAO definitions were respected, but where it was also accepted that under the broad classes of forest, other wooded land, other land, and inland-water the countries should have the possibility to tailor their own specific sub-classes. This was also done in Costa Rica resulting in the classes that are given in Table 1.

The usefulness of the classification proposed was validated during photo interpretation and field work, where some interesting findings came out:

- Contrary to our initial expectations, we found "open" forest classes (cover 10-40%), mainly for young secondary forest.

Table 1: Classification used in aerial photo interpretation and field work

Class / Alpha code		Numeric Code
Forest		1
Continuous		11
Primary forest		111
PFC	Primary Forest Closed	1111
PFM	Primary Forest Medium	1112
PFC	Primary Forest Open	1113
Recent Secondary Forest		112
RSFC	Recent Secondary Forest Closed	1121
RSFM	Recent Secondary Forest Medium	1122
RSFO	Recent Secondary Forest Open	1123
Advanced Secondary Forest		113
ASFC	Advanced Secondary Forest Closed	1131
ASFM	Advanced Secondary Forest Medium	1132
ASFO	Advanced Secondary Forest Open	1133
Forest Plantation		114
FPC	Forest Plantation Closed	1141
FPM	Forest Plantation Medium	1142
FPO	Forest Plantation Open	1143
Gallery Forest		115
GFC	Gallery Forest Closed	1151
GFM	Galery Forest Medium	1152
GFO	Galery Forest Open	1153
Fragmented		12
FF1	Fragmented forest 10-39%	121
FF2	Fragmented Forest 40-70%	122
Other wooded land		2
S	Shrubs	21
FA	Fallows	22
WGH	Woody grass land (5-10% crown cover)	23
Other land		3
Natural		31
BL	Barren land	311
G	Grass land	312
WGF	Woody grass land (<5% crown cover)	313
Cultivated Land		32
AC	Annual crops	321
PC	Perennial crops	322
RL	Range land	323
Built up areas		33
BAQ	Built up area with quadrants	331
BAN	Built up area – no quadrants	332
W	Inland water	4
ONI	Other Non Interpreted	5

- Gallery forest was finally defined as an own class. The justification is, that it is difficult to assign it to any other class, as gallery forests show many different characteristics (sometimes more primary and untouched, sometimes no understory at all, some times clearly secondary). In addition, the elongated shape of gallery forests along creeks and other waters make them have a very distinct ecological meaning: they probably offer more diverse living conditions as other forests of the same area, and they can easily serve as biological mini-corridors.
- For analysis, we created the class “trof land”, where trof stands for Tree Resources Outside Forests; this class comprises all lands where there is the chance that trees are found – mainly cultivated lands, and excluding water, high mountain areas, barren land, etc.

DEFINITION OF POPULATION AND SAMPLING FRAME

Population of interest is defined as the continental territory of Costa Rica, and the population of trees and forest on it.

For the interpretation of the aerial photographs, only a partial coverage was available, so that the sampling frame is restricted to them, covering about 2/3 of the area of continental Costa Rica. Area estimates coming from the aerial photo survey do therefore only refer to a part of Costa Rica. It is the Northern Zone where, due to frequent cloud cover, there were no aerial photographs available.

For the field work, all Costa Rica was planned to be the sampling frame. However, due to access problems in remote areas, some sample locations could not be visited, what modifies the sampling frame also for the field phase. As these non-response areas are mainly those in the center of closed forest areas (National Parks), this affects above all the estimates for primary forest. Therefore, estimates for primary forest do base more than expected on observations outside national parks; the primary forests in remote areas are under-represented in the sample plots. For area estimations, we obviously used “primary forest” as forest type; however, no imputation or other attempt of data generation was undertaken, but there were simply no tree data for these plots.

In both cases, for the aerial photo survey and for the field phase, the actual sampling frame has to be taken into account when making an interpretation of the results.

STEP 1: AERIAL PHOTO INTERPRETATION

PROCEDURE

Design and interpretation procedure of aerial photo interpretation and analysis is given in detail in “REPORT II GFS”. Figure 1 shows the sample grid used. In the context of the LoA of this report, the formerly made interpretation was re-visited to allow for integration of the experiences made in the field.

The field crew leaders had prints of the aerial photos of each sample site with them and checked the interpretation of the land uses intersected by the field plots. They also had the instruction to check the land uses in the direct vicinity, particularly in terrain that allowed to have an view over a larger area. Of course, this part of the "verification of interpretation" was less formal and less systematic than the verification using the field plots themselves. The field crew leaders did the correction of the interpretation directly in the field, marking the changes in the print of the aerial photograph. This procedure refers to the sample 26 locations of the field inventory where aerial photographs were present. The changes identified were then corrected in the digital photographs, and also taken into account while re-visiting the other aerial photographs.

Figure 1: Map of Costa Rica showing the original 15km x 15km grid (points). For each grid point, the closest aerial photograph was selected, and the central part of that photograph interpreted. In the northern part of Costa Rica, in about 1/3 of the national territory, there was no aerial photo cover.

The control team of CATIE staff, when being in the field to do the supervision of field inventory, visited several other aerial photo plots that were not part of the field work. However, for reasons of limited resources only 12 locations of aerial photographs could be visited for this verification purpose. Sites were selected where aerial photo interpretation was difficult and suggested that there might be confusions between land use classes. The estimated average time to do the on site verification work (by the control crews) in the 3 square km is 4 hours, and the average transport time to reach the site was 5 hours.

RESULTS: AERIAL PHOTO INTERPRETATION

Preliminary results of the photo interpretation were delivered in a former report (March 2001). Details of aerial photograph selection, preparation, and interpretation procedure are given there.

Having acquired comprehensive field experience, the interpretation was re-done. All 159 photographs were re-visited for interpretation and a series of corrections and enhancements made, including the new class "gallery forest" which – to the judgement of the authors – should be treated as a separate class even though its overall cover percentage might appear little (an estimated less than 3%). Major confusions could be reduced, which refers mainly to land use classes prone to mis-classification, including young secondary forest and range land, which may be confused with range land and forest, respectively.

Table 2 shows major characteristics of the 159 aerial photographs used for interpretation. While the idea was in the beginning to establish aerial photo plots of 3km side length in the field, we finally decided to utilize plots that are of fixed size in the aerial photos to avoid different degrees of geometric distortion (due to not having orthorectified the photographs). The fixed size of the aerial photo plots in the photographs made that the actual size in the field varied from 2.72km side length to 4.52km with the actual scale of the photograph varying from about 1:32,000 to 1:53,000.

Table 2: General characteristics of aerial photographs used for interpretation and estimation of cover.

	Mean	Minimum	Maximum
Side length of AP plot [km]	3.73	2.72	4.52
Area of AP Plot [km^2]	14.03	7.38	20.39
Scale 1:	43549	31684	52687

The results of the revised interpretation of the aerial photographs are given in detail (per land use class) in **Table 3**, a breakdown according to forest classes is in Table 4, and a gross breakdown into forest and non-forest in Table 5. The percent standard error given is the simple standard error, not the width of the confidence interval; and the standard error is given in % of the area estimate, not as % area. The absolute standard error of the estimates is low for those land use types that were more evenly found over the 159 aerial photo plots, and higher for those that show a bigger spatial variability; the relative standard error (in percent) does then also depend of the area estimation itself.

Table 3: Area estimations from interpretation of aerial photographs: all land use classes distinguished *(only area with aerial photo cover = 2/3 of the territory of Costa Rica)*

Variable		Estimation	% Standard error
PFM	Forest	1.2%	19.5%
PFC		23.7%	11.1%
RSFM		2.8%	14.1%
RSFC		5.4%	9.7%
ASFM		4.6%	9.8%
ASFC		11.7%	9.0%
FPM		0.1%	46.0%
FPC		2.2%	34.4%
GFM		0.2%	25.3%
GFC		2.6%	13.6%
BL	Others	0.8%	23.6%
G		0.6%	44.3%
W		1.2%	29.6%
S		0.3%	50.2%
AC	TROF land	7.5%	15.9%
PC		5.3%	19.1%
RL		27.1%	5.7%
BAQ		1.1%	38.4%
BAN		1.1%	20.8%
ONI		0.4%	23.4%

Table 4: Area estimations from interpretation of aerial photographs: forest types *(only area with aerial photo cover = 2/3 of the territory of Costa Rica)*.

	Estimation	% Standard Error
Primary forest	24.9%	10.7%
Secondary forest: young	8.3%	8.4%
Secondary forest: advanced	16.3%	7.2%
Gallery forest	2.9%	13.0%
Plantation	2.3%	33.0%
Pastures	27.1%	5.7%
Other TROF areas	15.1%	11.4%
Other (non-tree)	2.9%	19.3%
Not interpretable	0.4%	23.4%

Table 5: Area estimations from interpretation of aerial photographs: forest – non-forest *(only area with aerial photo cover = 2/3 of the territory of Costa Rica)*.

	Esti-mation	% Standard Error
Forest	54.6%	3.8%
TROF land	42.1%	5.2%
Others	2.9%	20.7%
Non interpretable	0.4%	25.0%

The sample frame must be considered when interpreting these results. A forest cover of 54.6% was determined for the area covered by aerial photographs. However, this refers only to about 2/3 of the territory of Costa Rica, which is roughly 34,000km^2 of the national continental territory of Costa Rica). For the missing about 17,000km^2 no immediate estimation can be derived from the aerial photo plot interpretation. In 1992/1993, a forest inventory in the Northern Zone of Costa Rica was carried out that gave an estimated about 25% of forest area (total inventory area was 6000km^2). This is about only 1/3 of the missing 17,000km^2), not including, for example, the densely forested northern slopes of the Cordillera Central. Therefore, if we extrapolate this 25% to the entire no-response area, we are likely to deal with a lower limit. Combining the two figures, one from our aerial photo interpretation of 2/3 of the area and one from this older inventory results in (54.6% * 2/3) + (25% * 1/3) = 44.7% as an approximation of forest area for the whole of Costa Rica.

ASSESSMENT OF ACCURACY OF AERIAL PHOTO INTERPRETATION

The field visit of a subset of air photo plots allowed to make an accuracy assessment. Though it was not the major purpose of the field work to do an air photo interpretation accuracy assessment, some general observations can be made from Table 6 and Table 7.

For the "simple" forest/non-forest differentiation, an overall accuracy of 83/93 was reached which corresponds to 89.2% (Table 6). Broken down to forest classes the overall accuracy is 70/93, which is about 75.3%. (Table 7). The data are based on 93 cluster corners in the 26 field clusters. In some clusters, no field observations could be made, for access problems. The non-accessible cluster sub-plots were practically all in densely forested area, where we may assume that the classification into the class "forest" would have been confirmed by the field observations. In that sense, what is given in Table 6 and Table 7 may be interpreted as a lower bound of the true accuracy.

It should be observed that this accuracy assessment embraces both locational and thematic accuracy, and also confusions that have to do with a real change in land use (the aerial photographs were about 4 years old).

Table 6: Confusion matrix for forest non-forest

Frequency	0 (trof-land)	1 (forest)	2 (others)	Total
0 (trof-land)	32	6	0	38
1 (forest)	4	49	0	53
2 (others)	0	0	2	2
Total	36	55	2	93

Table 7: Confusion matrix: 93 points observed in 26 field clusters, where aerial photographs were available (galler=gallery forest, nonfor=nonforest, prifor=primary forest, secfor=secondary forest)

Frequency	galler	nonfor	prifor	secfor	Total
galler	1	0	0	0	1
nonfor	2	34	2	2	40
prifor	0	0	18	7	25
secfor	2	4	4	17	27
Total	5	38	24	26	93

STEP 2: FIELD INVENTORY

DESIGN

The field sample design is given in detail in the field manual which is found in the Annex. We give here the general outline. Figure 2 gives the location of the sample locations.

From the grid of aerial photo plots a subset was selected for field sampling. One field sample per 2 x 3 aerial photo samples was taken so that, given the 15km square grid of the aerial photo plots, a 30km x 45km grid resulted for field sampling. As a consequence, out of the 235 grid points of the 15km grid, 40 were systematically sampled for field work. 26 out of these had aerial photo cover, for the remaining 14, no air photos were available for field work preparation. For the 26 aerial photo covered plots, the nadir point of the selected aerial photographs was used as the center point of the field square cluster (according to the aerial photo selection procedure described in "GFS Report II", for the remaining 14, the coordinates of the grid point from the 15km grid was taken.

Figure 2: Map of Costa Rica showing the location and numbering of the sample sites. The gray polygons are National Parks and other categories of protected areas.

Unit of reference in the field was a square area of 1km side length (which might be called Primary sampling Unit, if one wants to use the terminology of two stage sampling). This unit was sampled (in fact, sub-sampled) by a cluster of subplots in the center of it (where the sub-plots would be Secondary Sampling Units in the picture of two stage sampling). A square cluster of side length 500m of four elongated rectangular sub-plots was employed in which the tree measurements took place. Nested plots per sub-plot were for the observation of smaller trees and regeneration. The plot design is graphically depicted and given in detail in Figure 3 and Figure 4, and in Table 8.

In the field inventory, there were four levels of information gathered:

- Sample site / reference unit (1 km^2)
- Sub-plots within cluster
- Units of land use within sub-plots
- Trees, either individual tree measurements in the two larger plot areas, or density measurements (counts) in the regeneration plots.

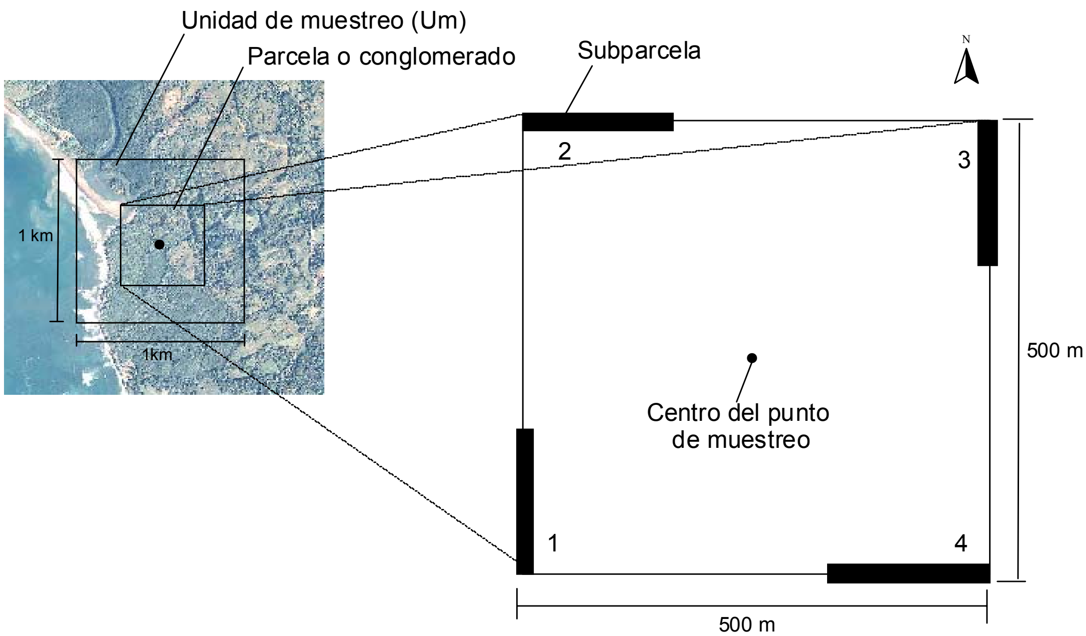


Figure 3. Plot design: position of cluster inside the 1km reference unit.

Table 8: Sizes of the different levels of sub-plots

Level	Plant size	Form and size of the plot
all subplot	dbh≥30cm	Rectangle: 150-250x20m (3000-5000m^2)
nested plot level 1	dbh ≥10≤30 cm	Rectangle 20x10m (400m^2)
nested plot level 2	h≥1.3m and dbh <10 cm	Circle r=3.99m (50m^2)
nested plot level 3	0.3m < h < 1.3m	Circle r=1.26m (5m^2)

Outside forest, no nested plots were not installed. Because of the expected relative low density of smaller dimension trees, trees with dbh > 10cm were measured and registered on the entire plot.

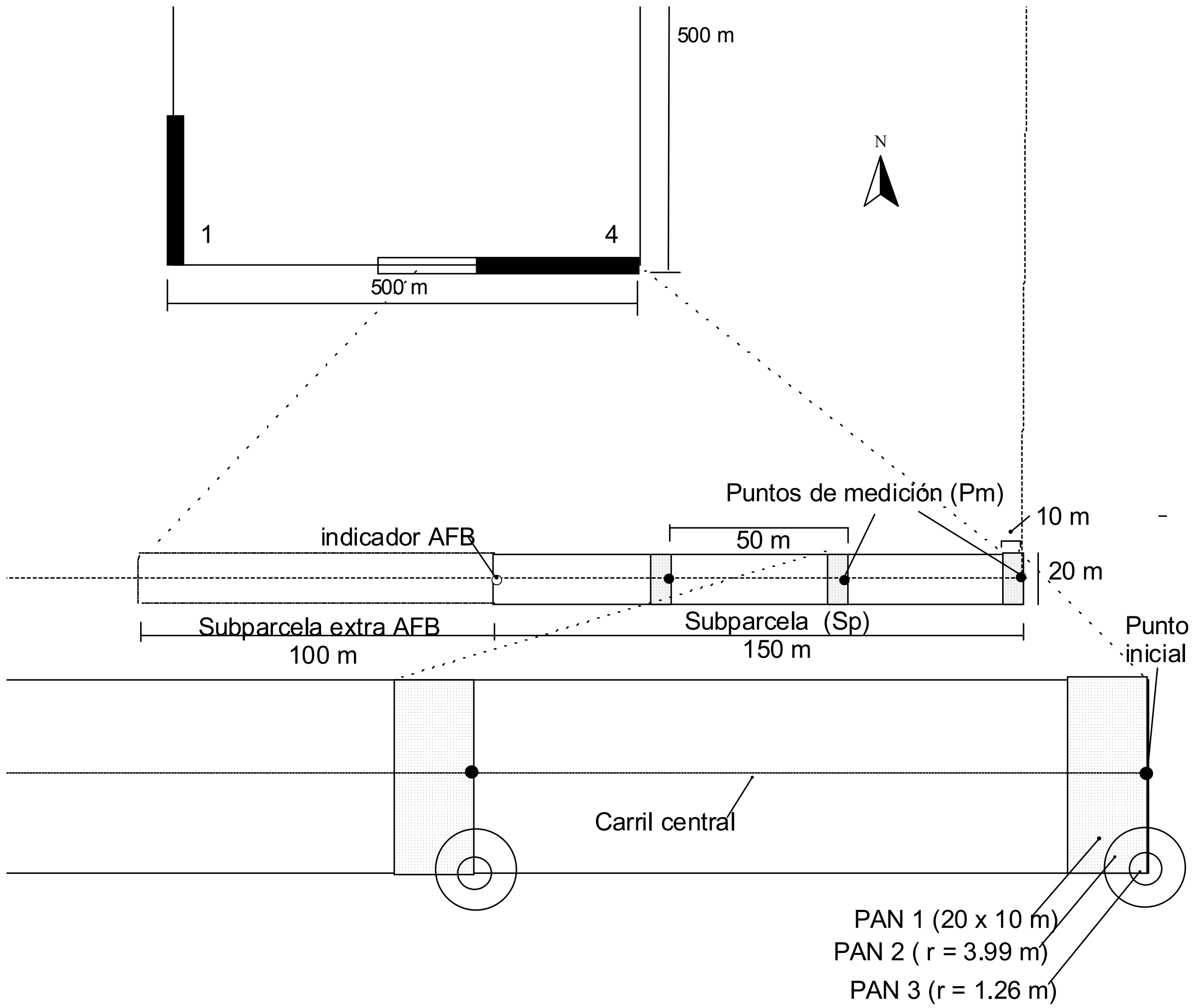


Figure 4. Plot design: cluster of 4 sub-plots where in each subplot there are three levels of "nested" plots for observation of smaller tree dimensions (PAN = nested plot).

The plots were established as permanent plots in such a way that they can easily be re-located; therefore it was part of the plot design to establish permanent markers (aluminum tubes), to sketch sample maps showing well visible reference points, and to take – wherever possible – a series of GPS measurements. Where available, the aerial photographs and the printing of the cluster on it will be an important help in re-location.

VARIABLES

The list of variables is in Annex 1. All listed variables were measured. Analysis done for this report, concentrated on the major dasometric variables.

PREPARATION OF FIELD WORK AND ACTIVITIES RELATED TO FIELD WORK

- A total number of 40 sample locations were selected for field work.

  34 locations were visited and completely measured,

  because of access problems for cluster 43, this one was not realized, but it was planned to shift it to cluster 40, which then also presented serious problems - only one circular plot could be established as, for topographic reasons and a (minor) accident in the field the field team was not able to complete the entire cluster,

  three clusters could not be completed for access problems: in cluster 76, only two sub-plots were measured, in cluster 78 three, and in cluster 80 only one,

  in cluster 126 one sub-plot could not be visited and measured due to access denial through the owner.

In what follows the organization of the field work is described:

Compiling all necessary information.

- 21 aerial photographs that were scanned with high resolution (corresponding to an about 1m ground resolution) were orthorectified. For the remaining 5 photographs (of the 26 for field measurements) an orthorectification could not be done due to lack of good ground reference points.

  Therefore, in a total of 19 field locations, only maps could be used for locating the sample points (the 5 not-orthorectified photographs and the 14 without aerial photo cover)

- Sample points were defined in the field according to the central point of the aerial photographs. Geographic coordinates (Lat-Lon) were calculated to allow for GPS application.
- The entire plot design was printed onto the aerial photographs and maps in order to help the field crew with the orientation in the field (examples of aerial photographs are in the Annex, and a complete set in the project materials delivered).
- A detailed field manual was written, discussed, reviewed, tested. Also, a detailed manual about the use of the GPS was written, as the contracted foresters had no comprehensive experiences.

- Design an elaboration of form sheets to accommodate the set of attributes to observe in the field. A relatively small format was chosen to facilitate working with it in the field. A portion of form sheets was printed on waterproof paper to enable the field crews to continue working in rain.

  Five different form sheets were developed according to the five levels of information (Cluster=Tract, Subplots, Stands, Trees and Reference points)

- A data base was designed to enter the field data; the structure of the data base followed the definition of FAO FRA. Data were stored in EXCEL.
- The field crew leaders contracted received a 2 days training in CATIE (early April).
- A workshop was organized in which ideas and definitions of the GFS initiative and also of the pilot study were explained and discussed. The field manual was also gone through in detail, and the use of the form sheets developed.
- The use of GPS, of the aerial photographs, and of the prepared sections of the topographic maps was trained.
- A list of those SINAC officers was set up who served as contact points for the field crew leaders in the regional SINAC offices.
- Each one of the field crew leaders was accompanied to the first field plot he realized; one or two CATIE experts were present. This was deemed necessary to guarantee a high level of standardization of the field procedures.

Activities for which each field crew leader was responsible for:

- Contacts to SINAC officers in the regional offices.
- First visit to the sample site to familiarize themselves with the area, contact the owners and have a first talk with them. Frequently, the regional SINAC officers accompanied the field crew leaders in this first trip. On this first trip field helpers and tree spotters were identified and contracted, where possible exactly from the same locality/farm where the sample was.
- Search of the starting point of the cluster, using GPS and the documentation provided by CATIE. The way to the starting point was described in a form sheet and marked with permanent marks for re-location.
- Measurements in the sub-plots.
- Possibly unclear details were written down to be discussed on telephone with the CATIE group in the evening.
- Field photographs were taken of typical aspects. Exact location of the photographer and direction of taking was recorded.
- Interview with the land owner.
- Organization of the information gathered, entering the data in the data base prepared by CATIE, and elaboration of a report and documentation of the data and experiences of the sample plot.

Activities of supervision and verification:

- The data and documents submitted by the field crew leaders were archived and checked for completeness. A first and superficial check of correctness was done upon arrival of the data.
- The field crews were accompanied in the field to supervise and discuss problematic issues. In most cases, this sort of control was preferred over the independent control measurements which lack the character of training. In total, 20 sample points were visited for supervision by the CATIE team.
- Seven sample points were visited independently (verification)
- For each supervision visit a brief report was composed analyzing the findings and impressions. These reports were then circulated to all field crew leaders so that all had always about the same level of information about the development of the discussions in the project.

  This flow of information was laborious but considered a necessary feedback.
- In each field visit additional terrestrial photographs were taken, above all when discussing problems of land use classification.
- A midterm meeting was organized in CATIE to have a common forum for discussion of problems and difficulties, with respect to field work and application of the methodology.

Activities with respect to data management:

- The geographic information (based on the GPS coordinates) was entered into a data base in the programs Surfer and ArcView for posterior easier access to the information. All sub-plots are georeferenced and accordingly registered. The tree coordinates within single sub-plots have been estimated in the field, and tree maps were produced for each sub-plot. All this plot description will help to re-locate the sample locations at later points in time.
- At the end all individual data bases prepared by the field crew leaders were combined into one single data base. This data base was checked step by step for consistency and correctness before entering in the analysis

Training and Capacity Building Activities:

- Training and capacity building accompanies necessarily each forest inventory. Our activities did also extend towards an awareness building, as the idea, concepts, and justification of large area forest inventories is not so well-known in Costa Rica and the region. On the contrary, little confidence was there with respect to what can be concluded from a study with such a low sampling intensity.
- For a number of reasons, we worked with several field crews. Thus, many foresters were trained in the inventory procedure, but learned as well about the GFS initiative, the FRA Programme, and the general background and justification of large area forest assessments. These training activities reached the 6 field crew leaders and their technicians. About 15 foresters have benefited from this training.

- In CATIE, a core group worked on the planning of the field work, on the documentation of the project and its results, on data management and data analysis. A total of 9 persons contributed in CATIE and received corresponding training.
- Several meetings and workshops were held with participation of foresters and experts from other sectors of different institutions in Costa Rica.

OBSERVATIONS

The maximum time consumed for the measurement of one cluster was ten days (Corcovado), with a total of 5 days for field work. The most rapid clusters were done in a total of 7.5 days, 2.5 days for field work, and those were clusters that came to lie completely in pineapple and in banana plantations.

Apart from Corcovado, the most difficult field conditions were found in Tapantí, Pejibaye and Chirripó; none of tose could be completed as it was too tedious to move from one subplot to the next one.

The geo-referenciation of the aerial photographs facilitated the use of geographical data in the field, the use of GPS and the location of the plots. However, in some cases there were not enough reference points on the 1:50,000 topographic maps that were used for this purpose as to allow for proper georeferencing. Possibly, the new 1:25,000 maps will improve the situation (they are not available as of October 2001).

Defining clear what the variables are, for what and how they are measured is of the most relevance to homogenize the assessment by the field teams. We had to re-discuss several variables in the course of the field work. This is a typical characteristic of a pilot study but must be avoided in final inventory implementation, as it may cause confusion and inconsistencies.

The permanent supervision and presence of the CATIE staff in the field was very important; errors and inconsistencies could be detected

RESULTS: FIELD SURVEY OF BIOPHYSICAL ATTRIBUTES

The results of the analysis of the field survey are presented in Table 9 to Table 22, where basal area is always given in m^2/ha and volumen in m^3/ha.

All results must be interpreted keeping in mind the relatively low sampling intensity. However, statistical validity is there. All results presented refer to the whole reference area (which is Costa Rica). Further geographical subdivisions would naturally reduce precision as less samples would come to lie in these sub-regions. For the dasometric variables, the relative standard error for the estimations is given. For the calculation of this standard error, the estimator for random sampling was employed. This is standard as for systematic sampling there is no design based unbiased estimation for the variance. It is known, however, that application of random sampling estimators leads to a conservative precision estimate; meaning that we are likely to be much more precise than the values given in the tables. Yet, how much better, can not be determined.

The analysis is focused on the forestry key variables basal area, volume, and tree density. For volume the formula of Lojan was used, the standard formula that is applied in Costa Rica. It gives the *commercial stem volume*. This was calculated for all trees with a dbh>30cm:

$$\log Vol = 2.03986 \log dbh + 0.779 \log h - 4.07682$$

Given the relevance of biomass and carbon estimations in the context of the UNFCCC, an estimation of carbon stored was also calculated. We used for that a still unpublished biomass formula of a research project currently concluded in CATIE, that bases upon biomass measurements of a total of about 75 forest and non-forest trees $<\text{tree dry weight[kg]} = -136.80 + 0.61446 d^2>$. From dry weight to carbon we used then the conversion factor 0.5. These calculations must be seen as approximations to above ground tree carbon.

Table 9 gives some basic characteristics of the clusters sampled, specifying the total area of the subplots sampled, and the corresponding absolute and relative area in forest, trof-land, and others. Of the 38 clusters, 7 were completely in forest, and 4 completely outside forest, while in 27 both forest and non-forest were found in the field plots. This is an indication for a fairly fragmented landscape, where there are more bigger compact forest blocks than bigger completely forest-free areas, or (the known fact) that there are still some major closed forest areas (above all in the national parks), and that forest fragments are in most regions of the country.

Table 10 to Table 12 give estimates per land use class. Table 10 presents estimates and relative standard errors for basal area, commercial volume, and number of trees, where also the corresponding area estimations are listed in the rightmost column. Table 11 gives basal area and number of trees for the class 10cm<dbh<30cm (frequently denominated "established regeneration"), and Table 12 gives the total basal area, combining the values of Table 10 and Table 11.

Table 13 and Table 14 give the corresponding estimations summarized according to forest type and Table 15 and Table 16 finally for forest/non-forest. When reading the "primary forest" data, one should take into consideration that several primary forest plots could not be accessed, particularly in the middle of National Parks. Therefore, this data is missing, and the statistics calculated for primary forest are somewhat biased towards "primary forests outside National Parks", or better, "primary forests with reasonable accessibility".

Table 17 to Table 21 give information about the species found. These are purely descriptive listings and give simply the number of species as found in the plots. Interesting (and clearly expected) that the percentage of unidentified trees is much higher in forest than outside forest. This can easily be explained, as outside forest frequently the commercial species are left as remnant trees, and the commercial species are usually better known than the non-commercial.

In Table 21 the data for closed primary forest (PFC) are separately presented for those plots that were in National Parks (PFPA=Primary Forest Protected Areas), and those outside the Parks (PFNP=Primary Forests Not Protected). Interesting to note – and actually expected – that in the National Parks the number of species is higher, and the percentage unidentified trees, as well. However, it must be taken into account that in PFNP there were about 350 trees measured, and in PFPA there were about 500, which may explain ion part the differences found.

Table 9: Some Characteristics of the clusters sampled

Cluster ID	Forest Area	TROF Area	Wateretc. Area	Total area	% Forest	%Trof	%Others
3	1.2000	0.000	0.0000	1.20	1.00000	0.00000	0.00000
5	0.9650	0.235	0.0000	1.20	0.80417	0.19583	0.00000
17	0.9160	0.284	0.0000	1.20	0.76333	0.00000	0.23667
19	0.7480	0.452	0.0000	1.20	0.62333	0.37667	0.00000
21	0.4630	0.737	0.0000	1.20	0.38583	0.61417	0.00000
23	1.1500	0.050	0.0000	1.20	0.95833	0.04167	0.00000
36	0.3250	0.875	0.0000	1.20	0.27083	0.72917	0.00000
38	0.1510	1.049	0.0000	1.20	0.12583	0.87417	0.00000
40	0.0825	0.037	0.0000	0.12	0.68750	0.00000	0.31250
41	0.3610	0.839	0.0000	1.20	0.30083	0.00000	0.69917
69	0.6700	0.190	0.3400	1.20	0.55833	0.15833	0.28333
72	0.3330	0.867	0.0000	1.20	0.27750	0.72250	0.00000
74	0.5150	0.685	0.0000	1.20	0.42917	0.57083	0.00000
76	0.6000	0.000	0.0000	0.60	1.00000	0.00000	0.00000
78	0.9000	0.000	0.0000	0.90	1.00000	0.00000	0.00000
80	0.3000	0.000	0.0000	0.30	1.00000	0.00000	0.00000
82	0.2400	0.960	0.0000	1.20	0.20000	0.80000	0.00000
118	0.5700	0.570	0.0600	1.20	0.47500	0.47500	0.05000
120	1.2000	0.000	0.0000	1.20	1.00000	0.00000	0.00000
122	1.1240	0.076	0.0000	1.20	0.93667	0.06333	0.00000
124	0.7860	0.414	0.0000	1.20	0.65500	0.34500	0.00000
126	0.1330	0.767	0.0000	0.90	0.14778	0.85222	0.00000
128	0.9310	0.269	0.0000	1.20	0.77583	0.22417	0.00000
130	0.0000	1.200	0.0000	1.20	0.00000	1.00000	0.00000
132	0.3510	0.781	0.0680	1.20	0.29250	0.65083	0.05667
154	0.3000	0.900	0.0000	1.20	0.25000	0.75000	0.00000
162	0.7680	0.432	0.0000	1.20	0.64000	0.36000	0.00000
166	1.2000	0.000	0.0000	1.20	1.00000	0.00000	0.00000
184	0.9000	0.300	0.0000	1.20	0.75000	0.00000	0.25000
186	0.0000	0.000	1.2000	1.20	0.00000	0.00000	1.00000
188	0.2820	0.918	0.0000	1.20	0.23500	0.76500	0.00000
190	0.3000	0.900	0.0000	1.20	0.25000	0.75000	0.00000
192	1.2000	0.000	0.0000	1.20	1.00000	0.00000	0.00000
194	0.0000	1.200	0.0000	1.20	0.00000	1.00000	0.00000
196	0.3000	0.900	0.0000	1.20	0.25000	0.75000	0.00000
219	0.6300	0.570	0.0000	1.20	0.52500	0.00000	0.47500
221	0.0000	1.200	0.0000	1.20	0.00000	1.00000	0.00000
223	0.3000	0.900	0.0000	1.20	0.25000	0.75000	0.00000
225	0.4360	0.764	0.0000	1.20	0.36333	0.63667	0.00000
227	0.0550	1.145	0.0000	1.20	0.04583	0.95417	0.00000

Table 22 gives an estimate of what percentage of forest and non-forest is in National Parks (not counting here the areas protected for proximity to rivers or because of steep slope). We see that an estimated about 40% of all forest is in National Parks, but an estimated about 20% of trof-land as well.

Table 10: Estimations per land use class (only dbh > 30cm). Empty cells for estimations means no trees in the sample, no specification of standard error: only observations in one cluster, not allowing the calculation of sampling error (galler=gallery forest, nonfor=nonforest, prifor=primary forest, secfor=secondary forest).

LU Class	Estimations			Standard error %			Forest type	Area prop.
	Basal area	Comm. vol.	No of trees	Basal area	Comm. vol.	No of trees		
GFC	15.6815	63.462	65.3527	32.3555	105.099	16.9766	galler	0.02209
FPC	.	.	.	.	.	.	planta	0.01714
FPM	2.4356	12.085	26.6667	.	.	.	planta	0.00669
PFM	19.3645	156.672	84.3882	31.6925	26.883	44.4314	prifor	0.01586
PFC	18.4221	136.349	88.0005	10.0395	15.288	10.5851	prifor	0.24411
ASFC	7.4985	48.281	50.8357	27.3900	50.755	18.0948	secfor	0.06604
ASFM	10.5139	59.158	47.6190	38.0827	87.134	66.5640	secfor	0.01513
RSFC	2.2523	11.201	13.4362	60.5125	77.786	41.9542	secfor	0.07838
RSFM	5.8279	39.522	44.4444	58.1164	38.786	13.4535	secfor	0.00239
RSFO	4.0181	22.644	10.4822	28.8590	55.156	8.6413	secfor	0.01600
AC	1.0607	9.745	9.5694	.	.	.	nonfor	0.04018
BAN	1.4586	0.625	14.2450	7.3336	242.536	15.5223	nonfor	0.01265
PC	0.6536	2.130	5.0088	48.4114	109.283	41.1663	nonfor	0.08664
RL	2.3777	11.602	11.9344	22.6413	37.812	23.8414	nonfor	0.29306
BL	.	.	.	.	.	.	nonfor	0.00112
G	.	.	.	.	.	.	nonfor	0.02045
S	.	.	.	.	.	.	nonfor	0.01941
W	.	.	.	.	.	.	nonfor	0.04266

Table 11: Estimations per land use class for smaller diameters of 10cm < dbh < 30cm (galler=gallery forest, nonfor=nonforest, prifor=primary forest, secfor=secondary forest)

Land use class	Forest type	Basal area	Number of trees
ASFC	secfor	6.49	298.8
ASFM	secfor	6.59	225.0
FPC	planta	16.46	628.6
FPM	planta	7.90	237.5
GFC	galler	6.82	312.5
PFC	prifor	7.58	305.0
PFM	prifor	8.18	293.8
RSFC	secfor	2.18	116.4
RSFM	secfor	4.37	225.0
RSFO	secfor	2.14	97.6
AC	nonfor	0.35	18.3
BAN	nonfor	0.99	42.3
BL	nonfor	0.00	0.0
PC	nonfor	1.31	49.7
RL	nonfor	0.59	23.8
G	nonfor	0.00	0.0
S	nonfor	0.00	0.0
W	nonfor	0.00	0.0

Table 12: Basal area per land use class, i.e. former two tables combined (galler=gallery forest, nonfor=nonforest, prifor=primary forest, secfor=secondary forest).

Land use class	Forest Type	Basal Area [m^2]
GFC	galler	22.4996
FPC	planta	16.4617
FPM	planta	10.3339
PFC	prifor	26.0034
PFM	prifor	27.5414
ASFC	secfor	13.9895
ASFM	secfor	17.1022
RSFC	secfor	4.4336
RSFM	secfor	10.1987
RSFO	secfor	6.1556
AC	nonfor	1.41385
BAN	nonfor	2.44915
PC	nonfor	1.96609
RL	nonfor	2.9709
BL, G, S, W	nonfor	

Table 13: Estimations per forest category (only dbh > 30cm) (galler=gallery forest, nonfor=nonforest, prifor=primary forest, secfor=secondary forest)

Forest type	Estimations			Standard error %			Area prop
	Basal area	Comm. vol.	No of trees	Basal area	Comm. vol.	No of trees	
galler	15.6815	63.462	65.3527	32.3555	105.099	16.9766	0.02209
planta	2.4356	12.085	26.6667	.	.	.	0.02383
prifor	18.4867	137.743	87.7531	9.3809	13.967	10.2157	0.25998
secfor	5.0032	29.827	30.1228	25.6707	40.566	21.1672	0.17793
nonfor	1.6447	7.770	8.7327	22.7890	39.274	24.0673	0.51616

Table 14: Estimations per forest class (only 10cm < dbh < 30cm) (galler=gallery forest, nonfor=nonforest, prifor=primary forest, secfor=secondary forest)

Forest type	Basal area per ha	Number of trees per ha
galler	6.82	312.5
planta	13.35	486.4
prifor	7.63	304.2
secfor	4.20	195.3
nonfor	0.61	24.3

Table 15: Estimations according to forest / non-forest (only dbh > 30cm)

Forest - Non-forest	Estimations			Standard error %			Area prop
	Basal area	Comm. vol.	No of trees	Basal area	Comm. vol.	No of trees	
1 (forest)	12.5416	87.7977	61.8284	12.4374	17.4202	11.2383	0.48384
0 (trof land)	1.8322	8.6550	9.7279	23.0400	38.4674	23.1485	0.43365
2 (others)	.	.	.	.	.	.	0.08252

Table 16: Estimations per forest / non-forest (10cm < dbh < 30cm)

	ba_mean	vol_mean	no_mean
1 (forest)	6.51253	16.1240	270.670
0 (trof-land)	0.72473	1.55447	28.9154
2 (others)	0.00000	0.00000	0.0000

Table 17: Most frequent species found in the sample plots (dbh > 30cm)

Obs	Tree Code	Species	Common Name	Freq.	%Freq.
1	Ni	Ni	Ni	189	4.01957
2	Penma	Pentaclethra ma	Gavilan	108	2.29689
3	Coral	Cordia alliodor	Laurel	47	0.99957
4	Ocosp	Ocotea sp	Ira	39	0.82943
5	F-Lau	Lauraceae	Ira	36	0.76563
6	Cordi	Cornus disciflo	Lloro	32	0.68056
7	Queco	Quercus costarr	Encino	32	0.68056
8	Lagra	Laguncularia ra	Mangle mariquita	28	0.59549
9	Spomo	Spondias mombin	Jobo	28	0.59549
10	Rhisp	Rhizophora sp	Mangle rojo	23	0.48915

Table 18: Most frequent species found in the sample plots (dbh > 30cm), broken down according to forest and non-forest

Obs		Tree Code	Species	Common Name	Freq.	%Freq.
1	Non-forest	Coral	Cordia alliodor	Laurel	32	19.0476
2		Spomo	Spondias mombin	Jobo	20	11.9048
3		Penma	Pentaclethra ma	Gavilan	15	8.9286
4		Ni	Ni	Sombra de iguana	8	4.7619
5		Goeme	Goethalsia meia	Guacimo blanco	7	4.1667
6		Pteof	Pterocarpus off	Sangrillo	6	3.5714
7		F-Are	Arecaceae	Palma real	5	2.9762
8		Cedod	Cedrela odorata	Cedro amargo	4	2.3810
9		Entcy	Enterolobium cy	Guanacaste	4	2.3810
10		Rolpi	Rollinia pittie	Anonillo	4	2.3810
1	Forest	Ni	Ni	Tabacon	181	14.9094
2		Penma	Pentaclethra ma	Gavilan	93	7.6606
3		Ocosp	Ocotea sp	Quizarra rojo	39	3.2125
4		F-Lau	Lauraceae	Palomo	36	2.9654
5		Queco	Quercus costarr	Encino	32	2.6359
6		Cordi	Cornus disciflo	Lloro	31	2.5535
7		Lagra	Laguncularia ra	Mangle mariquita	26	2.1417
8		Rhisp	Rhizophora sp	Mangle rojo	23	1.8946
9		Virko	Virola koschnyi	Fruta dorada	22	1.8122
10		Pousp	Pouteria sp	Zapotillo	20	1.6474

Table 19: Number of species found in forest and non-forest and % of unidentified trees (dbh>30cm)

	Identified	%indiv. not identified number of spcecies found	Number of indiv.
Nonforest	No	4.8%	8
	Yes	55	160
Forest	No	14.9%	181
	Yes	189	1033

Table 20: Number of species per forest type and % of unidentified trees (dbh>30cm).

Forest Type	Species identif.	%indiv. not identified number of spcecies found	Number of indiv.
Gallery forest	no	19.0%	12
	yes	32	51
Non-forest	no	4.8%	8
	yes	55	160
Plantation	no	0.0%	
	yes	2	8
Primary forest	no	15.5%	141
	yes	137	769
Secondary forest	no	12.0%	28
	yes	80	205

Table 21: Number of species per land use class, and % of unidentified trees (dbh>30cm). Here, data for primary forest are separately presented for plots in National Parks (PFPA=Primary Forest Protected Areas), and those outside (PFNP=Primary Forests Not Protected).

Landuse Class	Species ident.	%indiv. not identify. No of species sampled	No of indiv.
ASFC	no	15.1%	22
	yes	53	124
ASFM	no	0.0%	
	yes	21	31
FPC	no	0	0
	yes	1	.
FPM	no	0.0%	0
	yes	1	8
GFC	no	19.0%	12
	yes	32	51
PFM	no	8.3%	5
	yes	19	55
PFNP	no	12.7%	44
	yes	65	303
PFPA	no	18.3%	92
	yes	104	411

Landuse Class	Species ident.	%indiv. not identify. No of species sampled	No of indiv.
RSFC	no	12.8%	6
	yes	24	41
RSFM	no	0.0%	
	yes	4	4
RSFO	no	0.0%	
	yes	5	5
AC	no	50.0%	1
	yes	2	1
BAN	no	20.0%	1
	yes	5	4
PC	no	0	0
	yes	10	17
RL	no	4.2%	6
	yes	46	138
BL, G, S, W	.	.	.

Table 22: Percentage of forest / non-forest land use classes in protected areas.

Class	in protected areas	% of total	% in class
Trof land	no	34.9%	80.5%
	yes	8.5%	19.5%
Forest	no	29.2%	60.4%
	yes	19.2%	39.6%
Other	no	6.3%	76.9%
	yes	1.9%	23.1%

TIME CONSUMPTION FOR FIELD WORK

Table 23 gives an idea of the breakdown of time consumption during field work, calculated as an average per field cluster.

Table 23: Breakdown of time consumption at field work, average estimated per cluster (sample location)

Activity	Time/days
1. Preparación (CATIE)	
Orthorectification of photographs	1
Georeferencing of maps	
Identification of coordinates	
Printing of photographs and maps	
Preparation of form sheets	
2. Field (fieldd crews)	
Inventory planning	
Planning of field trip	0.5
First visit (contacts)	1
Contact to owner & interview	
1-2 owners	1
3-4 owners	1.5
Return trip to field cluster	
Difficult access	1.5
Easy access	1
Measurements	
Forest in mountainous areas	4 (8 hrs/plot)
Forest, flat terrain	2.5 (5 hrs/plot)
Pasture or tree plantations	2 (4 hrs/plot)
Pasture or plantations with few trees	1 (2 hrs/plot)
Field supervision	
Preparation of field trips	0.5
Difficult access	3.5
Easy access	2.5
3. Office (CATIE)	
Data input	
Excel data base	0.5
Geodata in Surfer and Arc View	0.5
Foto catalogue (scan and organization)	0.5
Review and correction of data base (complete information, digitalization, inconsistencies, link between data base files)	2.5

RESULTS: FIELD SURVEY – INCLUDING THE 250 EXTENSION OF FIELD PLOTS

GENERAL REMARKS

The standard sub-plots had a width of 20m and a length of 150m. It was expected this plot size delivered good and sufficient data for forest. However, for outside forest, where tree density is obviously much lower, a bigger plot size was felt desirable. Therefore, the sub-plot length was extended to a total of fixed 250m if the end-point of the 150m plot came to lie outside forest. That means, that 100m more were measured, regardless of what land use class was encountered in the course of the plot; therefore, not only non-forest area, but also additional forest areas were measured.

By that, a gain in precision was expected, particularly for the estimation of the tree attributes in land use classes outside forest. This conditional enlargement of the sub-plots can obviously not be used to improve area estimations. These must come from the 150m plots (as presented before) or from an analysis of point observations at the cluster corners.

When we now compare the results obtained from the 150m plots and the conditional 250m plots, we may conclude about whether it is worth to pursue that idea.

COMPARISON

In this section, the major results of the analysis of the 150m plots and the conditional 250m plots are compared in a series of tables.

The first effect of the conditional enlargement is that the total plot area measured in the field is bigger. With the fixed 150m plots a total area of 44.82ha was visited and tallied, and for the conditional 250m plots, the total area amounted to 62.90ha, wich means about 40% more area. Only in 10 sample locations (clusters) no plot-enlargement took place.

The total number of species observed for tree dimensions of 30cm and bigger increased only slightly from 205 to 212; this probably due to the fact that most of the additional area was outside forest, where the tree species diversity is not as big as it is inside forest.

While the additional planning effort is low, the additional field effort is an estimated average 30 to 90 minutes per sub-plot, depending on the land use classes and the density of the tree cover encountered, which translates to an estimated about 1-3 additional hours per cluster.

Interesting the breakdown into forest/non-forest in Table 24. While relatively little forest area was additionally included (an increase from 21.69ha to 24.58ha, or 13%), the area for trof-land increased from 19.44ha with the 150m plots to 32.03ha for the conditional 250m plots(corresponding to a 65% increase!). Also, the “others” class, where no trees are found nor expected increased from 3.7ha to a sampled area of 6.29ha; where the latter provide information which is of little relevance when interest is in the *tree* resource.

Table 25 gives the comparison of estimates and standard errors. While for forest the relative standard errors do not exhibit changes (at least the rounded values), the design with the conditional 250m plots produces lower relative standard errors for basal area (21% instead of 23%), for volume (35% instead of 38%) and number of trees (19% instead of 23%) in trof-land. This improvement of estimation accuracy has to be compared with the additional efforts / cost.

Table 24: Comparison 150m/250m sub-plots: Total areas tallied according to forest / non-forest

Class	Fixed 150m No. of units	Area (ha)	Area (proportion)	Conditional 250m No. of units	Area (ha)	Area (proportion)
1 (forest)	109	21.69	0.4838	123	24.58	0.3908
0 (trof land)	221	19.44	0.4337	241	32.03	0.5091
2 (others)	19	3.70	0.0825	19	6.29	0.1003

Table 25: Comparison 150m/250m sub-plots: estimations and standard errors per forest/non-forest

Forest Class	150m sub-plots						250m sub-plots					
	Estimations (per ha)			SE%			Estimations (per ha)			SE%		
	Basal Area (m2)	Vol. (m3)	No. of trees	Basal Area (m2)	Vol. (m3)	No. of trees	Basal Area (m2)	Vol. (m3)	No. of trees	Basal Area (m2)	Vol. (m3)	No. of trees
1 (forest)	12.54	87.80	61.8	12	17	11	12.07	84.33	59.91	12	17	11
0 (trof land)	1.83	8.66	9.7	23	38	23	1.57	6.95	8.92	21	35	19
2 (others)	0.00	0.00	0.0	.	.	.	0.00	0.00	0.00	.	.	.

CONCLUSION

Though some precision of the estimations of basal area, volume and tree density is gained by the conditional extension of the sub-plots outside forests, this improvement was found to be marginal. It is unlikely that the additional effort is justified. Also the additional information in terms of number of species is not great.

Therefore, we do not see the expected advantages of plot-enlargement and do not recommended to pursue this idea of plot extension.

ESTIMATION OF CARBON STORAGE

An estimation of carbon stored in the different classes was carried out. The results are presented separately, as the authors do not have reliable and "approved" models at hand that are generally accepted for these calculations. The estimations have therefore to be seen as approximations with relatively little accuracy. All calculations are made for the total of all trees with a dbh > 30cm, as the (unpublished, developed by ITC, Holland, in the EU funded TROF Project) model used for it is only for those diameters.

Also, for this analysis pastures were separated from the other non-forest categories, as there is a particular interest in Costa Rica to see to what extent pastures can contribute to the climate change discussions. Table 26 to Table 28 present the results. It is to be observed that the SE% are mere sampling errors and no do not include model errors, which are expected to be fairly high for the model applied.

Table 26: Carbon storage approximation per forest class (pastur=pastures, galler=gallery forest, nonfor=nonforest, prifor=primary forest, secfor=secondary forest)

"Forest" type	Forest	Mean [tons/ha]	SE%
pastur	0	8.485	22.8482
galler	1	56.872	34.3148
planta	1	7.705	
prifor	1	66.313	9.4523
secfor	1	17.511	26.4063
nonfor	2	1.738	39.3277

From Table 26 we see that pastures store an estimated about 13% per ha of what is stored in primary forests, and (Table 27) an estimated about 19% per ha of what is stored in all forest types combined. However, this number alone is, of course, misleading, as in primary forest the share of carbon stored in trees with dbh<30cm is much higher than on pastures. The 13% and 19%, respectively, are therefore upper bounds. Table 27 allows to estimate (with all restrictions of interpretation mentioned) the share of carbon stored in trees with dbh>30cm in forest and outside forest for the entire country: if we take 44.831*0.48384+0.43365*6.501=24.5 as a measure for the total carbon, then about 88% are in forest and about 12% outside forest.

Table 27: Carbon storage approximation according to forest / non-forest

Class	Mean [tons/ha]	SE%	Area
1 (forest)	44.831	12.6624	0.48384
0 (trof-land)	6.501	23.3702	0.43365
2 (others)	0	-	0.08252

Table 28: Carbon storage: mean value calculated for all land use classes and the whole country.

Mean [tons/ha]	SE%
22.8171	17.8476

STEP 3: SURVEY OF FOREST USE ATTRIBUTES

A set of attributes relating to the use of forests was assessed by means of interviews with forest owners. For this purpose a consultant (sociologist) was hired who worked in close cooperation with the SINAC team and with the CATIE team.

According to his ToR this consultant produced a separate report in which the method applied, the results obtained, and the experiences made are described.

Therefore, in this report, we restrict ourselves to some conclusions, presented in the Chapter "Conclusions".

CONCLUSIONS

EVALUATION OF THE DESIGN USED

INTERPRETATION OF AERIAL PHOTOGRAPHS, AND INVENTORY OF BIOPHYSICAL ATTRIBUTES

The inventory of the biophysical and vegetation data was designed on the basis of relatively long experiences in forest inventory. No surprises came up. The inclusion of non-forest land increases the field workload, as the subplots within the clusters must always be measured completely (no border plots any more, except on the country's border). Also, clusters must be visited in the field where there is no forest (or even tree) at all. This sounds inefficient from a "forest" inventory point of view, yet in the case of Costa Rica, this argument is not very strong as there were only 4 clusters where no forest was touched by the four subplots, and trees were found in all. The contrary is being believed, that it is, in fact, more efficient to go to all field sites and include the tree resource outside forest into the inventory concept; then it is not so inefficient any more to have to go to a cluster in the field where there falls, for example, only a small portion of one single subplot into forest.

Under Costa Rican conditions, the 500m side length of the clusters is a good compromise between statistical efficiency and cost. Unanimously the field crews confirmed that a larger spatial clusters extension is unlikely to be workable. An option could be to use different cluster designs (sizes, shapes, spatial sizes) in different strata – if the inventory is so designed.

The built-in component of using larger sub-plots if the end-point of the 150m subplot falls outside forest, is well workable in the field. However, the gain in precision is modest, so that this idea is not recommended to be pursued (see justification above in Chapter "Results: Field survey – including the 250 extension of field plots"). Larger sub-plots sizes could be considered for those areas, where access is easy. In difficult terrain, the 150m plots presented problems, particularly in cases where the strip plot came to lie on steep slopes, oblique to the slope gradient. Slope correction is critical in those cases.

The fotointerpretation followed a standard design and proved to be well workable. Orthorectification in an early project stage would have been desirable. Also, it was not optimal that we had to work with scanned copies of the photographs where we lost much detail information.

The systematic arrangement of aerial photo plots and of the field plots was certainly a good choice, for the standard statistical and practical reasons that this design offers.

INTERVIEWS

The amplification of the range of attributes collected to include also variables related to forest use, was very welcome from the national authorities. It was also recognized that it is a novel component where experiences are about to be collected. A more detailed analysis is prepared in the report on Forest Use. Here some summarizing conclusions and impressions from the CATIE team..

- Interviews can be carried out by the field crews directly. We see no need to employ an additional expert for that specific task. The field crew leaders have to contact the land owners, anyway; and they are in contact with local helpers who can provide part of the information required. However, training in interview techniques is required.
- To the knowledge of the authors there is no experience described in the literature about the integration of interviews in large area tropical forest inventories. Various studies are described, particularly in the fields of community and social forestry, where not only the biophysical resource forest was described and analyzed but also the user's perspective and problems. Typical for those studies is that the researchers stayed some time with the communities or stakeholders or visited them frequently so that in the course of the study a certain level of confidence could be built up. This can certainly not be reached in a large area inventory where there cannot be several days spent at one site to learn more about the forest uses. It is not possible to reach such high levels of confidence that the owners tell frankly about their true intentions.
- The general lack of experience in this field is also reflected in Costa Rica by the fact that it was difficult to find a consultant with academic formation and/or experience in both forestry and social sciences.
- In the Costa Rican study formal interviews concentrated on forest owners. However, a careful analysis should be made, which are the questions to which one may expect reasonable replies from them. For example, we learned that the owners will not respond about the use of the forest resource in a specific location of his property. It appears simply too sensitive a topic. We see the following options:

  - One could ask in a more general way about forest or tree uses that the owner is aware of in the area.

  - One could ask specifically about uses in defined areas, but outside the property of this specific owner (which could be mis-interpreted as "espionage").

  - One could (and should) include other groups of interviewees, like timber transport companies, sawmills etc.
- Therefore, the main topic to be re-defined is: What questions can reasonably be put to whom?

- While everybody (including the authors) feel that the additional set of variables assessed through interviews is useful, and that modern and future oriented forest inventories should consider also aspects of "forest use", it is from this study not clear yet what the immediate use and usefulness of the information will be.

  While presenting the results, major interest of forest experts was still in the more traditional variables like forest area, volume, species distribution. More convincing analysis and interpretation of the results of these additional (forest use) variables must be done; and an immediate usefulness for politicians and decision makers proven. Many data on socio-economic aspects and questions of forest use can probably be answered by the standard set of traditional variables, and by the inclusion of some more variables (on non-wood products, etc.).

  It is expected that much information can also be obtained from local helpers. Then, the hiring of local helpers is a must. If local helpers are hired, it is difficult to judge their level and coverage of knowledge. The information "retrieval" from them would have to be structured carefully.

- Ideas of how to optimize the interviews are detailed in the report of Franklin Solano, the consultant in charge of this project component.

CONSIDERATION FOR RE-MEASUREMENTS IN COSTA RICA

There is the declared will of SINAC to continue providing high quality data as a requirement for formulation and monitoring of good national policies. A complete documentation is there, so that, technically, the re-location and re-measurement is not a problem. Major concerns are cost and organization:

- Documentation is as complete as possible, including maps, aerial photographs, description of field access, terrestrial photographs, so that the documentation bas is there required for re-visiting the reasonably accessible sample locations. Control measurements carried out in the pilot study do confirm this clearly.

  However, there are some sample locations in very remote areas with difficult and long access ways where it is not possible to re-locate the plots established. There, dense crown cover and rough topography did impede reception of sufficient GPS signal.

- Major issue is cost, and organization. Despite recognizing the general relevance of improved forest information, it is doubtful that the Costa Rican government can afford to invest much money in a re-measurement campaign, nor so by using own staff to do the work.

- An idea developed by the CATIE group is to make the data gathered available for research institutions and NGOs working in the field of natural resources management and conservation, this raising interest in the activity and encourage them to complete the data base considering re-measurements, establishing new plots, etc.

  Optimal would certainly be if a group of interested institutions would take care of plots in sub-regions, re-measuring, say, 5 plots every second year, and possibly densifying the grid of sample locations. A natural partner are universities, where re-measurements of these permanent sample plots could be integrated in the regular forestry curriculum.

MAJOR LESSONS LEARNED FOR A TRANSFER TO OTHER REGIONS / COUNTRIES

From this pilot study, some lessons were learned that might be relevant when attempting to implement similar studies in other regions. We first address general observations and do then list particularities of Costa Rica that are not necessarily encountered in other regions.

GENERAL OBSERVATIONS

Strategic:

- The successful and smooth development of the pilot study in Costa Rica has much to do with the unconditional support given by the national forest authorities (SINAC). It was no doubt from the outset that there is a clear political will to improve the forest information situation in the country. As mentioned before, this will was explicitly expressed (before the beginning of the pilot study) in the National Forest Development Plan.

  If there is not an alike political support, an inventory undertaking is likely to remain a one-time exercise. If technical inventory work (including capacity building) is to be started in the absence of a clear positive political statement, much effort should be directed to develop the awareness of decision makers of the relevance of forest and natural resources information.

  Helpful in this context may be to bring the inventory in a proper context with the data provision required by various international conventions and processes.

- A key to success is the identification of key persons or key groups in the national government (or other responsible national institutions) who actively support the idea and the activities.

- Partnership building among national institutions should be started early, taking into account that there is frequently a competitive atmosphere between them, particularly when an inventory activity receives outside finding.

- It should be made clear that the project is in national ownership, and carried out for the good of the forestry and natural resources sector of the country – and that it is not meant to be an externally imposed activity. Simultaneously with the implementation of planning and field activities, one should keep in mind how to give permanence to the activity (data management, continued analysis of the data gathered, offering the data utilization to national research institutions).

Technical:

- Though an operational design has been developed in the Costa Rican study, it is deemed necessary to start a design discussion in other places, not from the very beginning, of course, but in sufficient detail to convince the national counterparts. Adjustments are likely to be required, and certainly acceptable.

- Also, the classification discussion will inevitably come up and must be gone through. Usually the situation in a specific country suggests adaptations of the classification used in other, even neighboring countries.

- While the systematic sampling approach is considered the optimal, some stratification should be considered - where the systematic grid provides a perfect base for stratification with (spatially) proportional allocation of sample locations.

  In Costa Rica, for example, while trying to visit all field sites, this turned out to be impossible. A logical stratification would therefore be, to form two strata (sub-populations):

  (a) Areas where field work can be done and where data are of immediate interest for forest policy, and

  (b) Areas where no human land use takes place and where it is unlikely that it will take place in the future; this refers, for example, to the center parts of national parks, which are difficult to access, and where we actually do not expect changes to take place.

  Then, also the analysis and interpretation of the data must adjust to this stratification, making clear that the conclusions based on field work do refer to the sampled strata only, and not to the entire country.

- Availability of aerial photographs and satellite imagery is a major point. When this data sources are readily available from other sources, the situation is optimal. If not, their provision may mean a major budget burden. In the absence of remote sensing data, field work obviously receives more relative relevance – and is much more difficult to plan and implement.
- Safety situation for field work.
- In countries where there is more than one official language, interviews must be prepared in several languages, possibly local interpreters have to be hired.
- Species identification is always a major problem. If all trees should be identified, a dendrologist must be hired, or samples taken and sent to a herbarium. Both options are expensive.

Organizational:

- In the Costa Rican study we made very good experiences with the contracting of several forestry experts who were taking care of the field measurements. This necessarily increased the investment in training and supervision, and resulted in an efficient spreading of the GFS idea.
- Contracting local helpers helped building confidence of land owners, facilitated movement and orientation on site, and offered the option to learn from them more about the area, its history and uses. Many of them have also a good knowledge of the locally present species.
- Field crews need a permanent supervision and feedback. It is advisable that one of the organizing group is accompanying the field crews repeatedly. This keeps the motivation alive and shows at the same time that there is a real interest in good data.
- Depending on the site conditions, one should decide what an appropriate number of field samples per field crew in a given time is. We observed that, probably due to the some times extreme situations in the field, the motivation and also data quality suffered after some 5 sample locations.

Capacity Building:

- The strategy was to include as many people as possible in planning an implementation of the project. While it inevitably increased the necessary organization efforts.

PARTICULARITIES OF COSTA RICA

Costa Rica exhibits some characteristics that facilitated the successful implementation of the GFS pilot study.

- Unconditional and highly efficient cooperation with government authorities, and active support from them.
- Sufficiently up-to-date aerial photographs were available and had not to be commissioned. The cost for air photos would have been definitively prohibitive.
- The country is relatively small and from an administrative point of view "homogeneous" (definitively not so from a biophysical, topographic or vegetation point of view!).
- Relatively good road network, in terms of density and quality, facilitating relatively easy access to most sample locations.
- Good communication infrastructure.
- Practically all the country is known, only some smaller regions are less explored (some area in the Cordillera de Talamanca like Kamuk).
- The country is safe, no relevant security problems have to be taken into account.
- Many well trained foresters available.

  In our case we utilized this situation to contract them for field work implementation. Also, foresters with specific knowledge in GIS and data analysis can be found.
- Several institutions in Costa Rica have good GIS and Remote Sensing Laboratories.
- Relatively high level of general education. Therefore, interviews were in many cases easy to be done.
- General level of information on natural resources is good. Several satellite image based forest mapping studies have been undertaken in the last years.
- Relatively clear land tenure situation. Most of the owners granted access without any problems. There are relatively few smallholders (minifundios) which would complicate the establishment of larger field clusters and plots (simply because one would have to contact many land owners). In Costa Rica, it was relatively easy to identify the corresponding land owners – where the active support by local officials of SINAC was decisive and is highly appreciated.

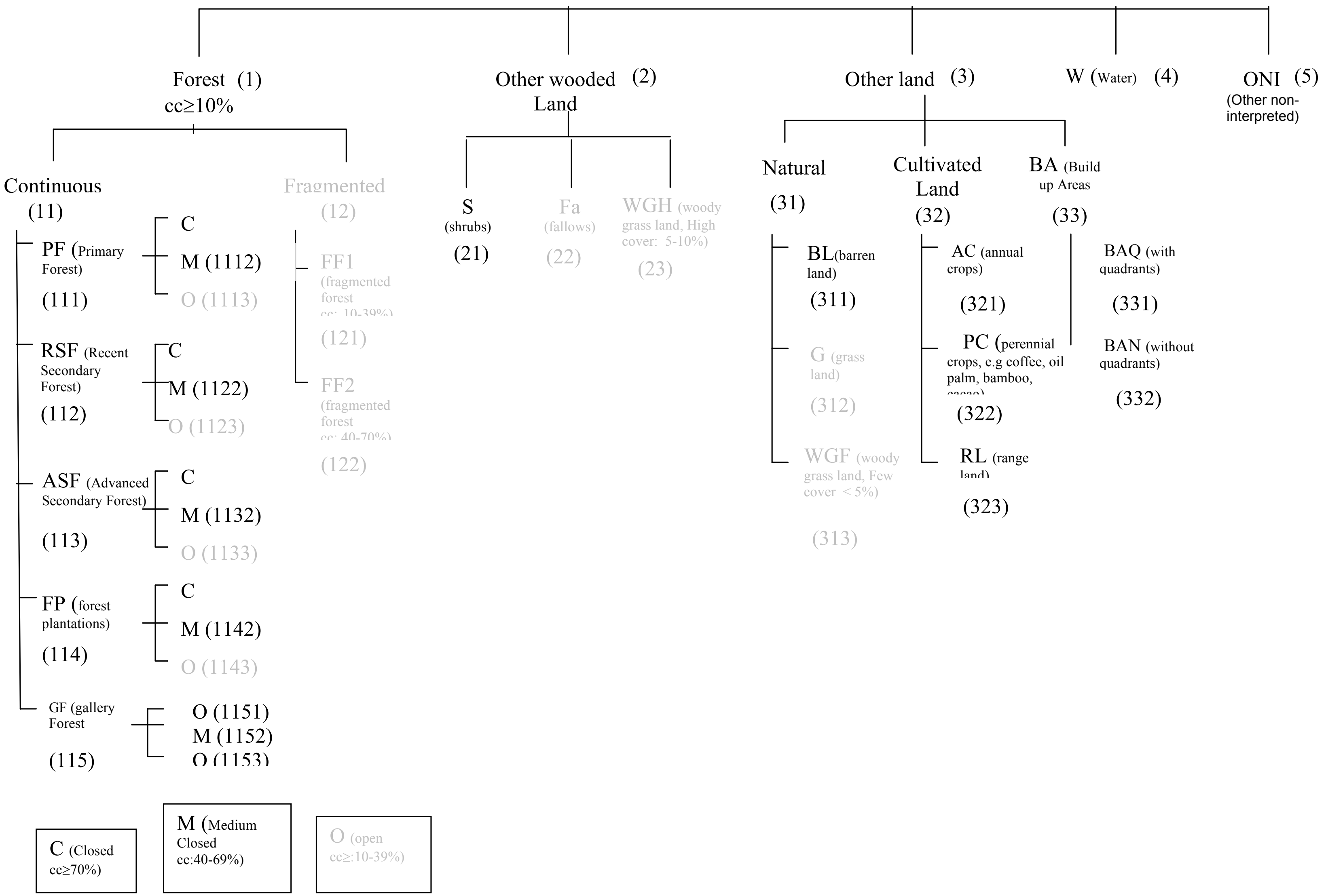
APPENDIX

Annex 1 complements the text of this report while Annex 2 contains a list of additional documents that are part of this report but are delivered separately.

ANNEX 1

A1-1 LAND USE CLASSIFICATION SYSTEM USED

Interpretation guide and aerial photo examples are in Annex 2-1



A1-2 Variables assessed and codes (as of data base)

Form sheet 1 (Tract)

Tract. Land Tenure

Land tenure	
1	Private
2	Governmental
3	Governmental protected area
4	Private protected area
5	Plot under usufruct

Tract. Access

Explanation: This variable explores the distance from the sample site to a road and other infrastructure. It will provide information on how distant the sample site is.

	Fill out all:	DISTANCE IN KILOMETERS:
	Distance from all weather road	Km
	Distance from seasonal road	Km
	Distance to nearest health-clinic	Km
	Distance to nearest school	Km

Form sheet 3_(Stand)

Stand._Erosion

Erosion	
1	No erosion
2	Hydric
3	Eolian

Stand._Hydric Erosion

Hydric erosion	
1	Furrows
2	Gully
3	Exposed rock

Stand._Landslide

Landslide	
1	Yes
2	No

Stand._Origin

Origin of the stand in the sub-plot.

Origin	
1	Natural
2	Plantations
3	Coppice
4	1 and 2
5	2 and 3
6	1, 2 and 3

Stand. Crown Cover

Projected crown cover in the stand as a percentage of total area

Options:
01 - <10%
02- 10-40%
03 - 40-70%
04 - >70%

Stand. Canopy Pattern

Canopy pattern of forest cover in the stand*

Options:
01 – Continuous canopy
02- Discontinuous canopy with small gaps
03 – Discontinuous canopy with large gaps and meadows

Stand. Structure

Canopy structure of the stand.

Options:
01 – Single layer
02- Two-layer vegetation

Stand. Disturbance

Disturbance observed in the forest stand.

Options:
01- Undisturbed (protected areas, all resources preserved)
02- least disturbed (exploitation of products according to management plans)
03- Moderately disturbed (Many products collected without fitting management plans, notion of sustainability non-respected)
04- Heavily disturbed (Removal of products at rates higher than MAI, biodiversity degradation due to high pressure on selected species, encroachment of agriculture leading to high rates of deforestation)

Stand._Timber Exploitation

Establishes type of (last) felling undertaken in the stand. These felling systems depend on management prescriptions set in accordance with forest functions: production or conservation.

Options	
1	No felling
2	Clearing
3	Selective felling
4	Group felling
5	Strip felling
6	Other

Stand._Silviculture

Silvicultural practices	
1	No practice
2	Improvement
3	Release of desirable superior tree
4	Release of lianas and tropical plants
5	Enrichment

Stand. Health

Phytosanitary status	
1	Healthy
2	Insects
3	Fungi

Stand. Fires

Evidence: Fires	
1	No evidence
2	Recent
3	Old

Form3__PM

PM. Exposure

	Exposure
1	Flat land
2	N
3	NE
4	NW
5	E
6	SE
7	S
8	SW
9	W

PM.Soil Texture

Typical soil texture in the subplot

Options	
1	Coarse Sand
2	Light Sand
3	Light Clay
4	Heavy Clay
5	Silt
6	Silt & Sand
7	Pebbly Silt
8	Alluvium

PM. Soil Moisture

Typical soil moisture type in the subplot

Options:	Explanation:
01- Dry	
02- Temporary Wet	Refers to inundated land during the wet and part of the dry seasons
03- Permanently Wet	Land filled with water all year around, such as lakes, swamps, etc.

PM.Organic Matter

Organic Matter	
1	Absent
2	1 cm
3	1 – 3 cm
4	> 3 cm

Form3__PAN

Section on land use

Type of Land Use:
PFC: Primary forest closed
PFM: Primary forest medium
RSFC: Recent secondary forest closed
RSFM: Recent secondary forest medium
ASFM: Advanced secondary forest medium
ASFC: Advanced secondary forest closed
FPC: Forest Plantations closed
FPM: Forest Plantations medium
S: Shrubs
G: Grass land
WGF: Woody grass land, high cover: 5 – 10%
AC: Annual crops
PC: Perennial crops
RL: Range land
BAQ: Build up areas with quadrants
BAN: Build up areas without quadrants
W: Water
BL: Barren land
GFC: Gallery forest closed
GFM: Gallery forest medium
ONI: Unidentified

Protected Area

Codes:
NP: Unprotected Area
AP: Water Protection
SP: Slope Protection
ASP: Water and slope protection
PA: Protected area
BZ: Border Zone

Form_4 Tree

Tree_code

Options	
1	Left
2	Right

Tree_Measure Type

Options	
1	Measured
2	Estimated

Tree_Protection Condition

Options	
1	Near to stream
2	On Slope
3	Near to stream and on Slope
4	Out of protected area

Tree_Health

Options	
1	Broken shaft
2	Burned shaft
3	Ringed shaft
4	Infected by fungi
5	Infected by insects

A1-3 STRUCTURE OF DOCUMENTATION

Thorough documentation of the data the project generated is a major issue. Only a detailed description will allow the responsible national institution to give permanence to the project, and to continue building partnership with other national institutions.
The complete documentation as delivered to SINAC has the following structure:
Digital documents

- 159 aerial photographs, interpreted and in the format of the programs Carta Linx and Arc View.
- Geographic data base of the field data, with the plots and georeferences tree positions, linked to the EXCEL data base of tree information.
- EXCEL files with the field data.
- EXCEL files with the interview data.
- Catalog of terrestrial reference photographs taken in the field (per cluster)

Hardcopies

- 159 sets of printed aerial photographs (from the scanned images), printed on glossy paper.
- 159 printed aerial photographs with the results of the photointerpretation.
- 40 photographs and maps, one for each field sample location.
- Original form sheets of field data collection.
- Original form sheets of interviews.
- Catalog of photographs
- Final report, including analysis results.

ANNEX 2 (DOCUMENTS COME SEPARATELY)

A2-1 AERIAL PHOTOGRAPHS: INTERPRETATION AND OBSERVATIONS

A2-2 FIELD MANUAL

A2-3 SET OF FORM SHEETS

A2-4 GPS INSTRUCTIONS

A2-5 INFORMATION PAPER PRESENTED TO INBIO AND SINAC AT SEPT. 12, 2001 TO START DISCUSSION WITH NATIONAL INSTITUTIONS.